Université de Montréal

The Perceptual Qualities of Concrete

A Change in Paradigm

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Abstract

The research investigates the quality perceptions of concrete artifacts from an industrial design standpoint. In order to document and examine how the material is being used and perceived nowadays, the study looks into the evolution of concrete technologies including its recipes, manufacturing techniques, and uses, as well as its appraisals.

A literature review helped us understand the problem field and organize the data amassed in order to find answers to our research questions. We were thus able to identify the critical milestones that triggered change throughout concrete's historical evolution, as well as gather different testimonies of its perceptions within various contexts.

Qualitative research methods were used to interpret our findings. We validated the data based on selected cases as well as non-participatory empirical observations of urban concrete artifacts from a first-person view. This method is influenced by the author's lived experiences, cultural background, and disciplinary gaze. Therefore, it was necessary to complement the author's interpretation by triangulating the data retrieved with information gathered from historical, scientific, technical, and mediatic literature.

The results were organized and analyzed using various analytical tools and methods. Timeline mappings were used to isolate and illustrate critical milestones triggering change and important developments (e.g. the discovery of Portland Cement, etc.). Categorizations helped us clarify and compare the data gathered to provide a more specific overview of concrete recipes and uses (e.g. primitive – modern concretes, structural – non-structural recipes, etc.). Semantic mappings allowed us to interpret the complied testimonies on how concrete artifacts are perceived in addition to helping us isolate semantic qualities within a bipolar semantic space (e.g. concrete is ugly – beautiful, concrete is cold – warm, etc.). Lastly, a product and material experiences framework (Desmet & Hekkert, 2007) was used to interpret concrete artifacts' appraisals as found within the testimonies retrieved, in addition to the first-person empirical observations.

The research revealed that concrete's quality perception is facing a dualism which draws attention to its ecological footprint as well as its surface's premature deterioration with time. Although many seem to appreciate the material's versatility, accessibility, and structural performance, the dualism can be partially attributed to the evolving collective consciousness which makes actors more aware of concrete's environmental impacts across its lifecycle.

The study thus showed that, despite modern society's production and consumption habits which focus on the superficial perfection of the material world, ideologies are seen to be evolving and are increasingly interested in more sustainable practices and lifestyles. This can help motivate designers to seek inspiration from emotionally-durable and resilient principles, thus allowing them to better address urban challenges. The latest trends revealed new concrete mixes (e.g. substitution of Portland Cement with by-products of other industries, etc.) and manufacturing techniques (e.g. 3D-printing, etc.) which can offer eco-friendly and innovative alternatives to traditional concrete productions. These emerging solutions are seen to pave the way for unexpected applications in various fields (e.g., product design, art, cinematography, etc.), thus attracting other disciplines beyond engineering and architecture.

The changing paradigm in the perception of concrete artifacts shows that value and beauty are not always associated with superficial perfection. In fact, more and more actors are found to reject premature obsolescence by embracing materials' natural and imperfect behavior as they age with time.

Keywords : industrial design, human-centered design, sustainable design, quality perception, product and material experiences, concrete artifacts

Résumé

La recherche porte sur la perception de qualité des artefacts en béton, et ce depuis la perspective disciplinaire du design industriel. Afin de documenter et examiner les applications et perceptions contemporaines de ce matériau, nous nous attardons à l'évolution des technologies du béton en termes de recettes, techniques de mise en forme, usages, ainsi que ses différentes appréciations.

Une revue de littérature a permis de formuler la problématique et d'organiser les données recueillies afin de répondre à nos questions de recherche. Ainsi, nous avons identifié certains événements marquants ayant provoqué des développements importants dans l'évolution du béton. De plus, nous avons regroupé plusieurs témoignages illustrant différentes perceptions du matériau dans des contextes d'usages variés.

Les résultats de la recherche ont été interprétés en mettant de l'avant une méthodologie qualitative de recherche. Nous avons également étudié une sélection d'artéfacts en béton à travers des observations empiriques non participatives ainsi que deux cas sélectionnés. Cependant, ce type de recherche à la première personne est influencé par l'auteure, ses expériences vécues, son bagage culturel ainsi que son regard disciplinaire. Ainsi, il était important de valider ces observations teintées par l'appréciation de l'auteure, et ce en triangulant les données avec celles regroupées de documents historiques, scientifiques, techniques et médiatiques.

Plusieurs méthodes et outils analytiques ont été mobilisés afin d'organiser les résultats de la recherche. Des cartes chronologiques nous ont permis d'isoler et d'illustrer les étapes déterminantes ayant affecté l'histoire du béton (i.e. la découverte du ciment Portland, etc.). À des catégorisations, nous avons pu classer et comparer certaines données plus spécifiques aux recettes et applications du matériau (i.e. les bétons primitifs – modernes, les bétons structuraux – non-structuraux, etc.). Des cartographiques sémantiques nous ont permis d'interpréter les témoignages compilés des différentes perceptions du béton et ce en se basant sur une échelle sémantique bipolaire (i.e. le béton est laid – beau, le béton est froid – chaud, etc.). Enfin, nous

nous sommes basés sur le cadre d'expériences de produits et matériaux (*product and material experiences framework*) proposé par Desmet et Hekkert (2007) afin d'interpréter les appréciations des artéfacts en béton recueillis à travers la revue de littérature ainsi que les observations empiriques à la première personne.

La recherche montre que la perception de qualité du béton fait face à un dualisme qui oppose ses avantages techno-économiques avec son impact environnemental ainsi que la détérioration prématurée de sa surface. Malgré l'appréciation générale de sa versatilité, accessibilité et performance technique, une prise de conscience collective semble rendre les acteurs plus conscients de l'empreinte écologique résultant du cycle de vie du béton.

De plus, la recherche démontre que les idéologies sont en train d'évoluer vers des pratiques et modes de vies plus durables malgré les habitudes de surconsommation de la société moderne. En mettant moins l'emphase sur la perfection superficielle, les designers sont de plus en plus motivés à trouver inspiration dans des pratiques plus sensibles et résilientes afin de trouver des solutions durables face aux enjeux urbains. Les dernières tendances révèlent l'émergence d'alternatives plus éco-responsables et innovantes comparées au béton traditionnel. Ainsi, nous trouvons des recettes de béton plus écologiques (i.e. substitution du ciment Portland avec des produits dérivés d'autres industries, etc.) ou des techniques de mise en forme plus optimisées afin de réduire les pertes en offrant un langage esthétique surprenant (i.e. impression 3D, etc.). Ces technologies donnent naissance à de nouvelles applications du béton dans différents domaines inattendus en dehors de l'architecture et de l'ingénierie (i.e. design de produits, art, cinématographie, etc.).

La recherche met en lumière changement de paradigme quant à la perception de qualité du béton qui semble être entrainé par la migration des idéologies sociétales vers un modèle qui trouve de la valeur et de la beauté dans les imperfections. Ainsi, des acteurs semblent de plus en plus apprécier le béton avec ses imperfections naturelles, et ont tendance à plus vouloir préserver les artéfacts vieillissants.

Mots clés : design industriel, design centré sur l'usager, design durable, perception de qualité, expérience de produits et de matériaux, artefacts en béton

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List of abbreviations

e.g. : Example

etc. : Etcetera

GRAD: Groupe de Recherche en Aménagement et Design

P. : page

UHPGC: Ultra-High Performance Glass Concrete

UNISDR: United Nations International Strategy for Disaster Reduction

UN: United Nations

JSTOR: Journal Storage

PAME: Product and Material Experience

PC: Primitive Concrete

MC: Modern Concrete

BC: Before Christ

AD: Anno Domini

FRC: Fiber Reinforced Concrete

SCC: Self Compacting Concrete

HPC: High Performance Concrete

ECC: Engineered Cementitious Compound

RPC: Reactive Powder Concrete

UHPC: Ultra-High-Performance Concrete

CO2: Carbon Dioxide

WBCSD: World Business Council for Sustainable Development

CSI: Cement Sustainability Initiative

EPA: Environmental Protection Agency

UNEP: United Nations Environment Program

EDD: Emotionally Durable Design

AOS: Aesthetics of Sustainability

FRP: Fiber Reinforced Polymer

AR: Alkali-resistant

GRP: Glass Reinforced Fibers

PP: Polypropylene

PVA: Poly-Vinyl Alcohol

PE: Polyester

FRC: Fiber Reinforced Concrete

GFRC: Glass Fiber Reinforced Concrete

UHPFRC: Ultra-High Performance Fiber Reinforced Concrete

MuCEM: Museum of European And Mediterranean Civilization

hBN: Hexagonal Boron Nitride

GGBSF: Ground Granulated Blast Furnace Slag

C&D: Construction and Demolition Debris

LTC: Light Transmitting Concrete

UV: Ultraviolet

MIT: Massachusetts Institute of Technology

MDF: Medium Density Fiberboard

ZHA: Zaha Hadid Architects

ETH: Eidgenössische Technische Hochschule

PFHC: Pneumatic Forming of Hardened Concrete

TU: Technische Universität

CNC: Computerized Numerical Controlled

3D: Three Dimensional

MOCCA: Museum of Contemporary Art Africa

MMU: Massive Masonry Units

AIL: Atlantic Industries Limited

MTQ: Ministry of Transport of Quebec

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Foreword

Materials have always been a source of inspiration.

When I reflect on my previous academic or professional experiences, materials often seem to take center stage. As a design student, one of my earliest interactions included experimentations with recycled cork molded into a polyurethane base to create a hunting shoe sole. This project gave me the opportunity to pursue an international internship at a natural rubber research center in the United Kingdom.

Later, during my last year as an undergraduate student, my partner and I had the opportunity to join the GRAD research group (Groupe de Recherche en Aménagement et Design) and to participate in professor Tatjana Leblanc's research program: '*Les voies publiques de demain et les enjeux d'aménagement des espaces à vivre*'. Her research proposed the valorization of recycled glass in new applications, particularly as a cementitious substitute in a high-performance concrete. With the goal of attracting the public's attention to this local technology, we created '*Peninsula: floating ecological concrete docks'*, a modular system made from Ultra-High Performance Glass Concrete (UHPGC) designated to offer access to Montreal's water banks.

Throughout this project, I had the chance to study - thought superficially - concrete in a more hands-on approach and propose a new application that showcases the material's advantages. Our concept earned the attention of some design experts and won 3 grants and 5 awards, including the prestigious Red Dot Design Award 2017, with the distinction Best of The Best in its category. It is needless to say that the experience of traveling to Singapore to accept an award celebrating our creativity lingered with me throughout my following professional career. In fact, I was continuously confronted with questions that I never had time to explore: How have concrete technologies and practices evolved? How is concrete used today and how does it differ from the past? How do concrete artifacts age? And how is the ageing process affecting the user's perception?

Immediately after my graduation, I began working in the field of urban design for a water play equipment designer and manufacturer. With my genuine interest in materials, I was able to introduce alternative mediums to create sensory water features for younger children. My tests included experimentations with superhydrophobic coatings, textured polyurethane, translucent and colorful polycarbonate, and thermal paint, amongst many others. This enriching professional experience led to copious observations which triggered my interest in the sensorial and experiential aspect of materials: Who are the users and stakeholders involved in the material experience? How do these different users perceive a material in its context and why? How can design influence the perceptual qualities and experience of artifacts?

Upon returning for my master's degree, my goal was to pursue those questions in relation to my first muse: concrete. I wanted to establish a repertoire and document the evolution of concrete technologies in terms of recipes and manufacturing/finishing techniques. I was also looking to understand how ageing concrete artifacts are perceived by their user. Lastly, I wanted to understand what role industrial design can play in changing user perceptions by investigating how it can affect or enhance a material's perceptual qualities.

My research did not intend to measure and compare different users' perceptions of ageing concrete artifacts, but rather to explore how the material and its uses have evolved in order to better grasp *why* it is perceived the way it is. I want to look into how concrete ages over time, and to understand how designers can elicit emotional responses which can influence its quality perceptions.

Chapter 1 – Contextual Framework

In this chapter, we present the problem field surrounding our study on urban concrete artifacts. We then expose some critical observations which motivated us to examine the evolution of concrete and its uses from an industrial design perspective. We will then explain how human centered design as well as sustainable and resilient approaches relate to and justify the research. Lastly, we will present the research objectives and the questions used to frame the study.

1.1. Problem field and observations

This study is interested in the field of urban design. In this section, we will present some key observations and describe our problem field: the urban context.

1.1.1. Urban densification

In recent years, urban projection studies have predicted the inevitable increase in population growth and of people living in urban spaces: these numbers are expected to reach up to 70% in 2050 (UN, 2013). Urban areas are both expanding in surface and densifying in numbers of occupants all over the world (Haaland & van den Bosch, 2015). The global phenomena of urban densification has been seen to impact various aspects of city life:

> "Dull, inert cities, it is true, do contain the seeds of their own destruction and little else. But lively, diverse, intense cities contain the seeds of their own regeneration, with energy enough to carry over for problems and needs outside themselves." (Jacobs, 1961/1992, P.81)

While some of the potentially positive characteristics are being investigated by some (e.g., decrease in traffic and environmental issues), more pressing negative effects are seen to directly impact multiple sectors (Gehl, 2010; Haaland & van den Bosch, 2015). Urban densification has led to multiple consequences on various levels, amongst them:

1. **Environmental impacts** include the generation of urban heat islands[1] (UHI) which cause significant health challenges for city dwellers (Stewart & Oke, 2012; Panno et al., 2017). Urban densification is also causing the eradication of natural green spaces leading to the radical deterioration of the ecology of landscapes, as well as the degradation of air and water quality, amongst other consequences (Wood & Pullin, 2002; Donovan et al., 2005).

2. **Socio-cultural problems** lead to overcrowding, recreational conflicts, excessive sensory stimulation, and overload of information to mention a few, thus reducing the overall quality of life[2] (Jacobs, 1961; Marcus, 1991; Amberger & Haider, 2005; Haaland & van den Bosch, 2015).

3. **Economic issues** arise and are linked to the rapid expansion of urban developments. These cause excessive production and consumption habits, planned obsolescence[3], and the alteration of resources flow, amongst other consequences (Mulder, 2017). Other impacts include natural resources becoming increasingly scarce, and energy consumption is seen to increase in denser areas (Mulder, 2017; World Bank, 2010).

Overall, there seems to be an agreement amongst experts that humanity is irresponsibly destroying the planet's natural resources, thus endangering our ecosystems and affecting our quality of life (Haaland & van den Bosch, 2015). Some even believe that the imprudent use of resources may lead to irreversible damages and reduced capacities to support future human civilizations (Arrow et al. 1995; Haaland & van den Bosch, 2015).

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[1] According to Gago et al. (2013), UHI are cause by the energy consumed by densely populated cities in order to function and carry out their activities. They manifest in a high concentration of heat which is intensified by solar radiation.

[2] According to Felce and Perry (1995), quality of life is a broad term which includes the evaluation of the factors defining different types of well-being within a large communities as well as on an individual level. Various aspects can improve quality of life for different people as what they want, need, and like is subjective to each individual or sub-group. Although "quality of life" can be an elusive concept, it can be defined as "an overall general well- being that comprises objective descriptors and subjective evaluations of physical, material, social, and emotional wellbeing together with the extent of personal development and purposeful activity, all weighted by a personal set of values" (Felce & Perry, 1995, P.60-62).

[3] Planned obsolescence is described as the manufacturing of artifacts with "[…] uneconomically short useful lives so that customers will have to make repat purchases" (Bulow, 1986, P.729)

In an effort to counteract the negative effects of urban densification, alternative approaches have been considered. For example, Danish architect and urban design consultant Ian Gehl (2010) promotes **well-planned densification** by being more sensitive to the needs of city users:

> "Density, which represents quantity, must be combined with quality in the form of good city space. There are many ways of applying an intelligent architectural approach to relatively high building density without making buildings too tall, streets too dark, and without constructing psychological barriers that discourage residents from making the "journey" from inside to outside." (Gehl, 2010, P.69)

His approach is increasingly concerned with the urban users (e.g., citizens, visitors, the homeless, etc.) and their lifestyles and needs. It is a more *human-centered* approach to designing urban centers, a central concept to our study as we explained earlier.

Densification has also been referred to as 'intensification' (Williams, 2004) which led to the conceptualization of the 'compact city', a term that first appeared in the 1970s (Dantzig & Saaty, 1973, cited in Breheny, 1996/2003). Compact cities developments have various characteristics in terms of forms, processes, infrastructures, and services (e.g., optimized transportation systems, accessibility to services, and proximity of development patterns, etc.) (Haaland & van den Bosch, 2015; OECD, 2018).

Cities are composed of multiple complex systems which constantly and dynamically interact with one another (Jabareen, 2013). These can include:

1. Socio-cultural sectors referring to communities or subcultures with their beliefs, values, activities, needs, etc.

2. Political sectors including governments with their organisms, laws, policies, etc.

3. Economic sectors including infrastructures in the forms of construction materials, buildings, roads, and services such as industries, transportation systems, etc.

These systems are perceived to be perpetually evolving and changing in non-linear ways (Jabareen, 2013).

> "[...] big cities are just too big and too complex to be comprehended in detail from any vantage point—even if this vantage point is at the top—or to be comprehended by any human; yet detail is of the essence." (Jacobs, 1992, P.121)

Therefore, although the city is usually seen as one monumental whole, it is sometimes important to observe and reflect upon those subsystems composing it. In fact, industrial design approaches are concerned with how these sub-systems impact users' well-being and quality of life. Perhaps these types of reflections led to Victor Papanek, advocate of socially and ecologically responsible design, saying that "nothing big works" (Papanek, 1985).

Amongst the details composing the city is the *well-known building material*: concrete.

1.1.2. Concrete uses

In order to satisfy the need for fast construction, expanding cities call for *accessible* and *practical* materials which can fit in operational budgets and time frames. Ever since its re-appearance[4] in the late 1800s, concrete rapidly became the *most widely used construction material* in the world with an estimated usage of over 2 billion tons per year (Meyer, 2005; Crow, 2008; Wangler et al., 2016;2019). It is also considered to be the second most used resource in the world, following water (Wangler et al., 2019).

Our research therefore focuses on concrete's widespread uses as a building material and how the material has shaped the urban landscape.

Concrete's popularity can be linked to its techno-economical properties. Composed of mostly accessible or available ingredients (e.g., water, sand, cement, etc.), concrete is considered to be a *globally easy-to-obtain commodity*[5] (Meyer, 2005; Wangler et al., 2019). Furthermore, the material is known to be relatively *easy to process* on site and can be used in a wide range of applications given that it starts in a fluid state and slowly transforms into a solid one as it cures. Concrete comes at a *low cost* compared to other common building materials due to its

[4] Refer to the timeline of historical evolution of concrete to understand why it was "re"-discovered (page 62)

[5] The "ease-of-access" of concrete's main ingredients has become a subject of controversy and will be further discussed in chapters 4 (pages 71-72) and 5 (pages 166-167).

increased construction speed and reduced costs for labor and formwork (Forty, 2013; Wrangler et al., 2016). Lastly, concrete structures can be *adapted to a wide variety of performance requirements*: for example, reinforced concrete gives artifacts the ability to bear considerable structural loads and withstand harsh conditions when *strength* and *durability* are required.

Overall, concrete technologies have been evolving since its first apparitions. Nowadays, we observe that concrete mixes, manufacturing and finishing techniques, as well as applications have significantly changed (see chapter 4, page 76).

1.1.3. The rise of the concrete jungle

Concrete's *widespread availability* as well as its techno-economic advantages drove the construction industry to cut corners thus diminishing its quality. Cheaper mixes as well as bad practices have led to *hastily or ill-conceived concrete artifact*s in terms of the recipes, the quality of the manufacturing, and the implementation within the environment. By consequence, these poorly ageing artifacts are seen to dominate the urban landscape (see figure 1) as well as aesthetically deteriorate after only a few years in some cases.

Although one of the most *practical* building materials, concrete has also been associated with negative connotations. After World War II in the 1950s, there was a need to quickly rebuild more resistant infrastructures and housing units (Forty, 2013; Collins, 2004). With the exponential rise of populations and the need for more housing, concrete became increasingly *synonymous with urban developments*.

Figure 1. – Kennedy Town in Hong Kong, China - image by Richard Lee from Unsplash.com (2017)

Being the predominantly used construction material, concrete became the *poster child of urbanization*. In fact, mega-cities such as Hong Kong, New York, or Moscow are often referred to as '*concrete jungles'*. This term is thought to be derived from Upton Sinclair (1985) referring to 'asphalt jungle', which he originally used in his 1905 novel *The Jungle*. Since the popularization of its usage in the post-war 1950s, definitions in both American and British English dictionaries refer to negative connotations including references to an "*ugly* or *unpleasant* town, city, or area" that is overflowing with "many modern concrete buildings" (Collins English Dictionary, 2021), and a "*harshly competitive*, *unwelcoming*, or *dangerous* place" (Merriam-Webster, 2021).

The modern city and its concrete artifacts became *offensive* in some cases. As infrastructures grew both in scale and in density, the city was straying away from the scale of its citizens and visitors, becoming an *intimidating* and almost *suffocating* place. In fact, urban modern life is characterized by population and housing crowding, overload of information, excessive sensory stimulation, heat islands and pollution, and the eradication of green spaces (Lewis, 1990; Cooper Marcus, 1995). As the city was seen to 'concrete over' green spaces, its citizens and visitors saw concrete as 'taking over' nature thus resulting in feelings of anxiety and worry. These have measurable negative impacts on humans both on a psychological as well as a physical level (Kaplan & Kaplan, 1989; Lewis & Booth, 1994).

To urban dwellers, concrete was regarded as a *cheap* and *ugly* man-made force that was replacing nature. Whereas to designers and architects, concrete was rather seen as a *practica*l, *versatile,* and *accessible* material offering a wide range of applications at a reduced cost.

It is therefore easy to imagine that, due to the timing of its exploitation and other contextual factors, concrete has been also associated with phenomena such as war and destruction, exponential industrialization, mass consumption, and massive urbanization. In addition, it is understandable why some link concrete with pollution increase and global warming, as well as the eradication of nature, amongst other connotations.

However, scholars agree that it is unlikely "[…] that the demand for concrete will decrease […] as developing countries such as China and India grow their infrastructure, and developed countries refurbish their own" (Van Damme, 2018, cited in Wangler et al., 2019, P.1). In the foreseeable future, concrete remains the *inevitable material of choice* for the unavoidable expansion of the urban world.

These observations triggered questions about the various meanings concrete may have, how it is perceived over time, and how designers compose with its ageing aspects.

Although concrete is a material used primarily in the construction industry to produce urban artifacts and infrastructures, it is less known within industrial design. It thus became interesting to apply both our academic and professional expertise in industrial design to our research interests.

1.2. The evolution of design

The ever-expanding research suggests that *design* as a discipline is continuously growing in its forms, significations, and connections (Buchanan, 1992). Initially, design was more closely related to the arts and craftsmanship as it designated the making-of *something* (McDonagh et al., 2004). Then, during the industrial revolution, 'design' was appropriated to refer to the "emerging need to make mass production acceptable to many and expand the markets for its products" (Krippendorff, 2005, P. XVI). The high demand for consumption goods and capital society's constant push for economic growth led to unsustainable design practices, which ultimately contributed to the creation of a 'planned obsolescence economic society' (Chapman, 2015).

However, throughout the years, industrial design evolved from its technical origins in engineering, which relied solely on deductive reasoning and was concerned mainly with the technical and mechanical aspects of products (Ashby & Johnson, 2014).

As the concept evolved, philosopher and design theorist Donald Schön (1983) observed that design was being used more broadly to include professionals such as architects, urban planners, regional planners, engineers, and product designers. He explains that design is a **reflective conversation** with situations by identifying and solving problems, ultimately leading to the proposition or creation of projects, services, products, plans, images, programs, and structures, amongst many other manifestations.

Overall, design is seen to be concerned with human creations: *artifacts* (Krippendorff, 2005). Above everything, mankind is *homo faber*, “the maker and user of objects, his self to a large extent a reflection of things with which he interacts” (Csikszentmihalyi & Rochberg-Halton, 1981, P.34). The etymology of the term ‘artifact’ can be traced back to its Latin roots meaning ‘factum’ referring to something that is done or created through craftsmanship (Krippendorff, 2005, P.12). Nowadays, artifacts are continuously evolving in nature and implications and can go on to include “fluid, indeterminable, and immaterial or virtual qualities” (Krippendorff, 2005). In our study, we use ‘artifact’ as an inclusive term that can extend to objects, installations, spaces, services, etc.

Throughout its evolution, several currents have helped design to establish its identity:

Some earlier schools of thought considered that properly functioning products will automatically evoke an aesthetic appeal (Ashby & Johnson, 2014). This reflected architect Louis Sullivan’s ideology that ‘form follows function’, a viewpoint which was predominant during the Bauhaus period in the early 20th century. This reasoning led to the view that industrial design as an active pursuit could be unnecessary, since good technical design will produce aesthetic appeal as a by-product. Some critics argue that, in this view, industrial design is reduced to mere packaging (Ashby & Johnson, 2014), which led to the introduction of alternative views.

Others thus considered that “[…] products that are built around function alone have not been designed at all, but merely engineered” (Ashby & Johnson, 2014, P.19). Therefore, design’s focus began to expand from *technicality* and *function* to include *sensuality* and *emotions*. Formulas such as ‘form follows emotion’ became part of the discourse (Sweet, 1999). Aspects such as *satisfaction*, *richness of meaning*, and *attachment* became equally as important as *usability* since they were proven to appeal to deeper to highly influential levels of human cognition: *emotions* (Sweet, 1999; Dandavate et al., 1996; McDonagh et al., 2004). While investigating the relationship between design and sensuality, objects were found to hold heavy emotional connotations leading to *desire*, *devotion*, and even *obsession* (e.g., collectors) (Bayley, 1986; McDonagh et al., 2004).

Today, design is seen as a **dynamic process** operating through continuously evolving approaches, methods, principles, and tools all while prioritizing the users and their environment. As such, design is an *improvement process* through which existing conditions are transformed into better, preferred ones (Simon, 1996). Designers propose novel solutions to contribute to the wellbeing of communities and ecosystems all while introducing “variations into the world that others may not dare to consider, creating something new and exciting” (Krippendorff, 2005, P.29).

Over the years, design has become an **integrated discipline** which adopts concepts, methods, tools, and frameworks from other fields, notably the cognitive sciences, human sciences, and engineering, which helped enrich the corpus of design knowledge (Desmet & Hekkert, 2007). In order to facilitate cross-disciplinary discussions and to clarify some fundamental concepts, some design theorists have elaborated specific frameworks. In our research, we use for example Desmet and Hekkert’s Product and Materials Experiences (PAME) framework to help guide our understanding and better frame our findings (see chapters 2 & 3).

1.2.1. Social, cultural and environmental preoccupations of design

Considering that design is also **future-oriented**, designers must “evaluate the desirability of [...] futures. Desirable worlds must make sense and be of benefit to those who could realize these worlds and might come to live in them” (Krippendorff, 2005, P.29). This view shows that design is concerned with the wellbeing and quality of life of future generations, a perspective which resonates with sustainable development ideologies.

Design literature shows how new avenues are being explored by looking at artifacts in the context of signs, actions, and thoughts (Buchanan, 1969). This is because design is highly influenced by culture (Ashby & Johnson, 2014). In fact, new design methods have evolved to stress the importance of understanding the user and their experience instead of only focusing on the physical artifact. Several theoretical models illustrate the shifted focus on either the actor within the design process itself, or the **user's lived experience** as a living entity (Findeli & Bousbaci, 2005). In recent years, design's preoccupation has significantly diverted its focus from the *artifact* to the *lived experiences*, thus transcending economic or technological aspects and focusing on sociocultural and environmental considerations (Findeli & Bousbaci, 2005; Leblanc, 2016).

> "Functional, aesthetic, and market considerations that justified the products of design in the past have been replaced or overshadowed by other more social, political, and cultural concerns, such as ecological sustainability and cultural identity." (Krippendorff, 2005, P. XVI)

Amongst those concerns, is the preoccupation with the natural environment's deterioration caused by modern society's unsustainable lifestyles and consumption habits, thus fueling debates about **ethics, sustainability,** and **resilience**.

The initial motivation for our study came from a sustainable point of view which we approached from a feminist ethics perspective. In order to better understand those concepts, we relied on the philosophies of Aristotle and Plato as well as Charles Taylor and Catherine Larrère. We defined our understanding of sustainable design based on the works of Victor Papanek, Buckminster Fuller, Richard Buchanan, and Mihaly Csikszentmihalyi. Considering its relevance to our research, we also included our conception of resilience based on the research of Crawford Stanley Holling, Carl Folke, Stuart Walker, Sara Meerow, and Simin Davoudi, as well as their collaborators.

Ethics and design

Today, after the damages inflicted by society's destructive behaviors (e.g., wars, consumption habits, etc.), ethics has come to the forefront animating lively debates on sustainable lifestyles, particularly in occidental societies.

As Aristotle described, ethics becomes an educational system that guides societies and enables them to coexist in a given space (e.g., in a city) (Hardie, 1980). As humans, we are continuously and relentlessly pursuing the greater *good*, which Plato perceived as a non-static and non-reachable ideal (Frede & Zalta, 2017).

This can be perceived from a variety of perspectives according to Canto-Sperber and Ogien (2006): for example, Stoics - who can be considered the predecessors of today's ecologists - related ethics and the pursuit of the greater good to three main relationships: according to oneself, to one another, and to nature. Whilst Epicureans focused on living a simple and humble life of pleasure and happiness. Today, their perspective can be linked to Hedonism, which is generally associated with self-indulgence and egocentric enjoyment (Crisp, 2006). Furthermore, according to Canadian philosopher Charles Taylor (1991), living an ethical and fulfilled life implies the combination of three conceptions of happiness: the first conforms to an epicurean perspective where life can be enjoyed to the fullest with very little (referring to material possessions); the second implies an active political engagement where happiness can be found in selfless hard work; and the third involves a contemplative view where one needs to devote themselves to the pursuit of something bigger than themselves.

In recent years, industrial design as a discipline and a practice has operated through a **human centered approach** with the goal of tackling problems from a lifestyle and needs perspective (Bousbaci, 2010). Within our research context, this approach is empathetic with the users (e.g., citizens, visitors, the homeless, maintenance workers, etc.) which results in social-driven solutions; human centered design also cares about the environment (both the artificial and natural one) which results in environmental-driven or political-driven solutions (Ferré & Hartel, 1994; Larrère, 2006; Fry, 2008).

In our research, we conform to the view that the role of design - and of the designer by consequence - is to take *care* of their users, with empathy at the core of their reasoning and decision making.

> "Design cannot avoid ethical questions." (Krippendorff, 2005, P.25)

This notion of *care* derives from a **feminist ethics** which can be seen as a systemic view in which one takes responsibility or charge of other's wellbeing[6] through an empathetic approach (Larrère, 2006). Empathy can be understood as an awareness or sensitivity to the feelings and needs of others without them explicitly communicating them (Buchheimer, 1963). In fact, feminist ethics refuses to perceive humans as independent entities, and abides by the incontestable fact that individuals are fundamentally dependent on one another (Larrère, 2006).

In that sense, layers of concern, empathy, and care are added to the previously mentioned fundamental relations that define human existence. We thus find our relationship with ourselves (in the case of design projects, this refers to the practitioner), with one another (referring to the users), with nature (the environment and its ecosystems), and finally, with the artifacts we create (the production/resultant of the project) (Bousbaci, 2010). By taking into consideration that "artifacts are not necessarily good for everyone, and aid not just individuals but influence also how they live together", design should "[…] support the lives of ideally large communities, not or only minimally impairing the lives of others" (Agre, 2000 cited in Krippendorff, 2005, P.25).

Understanding and utilizing empathy within a design project requires cognitive as well as affective abilities (which we will detail in chapter 3, pages 41-42). Considering the importance of this type of knowledge on the users' desires, needs, feelings, and perceptions is of high value within a design project and can have multiple positive impacts.

Sustainability and design

A human centered research approach empathises with the user and their wellbeing. After all, humanity and their artifacts' survival depend on the quality of the natural environment in which they exist. In fact, mankind relies on "[…] ecosystem services both for meeting primary

[6] Based on Felce & Perry's (1995) *Domains relevant to quality-of-life* model (figure 2 p.61), the notion of "wellbeing" encompasses physical (e.g. health, safety, etc.), material (e.g. financial stability, privacy, private possessions, etc.), social (e.g. involvement in community, interpersonal relationships, etc.), and emotional (e.g. self0esteem, satisfaction, etc.) aspects.

biological needs and for providing resources that are needed for economic and technological development" (Gaziulusoy, 2010, cited in Ceschin & Gaziulusoy, 2016, P.23). Throughout history, there has been a wide variety of positions towards the conception of nature: some blindly exploit, others opt to use wisely and responsibly while conserving, whereas others prefer to preserve in precaution (Larrère, 2006). However, within the past few decades, society has been indubitably faced with "growing environmental and social pressures and responsibilities'' (Sherwin, 2004, P.22).

> "By attempting to reorder our environment in terms of human goals, we have introduced such a heavy dose of entropy in the planetary ecology that we are making it unfit even for human habitation" (Csikszentmihalyi & Rochberg-Halton, 1981, P.12).

In response to the alarming impacts of our habits on our environment, there is an undeniable need for a radical change in how humanity operates across its sectors, extending beyond our technological, social, cultural, institutional, and organizational behavior (Ceschin & Gaziulusoy, 2016). The recent years have provided an increase in **ecological awareness** as the survival of mankind depends on the conservation of other independent systems (Csikszentmihalyi & Rochberg-Halton, 1981). In this context, conservation is not seen in dichotomy with preservation, but rather as symbiotically integrated into the equation by responsibly using nature's resources (Larrère, 2006). In fact, humanity recognized the need for change in terms of society's behavior - both on individual and collective levels – towards an attitude of understanding and respect of other cultures and life forms (Csikszentmihalyi & Rochberg-Halton, 1981; Costanza et al., 2000).

According to the UN report *Our Common Future* (1988), **sustainable development** is one "that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, WCED, 1988). In addition, the Forum for the Future (2021) described it as ''[...] a dynamic process which enables all people to realize their potential and to improve their quality of life in ways which will simultaneously protect and enhance the Earth's life support systems''.

In this day and age, there is an undeniable interconnectivity of social, ecological, and economic issues such as “climate change, population growth, poverty, urbanization, environmental degradation, biodiversity, conflict, health and well-being, economic turmoil, resource consumption”, amongst others (Karana et al., 2013, P.92). Some argue that **global sustainability** is becoming one of the primary concerns of the 21st century (Prahbu Kandachar cited in Karana et al., 2013).

In the late 1990s to early 2000s, design discourses saw a shift to design for a low environmental impact (Alting & Jøgensen, 1993; Vezzoli & Sciama, 2006; Manzini & Vezzoli, 2008). In response to the emerging social and environmental challenges, concepts such as *sustainable design*, *ecodesign*, *life cycle approach* and *resilient design* have emerged, amongst many others (Sherwin, 2004). These considerations come with a transition from *functional thinking* to *satisfactional thinking* in order to “emphasize and to be more coherent with the enlargement of the design scope from a single product to a wider system fulfilling a given demand of needs and desires” (Carlo Vezzoli in Karana et al., 2013, P.106). Sustainability and environmental concerns have become influential forces in the change in design intentions and decisions (Ashby & Johnson, 2014). Design thus becomes a “[…] powerful tool with which man shapes his [tools and] environments and by extension, society and himself” (Victor Papanek, 1972, cited in Karana et al., 2013, P.277).

Various design ideologies and practices emerged falling under the all-encompassing concept of sustainable design as it includes different levels and variations within innovative, ecological, ethical, and socio-economical dimensions (Brezet 1997; Sherwin, 2004; Charter & Tischner 2017). We find other designations for the same concept including *design for sustainability* or *designed sustainability* (Buchanan & Margolin; 1996), to name a few. Additional designations such as *ecodesign* focuses on “the whole life-cycle of products from extraction of raw materials to final disposal” (Ceschin & Gaziulusoy, 2016, P.121). Ecodesign integrates into the development process ecological aspects that aim to lower the environmental impacts of the results (Tischner & Charter, 2001). Others agree that a *life cycle approach* is the most common and dominant principle of all sustainable design types as it takes into account “material extraction, production, transportation, use and disposal and attempts to minimize environmental impacts across this entire lifecycle'' (Fletcher 1999, P. 98, cited in Ceschin & Gaziulusoy, 2016, P.27).

These approaches can be seen as a "powerful conceptual framework" providing strategies and techniques to help reduce the environmental impacts of a product at different stages of its full life cycle (Ceschin & Gaziulusoy, 2016, P.27).

Resilience and design

In addition to debates on ethics and sustainability, talks about *resilience* have been emerging in the past decades.

As a concept, resilience has permeated a wide array of traditions ever since its first appearance, including and not limited to biology, ecology, engineering, socio-economic sciences, psychology, disaster and risk management (Meerow & Newell, 2015). The definitions of resilience vary depending on the discipline or science defining it. They can range from notions of *stability* and *resistance* to a *disturbance* in engineering and physical sciences (Ahern, 2011, 2013; Davoudi et al., 2012), to the *persistence* of relationships within a system with the *capacity to absorb variants* after *exposure to risks* in biology (Holling, 1996). In its earliest conception in psychology and sociology, resilience refers to a system's ability to *persist and recove*r from an *adversity* (Tompkins & Adger, 2003; Folke, 2006; Manyena, 2006; Wilkinson, 2012; Pickett et al., 2013).

In most of these definitions, resilience evokes an ability to return *back* to the previous state of balance that existed before the disturbance. However, ecology provided a new perspective that was judged more appropriate for our research: it proposes a bounce *forward* into a *new and improved* state (Davoudi et al., 2012). This implies a notion of change and innovation triggered by hardship towards a preferred state, which goes hand-in-hand with context-sensitive and sustainable design principles.

> "The world breaks everyone, and afterward, some are strong at the broken places"
> (Ernest Hemingway, 1929)

Furthermore, climatic changes and natural disasters have led to the exploration of *urban resilience* (Jabareen, 2013). This concept considers the city as a complex, adaptive, and dynamic system capable of coping with the daily challenges of urban life (Ahern, 2013). In other words, resilient cities are system (composed of communities, societies, subgroups, infrastructures, sectors, etc.) that can "resist, absorb, accommodate to and recover" from various impacts and effects of external hazards in a "timely and efficient manner" (UNISDR, 2010, P.13).

Resilience theory (or resilience thinking) offered a unique perspective on some aspects that were interesting for our study on the quality perception of materials. When it came to selecting design ideologies that helped influence these perceptions, we looked into criteria that combined innovation with sensitivity and empathy to the users such as *resilience*, *adaptability,* and *transformability* (pages 175-176).

1.2.2. Sustainable development changing mindsets

In the midst of massive urbanization and its impact on the environment and wellbeing, a much-needed change in mindsets has been observed. In recent years, there has been a noticeable rise in ecological awareness; consequently, a long-overdue sustainable agenda was being put forward. Stakeholders including citizens, political leaders, businessmen, and practitioners have been searching for, testing, optimizing, and adopting more sustainable and resilient approaches to designing complex urban projects (Folke et al., 2010).

> "The problems of the 21st century come in all shapes and sizes. Some are massive, systemic problems with no easy solution. Some are small, discrete problems, the solutions to which can offer a brief respite of peace, of humor, or of success. We need people who can work on both kinds of problems, big and small, and especially people who can work on both at the same time, making sure the large systems we design—our cities, our governments, our companies, our products—are built for humans. And it's the tiny moments, the microinteractions, that can make these large systems humane." (Saffer, 2013, P.140)

Sustainable practices have been challenging the many disciplines involved in the conception of the urban world, including industrial design. Through human centered approaches, designers promote a greater sensibility to the human scale and interactions with everyday artifacts. With ecologically responsible and sustainable approaches emerging, the user is not limited to humans, but extends to other aspects of ecosystems that are vital to our survival (e.g., natural resources, fresh air, etc.). Designers are looking into solutions that are adaptable to the changing lifestyles brought by densification. A more specific example is the focus on sustainable, resilient, and adaptable design aspects addressing the use of urban materials across their complete life cycle.

1.3. Research questions

Our research questions concern concrete as an urban material observed from an industrial design standpoint.

Evolving concrete recipes and manufacturing techniques have allowed optimized industrial production, thus leading to new applications beyond the construction sector. Considering those technological developments offer new ways of perceiving concrete. This result in a change of mindsets when it comes to the quality perception of concrete artifacts.

The research's goal is to gain a better understanding on how concrete and its uses have evolved over the years. As designers, we are particularly curious as to how changing mindsets affect design, design practices, and user perceptions of materials and artifacts.

In order to reach those objectives, we aim to find answers to the following questions:

1. How have concrete technologies and applications evolved?
2. What are the perceptual qualities of concrete artifacts?
3. What influences concrete's perceptual qualities - particularly when it comes to its ageing?

Our study uses multiple methods in order to find answers to our research questions. We will describe the methods used to compile the answers to our first question in chapter 2 (page 22), while detailing the frameworks used to answer our second question in chapter 3 (page 38).

Chapter 2 – Methodological Framework

Design research and its methods have evolved greatly across the past decades, alongside the conceptions of design itself. In the late 1950s, the first mention of methodology emerged when theorist and engineer Bruce Archer (1964/1984) introduced his systematic design methods (Krippendorff, 2005). Later, British design researcher Nigel Cross (1993/2000) presented an overview on how these methods evolved and could be applied. Cross (2000) proposed different concepts of science in relation to design. He referred to an organized and rational systemic approach that aims to improve our understanding of design through reliable methods of investigation. The aim of these design methods, lessons, and practices is to "keep design discourse viable and productive" across the design community (Krippendorff, 2005, P.34). Another important name contributing to design methodology is cognitive psychologist Hebert Simon (1996/2001). Although his reflections were once considered ground-breaking, they were later criticized due to the limitations of engineering's technical rationality as design as a discipline is increasingly concerned with the user's experiences, in addition to those technical aspects. (Krippendorff, 2005). In our research, we apply a similar approach based on these concepts.

2.1. Qualitative research in design

In recent years, design scholars have been focusing on interpretative, qualitative, and human centered approaches originating in the social and humanities disciplines (Denzin & Lincoln, 2008b). Since today's design approaches are mostly preoccupied by user experiences, qualitative research methods have become of relevance to understanding complex cultural and social phenomena (e.g., the quality perceptions of materials in their context) (Hodder, 1994).

2.1.1. Constructivist paradigm

According to Hodder (1994), Denzin & Lincoln (2008a;2008b), and Creswell (2003/2013), qualitative research allows the researcher to observe and interpret the world through a **naturalistic approach**. This means studying phenomena as they are in their "natural settings, attempting to make sense of, or interpret [them] in terms of the meanings people bring to them" (Denzin & Lincoln, 2008a, P.4). This is of particular interest to our research when it comes to understanding concrete's different uses and the meanings generated within a specific context (e.g., post-war concrete).

According to Denzin and Lincoln (2008a), qualitative research can be structured according to different interpretive paradigms. In our research, a paradigm is understood as the constructive (or destructive) discoveries that are shared amongst members of a scientific community which can ultimately contribute to a change in theories, schools of thought, or practices, amongst others (Kuhn, 2012). Although a perspective can be similar to a paradigm, it is considered less unified (Denzin & Lincoln, 2008a).

> "[paradigms] are human constructions. They define the worldview of the researcher-as-interpretive bricoleur. These beliefs can never be established in terms of their ultimate truthfulness. Perspectives, in contrast, are not as solidified or as well unified as paradigms, although a perspective may share many elements with a paradigm, for example, a common set of methodological assumptions or a particular epistemology." (Denzin & Lincoln, 2008a, P.195)

We therefore apply a qualitative approach in which we mainly build our knowledge claims based on one perspective (Creswell, 2003). The most relevant to our research is known as a ***constructivist* paradigm**, through which we produced "reconstructed understandings of the social world" (Denzin & Lincoln, 2008a, P.197). Paradigms are seen to include four major elements: an axiology (ethics), an epistemology, an ontology, and a methodology. We demonstrate how this paradigm applies to our research as such:

Firstly, a ***relativist ontology*** assumes the existence of multiple realities. An ontology is understood as the "science of being", more specifically, "the construction of a world that is presumed to exist without its observers or constructors" (Krippendorff, 2005, P.22). This helped us assume that there are multiple ways to experience concrete artifacts, spaces, and structures. By consequence, there can be many perceptions and appreciations which are idiosyncratic and context dependent.

Then, the observer and the subject generate their understanding of a situation through ***subjectivist epistemology***. Compared to ontology, an epistemology can be described as the “science of knowing” (Krippendorff, 2005, P.22). Therefore, a *constructivist epistemology* - also known as a *subjectivist epistemology* - “studies how humans or members of a community come to understand” a specific phenomenon (Krippendorff, 2005, P.22). Through the criterion of **viability**, this epistemology allows observers, stakeholders, or participants to validate their understanding without the presumptions of ontology (Krippendorff, 2005). In our research, a *subjective epistemology* allowed us to gain a better understanding of various users’ opinions on concrete as voiced in articles, journals, books, manuscripts, blogs, and conferences, based on a documentary literature review.

We were also inspired to observe and document manifestations of concrete artifacts through a ***naturalistic set of methodologies.*** These take place in the natural world upon which the constructivist paradigm is based on, allowing us to experience the artifacts in-situ from the point of view of the interacting user (Krippendorff, 2005; Denzin & Lincoln, 2008a). These observations were based on empirical observations (e.g., on site photographs) as well as selected examples.

The **axiological** aspect of our constructivist paradigm was described earlier with out feminist ethics perspective (pages 14-16).

In that sense, a constructivist tradition is “rich, deep and complex”, and commits the researcher to “study the world from the point of view of the interacting individual” (Denzin & Lincoln, 2008, P.187). Scholars go on to encourage design practitioners to actively participate in the product or material experience by immersing themselves in the context and observing the user-product interaction firsthand in-situ (Schön, 1983; Schwandt, 1994; Cross, 2001; Findeli, 2006). However, it is important to note that these terms can be considered ‘sensitizing concepts’ as they “steer the interested reader in the general direction of where instances of a particular kind of inquiry can be found” as opposed to describing precisely what the observer should see (Blumer, 1954. P.7; Denzin & Lincoln, 2008b).

By reasoning on one specific material’s quality perceptions in a context, we apply **inductive logic** (Creswell, 2003): we attempt to draw general conclusions (e.g., on the perception of other urban ageing materials) from our investigation into one.

However, qualitative researchers must assume that they have a certain degree of **bias**: due to their personal backgrounds, experiences, values, preferences, and ideas, it is difficult to separate themselves from their research (Denzin, 1978; Jackson, 1990/2019; Fusch et al., 2018). Our study admits to this bias given that our personal beliefs in addition to socio-political circumstances produced research that is tainted with our subjectivity. Nevertheless, multiple sources will be used to configure our view and to provide more objectivity, reliability, and validity (pages 34-35).

2.1.2. Literature review

Firstly, **factual information gathering** was used to gain a better overview of our research field and our contextual framework, to understand the various key concepts, and to compile the relevant information for the theoretical framework. The data was compiled through various advanced scholar search engines and open access libraries (e.g., Google Scholar, Web of Science, JSTOR, etc.) using the combination of keywords (e.g., 'concrete* AND projects'; 'concrete* AND technologies'; 'concrete* AND sustainability'; etc.). The information was gathered through articles, journals, books, manuscripts, book chapters, citations, quotes, websites, blogs, as well as conference proceedings, expositions, cinematography works (e.g., movies, series, documentaries), forums, social media platforms (e.g., Instagram, Behance professional accounts), and comment sections, amongst others.

The documents referenced were selected based on either the author's notoriety on the subject, the source's rating (e.g., highest number of citations, where it's been published, etc.), or the publication date (e.g., more recent studies were prioritized in some cases). However, according to anthropologist Ian Hodder (1994), it is important to realize that documents which are used as references within a qualitative research methodology are "closer to speech" and are interpreted in their context by the researcher (Hodder, in Goodwin, 2012, P.172). Therefore, we are aware that the selection and interpretation of the data gathered only represents our subjective interpretations and conclusions.

All amassed information found and referenced was organized into four categories including historical, scientific, technical, and mediatic documents:

a. Historical documents

The study of history is of great relevance for design research: it represents an important frame of references and therefore helps inform and shape designs (Baljon, 2002). History is seen as a perspective allowing us to better understand human motivations and actions surrounding a particular phenomenon (Baljon, 2000).

> "Past and present meanings are continually being contested and reinterpreted [...]. Such conflict over material meanings is of particular interest to qualitative research in that it expresses and focuses alternative views and interests." (Hodder, 1994, in Goodwin, 2012, P.180).

Since our research concerns concrete, we have to include the evolution of its forms, compositions, uses, meanings, and influences through time. This includes both technical and socio-cultural considerations, amongst others, that are imperative to understanding today's material culture. Here, the study of 'material culture' is understood as a recent multidisciplinary field (including contributions from anthropology, sociology, psychology, design and cultural studies) "that incorporates a range of scholarly inquiry into the uses and meanings of objects" (Woodward, 2007, P.3). The term *material culture* is used interchangeably with 'objects', 'things', 'goods', 'services', 'spaces', for which we use the more inclusive term 'artifacts'. Therefore, artifacts are "the material things people encounter, interact with and use" and are "commonly spoken of as material culture" (Woodward, 2007, P.3). Material culture needs to be contextually interpreted "in relation to a situated context of production, use, discard, and reuse" (Hodder, 1994 in Goodwin, 2012, P.175)

> "[...] material culture, by its very nature, straddles the divide between a universal, natural science approach to materials and a historical, interpretive approach to culture." (Hodder, 1994 in Goodwin, 2012, P.183)

In that sense, the contextual interpretation of the historical evolution of concrete's material culture allows us to "explore multiple and conflicting voices, differing and interacting interpretations" (Hodder, 1994 in Goodwin, 2012, P.174). We thus use a non-exhaustive snapshot of the historical evolution of concrete artifacts to identify the significant elements that caused changes and affected its evolution.

b. Scientific documents

The scientific literature referenced in our study included some empirical but mostly theoretical studies in various fields of the social and natural sciences. The scientific documents were used in majority to build our theoretical framework. This includes the ideologies and methodologies of our disciplinary viewpoints (including and not limited to architecture, urbanism, landscape, interior, and industrial design); additionally, the theoretical notions related to the human sciences (e.g., anthropology, history, ecology, sociology, psychology, etc.); and lastly, the practical information offered by the natural sciences (e.g., material sciences, engineering, physics, etc.).

c. Technical documents

Furthermore, some technical aspects could not be overlooked in order to understand the material's evolution, as well as its current uses and technologies - particularly when it came to its composition, ingredients, and performances. Therefore, technical documents included specifications sheets, product/material requirements or warranties, and production/maintenance guides. The technical data gathered allowed us to better organize and analyze relevant aspects together and thus obtain a more holistic overview of the existing nuances (e.g., categorizations of structural modern concretes).

d. Mediatic review

And finally, a qualitative human centered research needs to also look into mediatic content to be closer to the public's (popular or unpopular) opinion on our research subject: concrete in the urban context. Therefore, our study takes into account design-related trade journals, popular magazines, websites, blogs, forums, conferences, and expositions, mainly as they were published on online platforms blogs (e.g., Dezeen, ArchDaily, Ignant, DesignBoom, DesignMilk, etc.). In addition, we also include some opinions on the subject featured in cinematography, television series, and documentaries, amongst others. This allowed us to better understand how concrete artifacts are perceived and represented by the media. By assessing the general tone of when and how concrete is mentioned for example, and by scrolling through the comments left by relevant members of the community, we were able to add more spontaneous perceptions to our historical, empirical, theoretical, and technical data. In addition, most of our new applications and technologies were found through keyword searches (e.g., ‘concrete designs’; ‘sustainable concrete’, etc.) on those platforms. The relevance of the media source was judged based on criteria such as notoriety and credibility. The information gathered through the review of media content provided candid and unapologetic comments, reflections, ideas, opinions, reactions, and sometimes actions towards concrete artifacts.

2.1.3. Empirical observations

Different concrete artifacts in their specific context can trigger a wide variety of reactions from the audiences. For example, while some seem to be *enthusiastic*, others seemed to be situated closer to the *indifferent* or even *repulsed* side of the spectrum.

In order to capture these complex dimensions, we gathered samples of concrete artifacts in its context through empirical observations. Although the term ‘context’ can refer to multiple aspects according to the discipline using it (Wapner & Demick, 2002), we understand it as “the interrelated conditions in which something exists or occurs: environment” (Merriam-Webster’s Collegiate Dictionary, 10th ed., 1995, P. 250).

Through our constructivist approach, the subject studied (e.g., concrete artifact) and its context (e.g., urban typologies) are considered important structural and dynamic components of the system we are observing (Koffka, 1935; Wapner & Demick, 2002). They help construct our perception of that system (e.g., concrete artifacts in the urban context) (Graumann, 2002). However, the “reality” represented becomes relative to the observer’s interpretation (e.g., myself as a researcher and user with my intentions, background, and associations, etc.) (Wapner & Demick, 2002). According to Heidegger (1962;1971), our awareness (how we perceive and associate meanings) of the physical world that surrounds us is grounded in the human activities afforded by it. In that sense, by having preconceptions of the physical world we are observing, we (as the observer) are able to analyse and understand it according to a range of meanings which we are aware of, as well as decide to act on (Graumann, 2002). We provide detailed reflection on the subjectiveness of perceptions and meaning in the next chapter.

Since little data was found addressing the ageing aspects of concrete artifacts, we have compiled a selection of non-participatory empirical observations in order to complement our literature review.

Our approach does not rely on participants of any kind (users, etc.) but is rather composed of the author's unstructured external observations of concrete artifacts in their context. These observations took place in Montreal and Quebec City (Quebec, Canada), Charlotte and Clement (North Carolina, U.S.A.), Tokyo and Kyoto (Japan), Singapore (Singapore), and Byblos and Beirut (Lebanon), and were distributed on a period of three years between 2017 and 2021 (one of which was during the thesis diploma projects in industrial design as was described in our foreword). The purpose was to document mainly physical and contextual characteristics of our subject, and thus offering visual examples to illustrate various perceptual qualities of concrete, which tend to vary greatly.

The documentation takes on the form of photographic content (images). By capturing photographs of the phenomena observed, we were able to document, annotate, compare, and assess our findings.

2.1.4. Examples studied

In order to further support our empirical observations, we have opted to look into the details of two examples of concrete artifacts. The methodology used to analyse the examples was inspired from case study inquiries, which are used to "investigate[s] a contemporary phenomenon (the 'case') in depth and within its real-world context" (Yin, 2014, P.16). Case studies are usually used with the purpose of "understanding a larger class of (similar) units", in which a unit is understood as a spatially bounded phenomenon that is observed over a predefined amount of time (Gerring, 2004, P.342). Furthermore, they “strive towards a holistic understanding of cultural systems of action”, which refer to a set of interconnected actions between actors in a situation (Feagin et al., 1990, cited in Tellis, 1997).

> “Case studies are multi-perspectival analyses. This means that the researcher considers not just the voice and perspective of the, but also of the relevant groups of actors and the interaction between them. This one aspect is a salient point in the characteristic that case studies possess. They give a voice to the powerless and voiceless.” (Tellis, 1997, P.9)

Within our research, two examples were selected to better understand how concrete artifacts are perceived in their context and throughout their ageing process. The information gathered was based on a literature review (e.g., mediatic articles on the project) and was occasionally paired with empirical observations (e.g., images of the artifact). In addition, they were used to maximize what can be learned on the subject (Tellis, 1997) and to complement the larger scope of our study (Yin, 2014).

The examples we have studied thus provide **explanatory information** (Yin, 2014), and were selected based on the types of concrete applications identified through a categorization (page 101). They were used to capture the “temporal changes” and the “contextual conditions” (stakes) of ageing concrete artifacts in the urban context (Yin, 2014).

2.2. Data analysis

Today, designers find themselves tackling complex situations while working to find adequate solutions for problems varying widely in scale and nature (Wakkary, 2005). As the urban context is perceived as an intricate web of systems dynamically interacting with one another, designers operate in multi/trans/pluri-disciplinary settings while utilizing various methods to tackle inherently complex design problems. These techniques have been borrowed from other disciplines (e.g., human sciences, etc.), and then developed, tested, and optimized over the years in an effort to support systems thinking. Here, ‘systems thinking’ is understood as a systemic reasoning process allowing one to understand the dynamics (including relationships, problems, and sub-issues) between various parts of a complex system (e.g., the urban city)

(Richmond, 1994; Arnold & Wade, 2015). This then enables one to adopt a holistic approach to gain a deeper understanding of the underlying stakes on one hand, and to analyze the subsequent parts before modeling a combined entity on the other hand (Richmond, 1994).

Furthermore, analysis can be considered to be inherently reductionist in some cases (e.g., when all the relevant sub-systems are not considered as part of a whole). Nevertheless, identifying and outlining various aspects of the problem field (e.g., context, object of interest, etc.) as well as studying and analyzing them offers precious insight into the problem field (Leblanc, 2016). This allows designers to broaden their understanding of the impacts of design interventions of a complex system.

2.2.1 Semantic mapping

In the planning and inquiry phases of the research process, we used mind mapping tools to map out our preliminary thoughts and associations over key concepts of our problem field (Buzan & Buzan, 2000; Davies, 2011). Mind maps are non-restrictive brainstorming and communication diagrams that were used to mentally represent the initial comprehension of our scope. They mirror the author's subjective intentions and associations with the subject matter without venturing into the underlying dynamics between various parts of a system (Buzan & Buzan, 2011; Novak, 2006). Our preliminary mind maps were loosely structured around a central topic; and as our comprehension of our problem field became more defined, purposeful, and specific, additional mind maps were produced. These helped us firstly gather our preconceived thoughts on various key concepts (e.g., 'the urban context'; 'nature'; 'concrete artifacts'; 'resilience'; etc.), then identify the gaps in our framework, and finally redirect our more specific subsequent literature review.

In order to organize and analyse the perceptual qualities of concrete artifacts gathered through the literature review, other semantic mapping techniques were used help structure the information (Johnson et al., 1986). Based on the semantic differential procedure research provided by Osgood, Suci, and Tannenbaum (1957), and we used oppositional terms (e.g., beautiful – ugly) which we situated at opposite ends of the semantic space. The bipolarity of the semantic space was found to be an “intrinsic quality of the subject’s response” (Bentler, 2012, P.33). In that sense, people tend to intuitively appraise things based on a bi-polar scale, thus communicating more easily ‘where’ they stand according to an experience (e.g., I find this object *attractive, plain, repulsive,* etc.).

Through our semantic review (see annex table 5, page 228), we were able to compile testimonies on how concrete artifacts are perceived through the attribution of semantic qualities. These descriptive terms were used to label the opposite sides of each semantic category (e.g., *beautiful* vs *ugly*), while offering definitions of each term and its sub terms accordingly. This allowed us to circumscribe the semantic space. In addition, in order to further understand the various perceptual qualities in their context, we isolated examples of instances where each term or sub term has been cited to describe concrete in the form of quotes, based on the literature review.

2.2.2. Analytical tools

The following analytical tools were used to help us inquire into our problem fields:

a. Categorization

Within later phases of our research process, there was a need to organize the information we had compiled on certain subjects (e.g., ‘concrete recipes’; ‘concrete applications’; etc.). Categorizations were thus utilized as a method to mentally compartmentalize some of our key concepts according to shared characteristics as well as distinctive qualities or differences (e.g., types of concrete reinforcements) (Rosch, 1987). The resulting specific categories were judged based on the researcher’s subjective perception, making our categorizations idiosyncratic representations of category prototypes (Rosch, 1987). Here, a ‘prototype’ refers to the most representative model that can be assigned to a specific category (Rosch, 1978;1999), according to our subjective reasoning. In addition, categorizations are more structured visual tools that follow a certain set of principles - as opposed to mind maps: the most important rule is the respect of the vertical hierarchy (Rosch, 1978). The top levels of a categorization are thus the most abstract (e.g., reinforced concrete), and the lowest levels become increasingly detailed and specific (e.g., fiberglass reinforcement).

Throughout our research, the data gathered was firstly organized and classified, and then analysed and compared according to identified criteria that were relevant to the scope of our study (e.g., sustainability, adaptability, resilience, etc.). Our categorizations allowed us to translate the raw data we gathered into visual hierarchical classifications that continued to evolve as our research became richer. For example, we chose to organize the types of concretes into two main categories, primitive and modern concretes, based on the period they were developed in and the level of sophistication of the recipe.

b. Timeline

In order to graphically represent snapshots of the evolution of concrete technologies, we use timeline mapping highlighting the major milestones that have helped trigger change and developments.

Timeline mappings have been used in life story research, amongst other fields, to relate subjective patterns to broader historical, socio-political, or environmental contexts (Goodson & Sikes, 2001; Adriansen, 2012). It is a “visual, arts-based data collection method, derived from a broader framework of graphic elicitation designs” (Kolar et al., 2017, P.15). In order to situate concrete artifacts in their various contexts of use, we use the timeline tool to visually illustrate the major milestones. We have organized the historical evolution of concrete into two timelines based on the two concrete categories: primitive and modern concretes.

The elements were placed in chronological arrangement and were identified with a date, title, and brief descriptors. In addition, the most influential milestones are highlighted with “visual indication of the significance or meaning attached” (e.g., use of a bolder font for the more important events) (Kolar et al., 2017, P.16).

c. Framework for product and material experiences

The literature review on quality perception of materials led us to the body of work brought forward by industrial design engineering professors Pieter Desmet and Paul Hekkert (2007) and their framework knows as PAME. **We thus use the PAME framework to interpret and analyze artifacts' quality perception as described and vocalized by their users.** This helped us identify patterns in the types of affective experiences and their underlying processes which can be then utilized by designers to influence product and material experiences. We apply their framework to concrete artifacts by analyzing the experience of concrete on 3 levels: aesthetic appraisal, meanings generated, and emotions elicited (see description on pages 48-55 & and application on pages 156-163).

2.2.3. Structure of analysis

The information gathered was analyzed and interpreted on various levels:

The amassed information was organized into categorizations according to predefined criteria that are relevant to the scope of our study (e.g., innovation, sustainability, resilience, user-centeredness, etc.). The emerging category types are grouped together according to evident similarities or obvious differences (e.g., 'cementitious substitutes'; 'recycled aggregates', 'alternative framework', etc.). This enables us to assemble visual communicative representations of our unique perspective and understanding of the subject matter.

Both cases studied were then examined using a list of criteria allowing us to systematically assess different factors on multiple scales. Firstly, we find the context of use referring to the time frame it was developed and produced in as well as its geographical and socio-cultural environment (pages 55-68). Secondly, we analyze the artefact itself in its materiality and technicity (pages 69-119). And finally, we look into the active and passive users (pages 119-122).

Triangulation

It is imperative to mention that we choose to retain and analyse the information that is judged relevant to our research in order to reduce the scope of the study due to time limitation. However, we intended to limit this bias through the **triangulation** of data by combining information extracted from the documentary literature review, the empirical observations, and the cases studies.

Within qualitative research, triangulation is used as a strategy to validate the procedures and results within a study (Denzin, 1978; Flick et al., 2004). In addition triangulation can even extend to theories to combining data drawn from various sources and places, as well as using multiple analysis methods. In the next chapter, we will describe the various theories and perspectives allowing us to shape our understanding of the problem field (e.g., phenomenology, perception, product experiences, etc.).

For example, through a phenomenological approach, we identified and conceptualized key factors such as the urban city (e.g., urban materials, densification impacts, etc.), concrete artifacts (e.g., typologies, etc.), and user quality perceptions (e.g., associations, general attitudes, etc.). This approach enabled us to be closer to the lived experiences of concrete artifacts in their context (time and space) and was combined to the previously mentioned literature review (historical, scientific, technical and mediatic documents).

Chapter 3 – Theoretical Framework

Our second research question investigates the perceptual qualities of materials and their artifacts which are understood through the concepts of **perception** and **experience**. In this chapter, we will introduce the theoretical notions that have guided our research and allowed us to interpret our findings.

A phenomenological approach allows us to better understand some key concepts which offered insight into the complex process that is perception. We base our understanding of those notions on the contributions of Maurice Merleau-Ponty, Martin Heidegger, and Georg Wilhelm Friedrich Hegel. Their findings in the field of phenomenology have been translated to design disciplines through the works of Deana McDonagh and her collaborators, amongst other scholars. Then, we elaborate further on notions relating to user perceptions mainly based on the works of Charles Bonnet, James J. Gibson, and Kurt Koffka. Our understanding in the field of semiotics is based mostly on the contributions of Ferdinand de Saussure and Charles Sanders Peirce, as well as Roland Barthes, Charles William Morris, and Daniel Chandler. To assess product semantics and concrete's perceptual qualities, we relied on the works of Klaus Krippendorff and Donald Norman. We base ourselves on a PAME framework through which we were able to interpret the perceptual data gathered throughout our study. The framework presented is founded on the collaborations between Pieter Desmet and Paul Hekkert, as well as the contributions of Michael Ashby and Kara Johnson, and lastly Elvin Karana, Owain Pedgley, and Valentina Rognoli.

3.1. The phenomenology of perception

Phenomenology is the branch of sciences which focuses on understanding the person's **lived experience**. We approached the research subject from a phenomenological perspective. More specifically, a 'perspective' is understood as a medium by which we first position ourselves according to the world, and then we attempt to discern and grasp it (Hegel et al., 1977). Philosopher Maurice Merleau-Ponty (1996) goes on to specify that the phenomenon of perspective is "ubiquitous – not just in sense experience, but in our intellectual, social, personal, cultural, and historical self-understanding, all of which are anchored in our bodily being in the world" (Merleau-Ponty, 1996, P. X-XI). Here, the concept of experience is seen as the intuitive and coherent sense or meaning that circumstances and events have for us (Merleau-Ponty, 1964;1996).

3.1.1. Embodied experiences of artifacts

Merleau-Ponty (1964) explains that humans exist as primarily 'thinking bodies' and tend to see reality as something that constantly needs to be interpreted to be understood.

> "To perceive is not to have inner mental states, but to be familiar with, deal with, and find our way around in an environment. Perceiving means having a body, which in turn means inhabiting a world" (Merleau-Ponty, 1996, P.X)

The premise of this research is based on the works of philosophers Edmund Husserl and Martin Heidegger and proposes that, when we begin to view our world from a body-centered epistemology, we allow ourselves to experience a level of engagement that is truly *lived* rather than *signified*. According to the phenomenology of design researcher Deana McDonagh and her collaborators (2004), we are able to make sense of the world through our bodies. Bodily perceptions thus offer rich and engaging experiences by acknowledging the emotional and ethical values of product and material characteristics such as shape, texture, color, weight, assembly type, resources origin, amongst many others (McDonagh et al., 2004).

> "We need to re-acknowledge that we have much to gain from paying attention to the meanings and experiences that are to be derived through our embodied perceptions. If we want to engage positively with the quality of emotion in design, we should start attending to the way that our bodily perceptions already make sense of the world for us" (McDonagh et al., 2004, P.431)

3.1.2. Perception

Perception is thus seen as an active cognitive process in which the perceiver receives sensory information from the surroundings and then interprets them into meaningful understandings (Bonnet, 1995). Many think of perception as something which can be *seen* such as psychologist James Gibson (1950), to whom visual perception refers to the sensory information received by our ocular system.

> “The visual world can be described in many ways, but its most fundamental properties seem to be these: it is extended in distance and modelled in depth; it is upright, stable, and without boundaries; it is colored, shadowed, illuminated, and textured; it is composed of surfaces, edges, shapes, and interspaces; finally, and most important of all, it is filled with things which have meaning.” (Gibson, 1950, P.3)

However, the sensory information that our brain processes is provided not only by visual perception, but also by sounds, odors, and tactical experiences. We register them through our sensory systems which include our entire body (Gibson, 1979). According to some scholars, we also rely on proprioceptive senses which allow us to be aware of our body and its actions in space (Whitehead, 1978). The world that surrounds us thus becomes a rich source of various sensory stimulations that are processed through our cognitive functions, and to which we associate meanings.

These perceptual experiences help form our reference systems which ultimately impact our decisions. Simultaneously, this knowledge shapes the way we perceive the world (Brewer & Lambert, 2001; Tacca, 2010;2011). We gain *knowledge* through our interactions by interpreting the large panoply of *information* available to us, transforming it through our cognitive processes (Norman, 2013). The perceptual and cognitive processes are thus intricately interconnected, each depending on the information provided by the other (Goldstone & Barsalou, 1998; Tacca, 2011).

Affordances and direct perception

Throughout history, scholars have attempted to understand how human beings perceive and decode the physical world that surrounds them. For example, the ancient Greek philosophies of Protagoras suggest that “man is the measure of all things” (Russell, 1959/1992, P.47). By the 18th century, Italian scholar Gambattista Vico, one of natural scientist and humanist Goethe’s contemporaries, developed the belief that mankind’s knowledge is a resultant of doing, creating, and experimenting with the world that they built (Krippendorff, 2005). Here, Krippendorff’s epistemology of human centeredness finds itself grounded in the design activity itself (Krippendorff, 2005).

Amongst the many contributors to the field of cognitive psychology, we find American psychologist James J. Gibson (1979) with his *ecological theory of perception*. Over the past decades, Gibson's human centered theories on perception and affordances have been shaping the design discourse (Flach, 1995; Krippendorff, 2005). Gibson's (1979) concepts of **affordances** and **direct perception** brought forward the need for a human centered language, which was adopted in many design approaches (Krippendorff, 2005).

> "Perception is economical. Those features of a thing are noticed which distinguish it from other things that it is not—but not all the features that distinguish it from everything that it is not" (Gibson, 1966, P. 286)

An affordance is the ability to *do something* with features of the world (Gibson, 1979). When we interact with an artifact, we perceive certain attributes that suggest certain functionalities that can be useful to us. Krippendorff goes on to describe an affordance as "[…] a reciprocal relationship between an observing actor and features of the environment. Affordances describe what is meaningful to the user of artifacts, not something independent of human involvement or described by a detached observer" (Krippendorff, 2005, P.43). They refer to fundamental properties – or clues – suggesting how an artifact can be used, manipulated, or operated (Norman, 2013).

Gestalt psychologist Kurt Koffka (1935) referred to this as the "demand character" of an environment. For him, artifacts have pre-dominant action-relevant properties which are immediately understood by us: for example, a sidewalk *says* 'walk on me', a bench in a park *says* 'sit on me', etc.

> "I have a need which for the moment cannot be satisfied; then an object appears in my field which may serve to relieve that tension, and then this object becomes *endowed* with a demand character" (Koffka, 1935, P. 354)

Gibson (1979) further explains that direct perception highlights the fact that affordances of everyday features are understood spontaneously and effortlessly by the user, or, as Krippendorff suggests, "direct perception is essentially what product semantics called self-evident, intuitively obvious, and natural" (Krippendorff, 2005, P.43).

Three levels of information processing

There are various levels of cognitive processing. Here, cognition includes all mental activities which occur within our bodies (e.g., thinking, remembering, learning, talking, etc.). Design scholar Donald Norman's studies conducted with psychologists Andrew Ortony and William Revelle suggest that our cognitive process relies on three levels of cognitive functions: the visceral, behavioral, and reflective levels (Norman, 2005; Ortony et al., 2005).

The more primitive ***visceral* level** is fast-acting and automatic, it allows us to make rapid decisions in quick-acting situations. It is considered to be the starting point of the *affective* information processing. Since this level is pre-thought, it mainly concerns the spontaneous reaction to outside stimuli. As Norman explains, "visceral design is about the initial impact of a product, about its appearance, touch, and feel" (Norman, 2005, P.37).

The ***behavioral* level** is subconscious and controls the majority of everyday human behavior. It is where the instant feeling of satisfaction from accomplishing a complex everyday task quickly and effectively comes from (Norman, 2005; Ortony et al., 2005).

The ***reflective* level** is concerned with more contemplative and reflective continuous activity. It generates lingering feelings of pleasure from tasks requiring study and interpretation as opposed to everyday tasks (e.g., solving a riddle). It is where "the highest levels of feeling, emotions, and cognition reside" (Norman, 2005, P.38). And thus, this is where *good*[7] design can have a long-lasting effect and produce pleasant experiences, ultimately playing on satisfaction and creating pleasurable memories.

> "The human mind is exquisitely tailored to make sense of the world. Give it the slightest clue and off it goes, providing explanation, rationalization, understanding." (Norman, 2013, P.2).

The visceral level is mostly common to all individuals. The behavioral and reflective levels are influenced by contextual factors such as lived experiences, cultural environments, and more.

[7] We use "good design" in reference to one of the most influential industrial designers of the century, Dieter Rams, and his Ten Principles For Good Design. For Rams, *good design* was simple, innovative, and responsible, and came from understanding the users and their needs and expectations.

Although the visceral and behavioral levels together generate what Norman calls '*affect'*, it is the reflective level that provides the interpretation of those affects into understandings.

Affect

In the cognitive sciences, 'affect' refers to the experience of feelings or emotions which are visible through "a set of observable manifestations of an experienced emotion" which occur "in reaction to a thought or experience" (Ortony et al., 2005). The affective state refers to "all types of subjective experiences that are *valenced*, that is, experiences that involve a perceived goodness or badness, pleasantness or unpleasantness." (Desmet & Hekkert, 2007, P. 12). Through this bipolarity, **valence** is used in experimental research to understand and identify different affective states (Bradley & Lang, 1994). Affective experiences tend to manifest through subjective feelings, behavioral tendencies (e.g., approaching, avoiding, attacking), automatic facial, vocal, and postural expressive reactions (e.g., frowning, standing up), as well as physiological manifestations (e.g., pupil dilation, sweat production), etc.

Consumer researchers for example investigate how the affective response to product appearances influences consumer choices as well as post-purchase product evaluation and brand loyalty (Olivier, 1993; Blijlevens et al., 2009). In engineering, *Kansei* is known as a method studying the relationships between product properties (e.g., ergonomics) and the user's affective responses in order to design products that elicit desired experiences (Nagamachi, 1988/2004). Within the domain of ergonomics, the influence of emotions has been investigated in "effective and efficient operations" (Demir, 2008, P.136), and so on.

Up until recent years, the emotional aspect of human psychology was ill-explored and only explored from a rationalist and logical perspective (Norman, 2005). Human-centered approaches however revealed that affect plays a critical role within all 3 levels of information processing, including decision making (Norman, 2005).

Aesthetics experiences: between cognition and affect

Along the same lines as Desmet and Hekkert's research – which we discuss in the later sections of this chapter (page 48) - Norman (2005;2010) relates the findings on emotions to **aesthetics** in product design.

'Aesthetics' is defined as a set of philosophical principles specializing in the understanding and appreciation of beauty in various sectors and contexts of our everyday lives (Saito, 2008;2017; Melchionne, 2013). Since it is a way to perceive and appraise various experiences, aesthetics can be attached to taste and preferences and are therefore subjective and idiosyncratic. In general, an aesthetic experience is one that is pleasing to the senses.

Norman (2005) makes a distinction between *cognition* and *affect*: whilst the former refers to understanding and interpreting information to build knowledge, the latter helps us evaluate and make judgments between two situations or options (e.g., good or bad, easy or hard, safe or dangerous, etc.). An aesthetic experience is a judgment resulting in pleasure or satisfaction for example, taking place in the affective state of our system.

The process of cognition allows us to understand perceived information (manifestations) using our memories and knowledge from past experiences. Affect allows us to interpret information according to our preferences, values system, and personalities. This is how we understand and relate to both the natural world that surrounds us and the artificial world that we have built.

In general, a **product experience** usually refers to an interaction with the artifact that is affective, one that is capable of creating emotional responses (Desmet & Hekkert, 2007). The three levels of processing (visceral, behavioral, and reflective) interact, influence, and even override one another continuously throughout our daily conscious and subconscious actions. Everything that we do "has both a cognitive and an affective component - cognitive to assign meaning, affective to assign value" (Norman, 2005, P.25). As Norman's research (2005) suggests, we cannot escape the affective state - whether it is positive or negative - as it influences how we feel and what we think.

The subjectivity of perceptions

What we perceive refers to "something essentially subjective in that it depends on some contribution made by the observer himself" (Gibson, 1950, P.13). Although the sensory information that are received may be the same, individual perceptions can be very different as they are conditioned by the particular experiences, personalities, and experiences of each observer (Gibson, 1950). As a highly context-sensitive process, perception is influenced by the contextual environment, the cultural background, experiences, memories, and pre-established associations (e.g., education, values system, beliefs, etc.), amongst various other aspects (Tacca, 2011).

> "[...] each man learns the meaning of the world for himself, within the framework of his upbringing and the society in which he lives. Significance and value are formed partly by the cultural background and partly by the individual's unique experience" (Gibson, 1950, P.206)

Perceptions are thus subjective, idiosyncratic, highly influenced by the individual perceiving, and context dependent.

To conclude, artifacts can convey a wide range of meanings and associations depending on contextual factors. These perceptions and experiences are described and communicated to us through the 'agency of language'.

3.1.3. Language and perception

Another central concept in our theoretical framework is the use of **language**, the principal communication system adopted by a community (Taylor, 1985). According to anthropologist Laura Ahearn (2001), language and culture are seen to be intricately connected and cannot be observed in isolation.

> " [...] language [is] a range of activities in which we express/realize a certain way of being in the world. And this way of being has many facets. It is not just the reflective awareness by which we recognize things as -, and describe our surroundings; but also that by which we come to have the properly human emotions, and constitute our

> human relations, including those of the language community within which language grows" (Taylor, 1985, P.234)

Language can be described as an 'agency'. Although the term is ubiquitous and has been the subject of debate in many disciplines, particularly anthropology, we understand agency as a "socioculturally mediated capacity to act" (Jaspers et al., 2010, P. 28). This 'capacity or action' is also subjective and context-sensitive, varying within different cultures and time frames (Pickering, 1996; Jaspers et al., 2010). The agency of language can thus include words in a specific tongue or dialect, their pronunciations, vocabulary, and phraseology, all while extending to signs and symbols including all forms of expression (e.g., sign language, gestures, speech, written text, etc.).

Language is seen to help deepen and transform our experience of the world "by expanding, refining, and varying the significance we have always already found in situations and events before we find it in sentences, thoughts, inferences, concepts, and conversations" (Merleau-Ponty, 1996, P. X). Speech, similarly to existential modalities such as motricity and sexuality, is one of the body's "natural power of expression" (Merleau-Ponty, 1996, P.187). We thus communicate our understandings of our world through the 'cultural artifact' of language, our "primary source of conceptions", which ultimately became intricately interwoven with our reality (Krippendorff, 2005, P.20).

In that sense, a phenomenological account of language showed that perceptions and thoughts are accomplished through speech, that their "expression is made possible because [we are] situated within a linguistic world, just as [we are] situated within the perceptual world" (Merleau-Ponty, 1996, P.186).

Krippendorff (2005) also explains that since design has industrial roots, its vocabulary encapsulates mostly industrial-era conceptions such as gestalt (form), beauty, and function, amongst others. These concepts are used to describe, through language, properties of artifacts independently from their observer (and by consequence their cultural and linguistic background). However, he continues to point out that some material properties, such as color, are solely interpreted through human perception. And thus, most of our understandings of material qualities are the product of human perceptions: “without language one would have no inclination of what other fellow humans perceive.” (Krippendorff, 2005, P.23)

To conclude, we communicate the different perceptions of our world through language. Our study is particularly concerned with these two complex concepts, as our perceptions of the world are expressed and translated through the agency of language. According to Krippendorff (2005), through language, humans are enabled to construct their conceptions of the reality they perceive by expressing our feelings and desires through words and sentences. In the next section, we will elaborate further on the process of interpretation.

3.2. Semiotics in design

When designers mention intuitive and meaningful design, they are referring to phenomena relating to the field of semiotics, which studies *signs* (Chandler, 2017). A ‘sign’ is defined as “something which stands for somebody for something in some respect or capacity” (Peirce, 1966, P.228).

> “To interpret something is to treat it as a sign. All experience is mediated by signs, and communication depends on them.” (Chandler, 2017, P.2).

The theories of signs began to emerge with Swiss linguist Ferdinand de Saussure (referring to it as *semiology* in the early 1890s) and American philosopher Charles Sanders Peirce (referring to it as *semeotics* in the late 1860s).

For Saussure (1916/1995), a sign is composed of two interdependent components, the ‘signifier’ and the ‘signified’, which relate to each other within an ‘interpretative system’. The ‘signifier’ is mental representation of something material that can be explicitly perceived (e.g., taste, smell, shape, etc.) (Saussure, 2006; Yakin & Totu, 2014; Chandler, 2017). Whilst the ‘signified’ is the abstract interpreted outcome or concept (mental construct) of the ‘signifier’ (e.g., rotten, fresh, clean, etc.) (Eco, 1976; Chandler, 2017; Yakin & Totu, 2014).

For Peirce (1931-58), a sign is composed of a triad of three functions : the ‘representamen’, the ‘object’, and ‘the interpretant’. The ‘representamen’ refers to what does the representing or “the form that the sign takes – the ‘sign vehicle’” (Chandler, 2017, P.29). The ‘object’ is what is represented or exemplified by the sign (Leeds-Hurwitz, 1993; Chandler, 2017). Whilst the ‘interpretant’ describes how the sign is interpreted referring to the abstract and previously unknown meanings which can be conveyed about the ‘object’ (Leeds-Hurwitz, 1993; Chandler, 2017).

3.2.1. Types of signs

According to French semiotician Roland Barthes (1972), a sign can also be interpreted on two levels: ‘**denotation’** and **‘connotation’**. Although these terms can be defined in different ways, we choose to stray away from the philosophical significations. Therefore, a meaning that is denotative is what is “definitional, literal, obvious, elementary, or commonsense” within a sign (Chandler, 2017, P.162). whilst connotation is the meaning derived from an individual’s subjective experience, which are often shared within a culture or community (Chandler, 2017). Barthes (1972) explains that connotative meanings require some knowledge of the social context and are thus influenced by contextual factors such as dominant ideologies, politics, beliefs, educational background, past experiences, etc.

Most scholars agree that although it is useful to analytically separate connotation from denotation, there are no signs that are purely denotative (Barthes, 1972; Volosinov, 1973/1986). There is no strict division between the two as “meaning is always permeated with value judgement” (Volosinov, 1973, P.105). Therefore, regardless of the initial intention, **a sign cannot have a denotative meaning without being connotative**.

Furthermore, Pierce (1931-58) makes a distinction between **‘natural’** and **‘artificial’** signs. Semioticians explain that the world can be experienced through two categories: one that is ‘continuous’, and one that is ‘discontinuous’ (Wilden, 1987). The former relates to ‘analogue’ signs - often represented as ‘natural' - which speak to our romantic ideology as opposed to our rationality (Wilden, 1987; Chandler, 2017). The latter refers to ‘digital’ signs - often described as ‘artificial’ - which, due to our attachment to analogical modes, are sometimes regarded as *less authentic* or even *fake* (Wilden, 1987; Chandler, 2017).

> "Denotation is sometimes regarded as a digital code, based on either/or distinctions of kind, and connotation as an analogue code, based on 'more-or-less' differences of degree." (Chandler, 2017, P.183)

3.3. Product semantics

While semiotics is the study of signs, semantics is the sub-branch which studies the meaning of linguistic signs and how they are interpreted.

> "[...] semantics deal with the relation of signs to objects" (Morris, 1938, P.34)

Product semantics is defined as "[…] the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design" (Krippendorff & Butter, 1984, P.4). This implies that, in order to be understood, artifacts need to have a 'form' which is perceivable by the user.

In our case, concrete, as a material, is defined by different physical properties (e.g., its shape, texture, color, etc.) which are perceivable by people. The different meanings they attach to concrete depends on their interaction with the artifact (e.g., walking on a concrete sidewalk, sitting on a concrete bench, driving on a concrete bridge, etc.).

3.3.1. Product and Material Experiences

Product experience is a multi-faceted phenomenon that refers to "all possible affective experiences involved in human-product interaction" (Desmet & Hekkert, 2007, P.2). It can be defined as "the entire set of affects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning) and the feelings and emotions that are elicited (emotional experience)" (Hekkert, 2006, P. 160).

As part of the product experience framework, materials are recognized to influence the physical attributes of artifacts (Karana et al., 2013). Materials alone can evoke aesthetic experiences, generate meaning, and elicit emotional response through their sensorial properties (Desmet & Hekkert, 2007). Different materials can attract and appeal to people with their texture, color, and symbolism, amongst other physical and metaphysical aspects (e.g., the authenticity and naturalness of wood, the luxury of marble, the strength of steel, etc.).

Based on semiotician and philosopher Charles William Morris's work on the theories of interpretation of signs (1938), materials can have three overlapping roles: one aspect can be **pragmatic** relating to physical and technical properties in terms of its usability, ergonomics, etc. Another aspect can be **semtiocial** referring to the interpretation and comprehension through understanding the intended use, or associating a meaning, a value, or a memory with the experience, etc. Lastly, materials can be **syntactical** referring to the relational aspect of signs to artifacts and their interpreters in terms of their physical properties.

Morris (1938) goes one to say that "[…] logical syntax deliberately neglects was here been called the semantical and the pragmatical dimensions of semiosis to concentrate upon *the logico-grammatical structure of language*, i.e., upon the syntactical dimension of semiosis" (Morris, 1938, P.14).

Character and meaning are easily ascribed to a physical artifact as well as the materials they are composed of. It is important to point out that it is very difficult if not impossible to separate the experience of the material from that of the product itself (Hekkert & van Djik, 2011). Therefore, materials (and by consequence their products) can help define a lasting negative or positive user experience as they are a way to lure initial attention and then to captivate, as well as inspire and generate *pleasure* or *repulsion* (Karana et al., 2013; Ashby & Johnson, 2014).

> "[…] materials convey particular, social, historical, and technological information"
> (Blaine Brownell in Karana et al., 2013, P.51)

Similarly to their products, materials can also evoke basic affective responses such as *fascination, boredom, amusement, anger, disappointment,* and *surprise*. These emotions can be evoked either directly (with the interaction with the physical sensorial aspect of the product itself), or indirectly (through aspects and associations that the product represents in its context) (Desmet, 2002;2008). Designers thus use materials to tell a story that is extraordinary, iconic, and unique through the purposeful manipulation of material modalities and properties (Ashby & Johnson, 2014).

Sensory modalities

Some scholars to describe a 'sensory modality' as the "[…] properties of materials that can be perceived by humans via sensory organs and can evoke physiological and psychological responses" (Zuo et al., 2004, P.28). Product characteristics are thus perceived through: **visual impressions** include surface color, finishes and textural characteristics (such as glossiness, roughness, patterning, waviness, etc.); **tactile impressions** refer to aspects such as weight, elasticity, coldness or warmth, hardness or softness, roughness or waviness, etc.; **auditory modalities** are the perceived acoustical responses emitted by the material in relation to surrounding sounds; and **smell and taste** which depend on how we perceive chemical molecules (Schifferstein & Cleiren, 2005; Karana et al., 2013).

In addition, cues such as weight (e.g., *light* or *heavy*), textures (e.g., *smooth* or *rough*), and temperature (e.g., *warm* or *cold*) can be first perceived upon visual inspection and are compared to previously lived experiences and references. In fact, vision and touch are known to be the most investigated in design for being the most successful modalities in providing detailed information on the product's properties (Schifferstein & Cleiren; 2005). For example, concrete is expected to be *heavy*; however lightweight technologies (which we will mention in chapter 4) may trigger a surprising response in relation to the material's envisioned weight. In this case, the previously made assumptions are not met.

Intrinsic and extrinsic material properties

Other scholars go to the extent of differentiating between **'intrinsic'** and **'extrinsic'** material or product properties (Addington & Schodek, 2005). Intrinsic properties include physical aspects (e.g., mechanical, chemical, molecular, etc.) and can be considered inherent to the material and remain relatively unchanged within stable environmental conditions. Whereas the manufacturing process and finishing techniques produce extrinsic properties which define the material's macrostructure and depend on the context and conditions. These extrinsic properties can help define elements of the material's appearance, regulate the user's perceptual responses, and alter their meaning and significations. Our research focuses mainly on the extrinsic properties of concrete artifacts, given that design may be able to influence them. This is observable particularly when we present the new technologies and applications overview, as well as the notions relating to extrinsic properties in the discussion section.

3.3.2. Three-level product and material experience framework

Desmet and Hekkert (2005) refer to three levels of PAME which can be conceptually separated into **aesthetic pleasure**, **attribution of meaning**, and **emotional response**. These levels are relevant to our study given that the quality perception of concrete artifacts in their context is a resultant of these three layers of processing. Although these concepts can be explained separately, they manifest in unity and are indistinguishably intertwined within our everyday experiences. The three levels display a hierarchical relationship as meaning and aesthetics elicit emotional experiences (Desmet & Hekkert, 2007).

1. **Aesthetic experience**

Products are capable of stimulating our senses and generate affect which is our human capacity to detect 'structure', 'order', or 'coherence' through our perceptual system, and to assess their 'novelty' or 'familiarity' (Hekkert et al., 2003). It is comparable to the sensory pleasure felt at the visceral level as described previously. Others such as Crilly, Moultrie and Clarkson's (2004) refer to it as 'aesthetic impression' within their cognitive response categories.

When it comes to aesthetic experiences, most of the research focuses on the visual domain (Desmet & Hekkert, 2007). However, Overbeeke and Wensveen (2003) draw our attention to another modality which they refer to as the 'aesthetics of interaction'. This means that beauty and pleasure can be found not only in physical manifestations but also in the interaction with the product within a given environment and time (Desmet & Hekkert, 2007). This notion is of particular interest to our observations as it introduces an additional layer of complexity when it comes to user interactions with concrete artifacts; this will be discussed further in the discussion chapter.

2. Experience of meaning

Deriving meaning from an experience is highly context-sensitive and is known to be influenced by individual and cultural aspects, as explained previously. Through these cognitive processes, we are "able to recognize metaphors, assign personality or other expressive characteristics, and assess the personal or symbolic significance of products" (Desmet & Hekkert, 2007, P.4). Some scholars refer to this level as the 'semantic interpretation' and the 'symbolic association' in their cognitive response categories (Crilly et al., 2004). For example, the experience of luxury is influenced by certain characteristics, and thus manifests when the artifact evokes some profound and sustained meaning to its users (Desmet & Hekkert, 2007). In other words, an artifact's **attributes** (e.g., characteristics, personality) can attract or repulse the user, all according to their values and preferences. In addition, long-lasting feelings of attachment come from multiple sustained interactions with time (Norman, 2005). These can help create memories and generate positive (or negative) associations with the artifacts.

These notions are also of relevance to our study as concrete artifacts can be associated with different meanings. By identifying potential associations, we may gain a better understanding of the different appraisals. For example, the historical uses of concrete within different time frames, geographical location, and amid various socio-cultural, political, and economic events has an impact on people's appreciation of the material's experiences and the meanings derived.

According to Gibson (1950), our experience of the visual world allows us to understand it in terms of distance, depth, motion, bounds, colors, textures, shadows, light, surfaces, edges, shapes, and spaces. However, it is important to keep in mind that we recognize these elements, we identify their functions, we predict their behavior, and we find them *familiar*. Gibson (1950) explains that, over time, we have learned, remembered, and apprehended the elements constituting our world. We have translated the edges and surfaces into specific shapes (e.g., geometrical shapes, organic forms, etc.), materials (e.g., concrete, wood, metals, textiles, etc.), artifacts (e.g., windows, tables, doors, etc.), people (e.g., children, firefighters, teachers, etc.), places (e.g., streets, sidewalks, parking, fields, jungles, etc.), and so on.

Types of meanings

For the purpose of this research, we have excluded the metaphysical and philosophical discussions about meanings in order to better focus on the human cognitive ability to perceive something as significant. As designers, we are concerned with how users derive meaning from their experiences and interactions with artifacts. Meaning is therefore understood as the significant quality that things have to their users (Grice, 1957).

According to Gibson (1950), there can be many levels and kinds of meanings. While some are more **primitive concrete meanings**, others are identified as **simple use-meanings** such as the satisfaction found in eating, playing, building, fearing, and loving. Some meanings are **of emotional value**, making something attractive or repulsive. Others **refer to a significance**, a suggestion of something that is not physically present, such as facial expressions (e.g., a frown means anger/sadness), heat indicators (e.g., sweat on skin indicates heat), or even weather changes (e.g., the sound of thunder indicates a storm approaching), and so on. There is also a whole range of **social meanings**, including body gestures, physical expressions, and different interactions between people. Then, there are the **abstract symbolic meanings** which can be mostly determined by culture (e.g., sports, money, language, etc.).

> "[symbolic meaning is] the most complex and the most momentous of the list. They mediate knowledge, as distinguished from perception, and they are the basis for reasoning, creative imagination, invention, and discovery." (Gibson, 1950, P.199)

Other scholars make the distinction between **'universal' and 'learned' meanings** (Karana & Hekkert, 2010; Karana et al., 2013). Although attributes, labels, and qualities that are assigned to materials allow them to theoretically inherit many meanings in different contexts, some patterns and irregularities have been identified (Karana & Hekkert, 2010).

In fact, some **figurative qualities** are attributed to materials - and by consequence to their artifacts - through 'embodied metaphors' or 'embodied projection' (Van Rompay, 2008). These qualities refer to the expressive character of objects through the spatial-rational references and metaphors which are omnipresent in our everyday experiences and languages (Gibbs, 2006; van Rompay, 2008). Through these deeply rooted bodily experiences, concepts are consequently formed and transferred as references or preconceived notions. We are thus able to predict a material's universally recognizable "designated, embodied meaning" (Karana et al., 2013, P.9). For example, transparent materials are usually perceived as more *delicate* and *fragile*, as opposed to opaque materials which are generally perceived as *heavy* and *resistant*.

Material associations can also be acquired and learned within the cultures and societies in which they are being used (Karana et al., 2013): for example, porcelain is used in long-lasting dinnerware that are passed on between generations; this reinforced the material's association with high quality and luxury, but also durability (even though ceramics are fragile). These attributions can be arbitrary or directly linked to the material's intrinsic properties (Karana et al., 2013). This also means that there can be inevitable variations within those associations depending on the cultural expressions, the social patterns, the technological possibilities, and the society's expectations (Karana et al., 2013).

It is important to point out that concrete, as a material with a rich history and complex associations, similarly to its appraisals, can also have universal as well as learned meanings. We will give examples of those nuances in the discussion chapter.

3. Emotional experience

Emotions are neuro-psychological responses of our bodies and are continuously being triggered and influenced by external or internal stimuli (Norman, 2004). They include affective phenomena such as *happiness* and *sadness, love* and *disgust, pride* and *despair, attraction* and *repulsion*, amongst many others (Desmet & Hekkert, 2007). According to Desmet (2002), positive emotions such as *happiness* and *relaxation* are also seen to pull us towards experiences that we judge as beneficial, whereas negative emotions such as *anxiety* or *fear* are seen to push us away from experiences that might compromise us.

Furthermore, emotions are seen as 'functional systems' operating in a coherent and organized manner (Desmet & Hekkert, 2007; Smith & Kirby, 2011). These indicate where we stand according to our environment through feelings of *attraction* or *repulsion* towards certain elements (e.g., certain behaviors, ideologies, etc.) (Frijda, 1986).

For example, concrete artifacts can provoke a wide spectrum of emotional responses from users, which will be detailed in chapters 4 & 5. By understanding the construct of the process that leads to an emotional experience, we can better position the variety of these human reactions based on a positive to negative spectrum.

Appraisal theory

The current - and most widely adopted - theory on emotions is known as 'appraisal theory' (Arnold 1960). Through this process, "an emotion is elicited by an evaluation (appraisal) of an event or situation as potentially beneficial or harmful" (Desmet and Hekkert, 2007, P.5). To put in simple terms, the interpretation of the experience of a material, product, service, space, or event can be the source of the emotions generated in a person.

Appraisal becomes relevant when we look into how it can mediate between the PAME, and the emotions generated. Since appraisal is the individual's judgment of the significance of a product or material experience according to their wellbeing, appraisals become 'inherently rational' (Scherer, 1984). This means that "different individuals who appraise the same product in different ways will experience different emotions" (Desmet & Hekkert, 2007, P.5). People tend to bring their dispositions and concerns into the emotional process, and thus construct an experience's emotional relevance according to them (Lazarus, 1991). These concerns are often referred to as 'affect dispositions', 'sentiments', 'tastes', or 'attitudes' (Ortony et al., 1990). And while some concerns can be universally shared amongst most humans (e.g., the concern for health), most are influenced by culture and context (e.g., the concern of finding a good parking spot after a snowstorm).

This relational aspect is of great importance to assess the quality perception of concrete artifacts and the appraisals they can generate in different users. This means that PAMEs of concrete can be context-sensitive and idiosyncratic, or universally shared amongst a community or culture.

3.3.3. Experiences, like perceptions, are context-sensitive

PAMEs are constantly subjected to cultural and temporal influences (Desmet, 2002).

> "People can differ from one another with respect to their concerns, motives, abilities, preferences, goals, and etc., and thus with respect to their affective responses to a given event" (Desert & Hekkert, 2007, P.7).

In that sense, different aspects directly contribute to the overall experience from cultural, ideological, and socio-political standpoints, including values (ecology, ethics, etc.), motives, traditions, personalities, expectations, etc. Others belong more to the contextual realm such as location, weather, time. Whereas some are linked to the artifact such as its ergonomics, color, texture, scale, etc. Additional influential aspects include perceptual and cognitive processes such as observing, understanding, exploring, manipulating, comparing, etc.

PAMEs are thus linked to the context in which the interactions occur, the attitude and experience level of the user involved, as well as the artifact itself (Desmet & Hekkert, 2007).

In the next chapter, we present the results of our research. The first section (4.1 - 4.4) answers our first research question and is presented as an overview of the historical milestones triggering the evolution of concrete technologies in terms of mixes and techniques. In order to better situate concrete's material culture and perceptions today, we decided to include technical, social, and cultural considerations, amongst others. The second section (4.5 - 4.6) answers our second research question and looks into the various semantic attributes characterizing concrete artifacts. The last section (4.7) offers field observations and studied examples which were used to validate and complement the findings from the first two sections.

Chapter 4 – Results and Contextual Analysis

In order to better situate concrete's material culture and perceptions today, we decided to include technical, social, and cultural considerations, amongst others in the overview of its historic evolution.

4.1. The evolution of concrete

The origins of concrete-like materials as well as their uses and applications can be traced back to ancient civilizations. In our research, we describe them as "primitive concretes" (PC), whilst the more recent and standard compositions will be referred to as "modern concretes" (MC). Categorizations representing their differences can be seen respectively on pages 60 & 62-62. We also used those categories to organize the evolution of concrete according to 2 timelines, which can be found respectively on pages 61 & 68.

Although the material has been utilized in a wide variety of fields, it is incontestable that "architects have paid more attention to concrete as a medium of culture than any other occupation" (Forty, 2013, P.11). Our overview on concrete's evolution predominantly refers to the work of architect historian Adrian Forty, as well as Cyrille Simonnet, and Peter Collins. Additional significant findings are based on the works of concrete pioneers in the planning, engineering, and arts disciplines such as Auguste Perret, Francois Hennebique, and Le Corbusier. These individuals were amongst the first to exploit concrete's advantages in their projects, leading to its popularization. Considering concrete's evolution in recent years, it was necessary to look more closely at the works of their contemporaries such as Kenzo Uno, Christian Meyer, Timothy Wangler, Mark West, and Diederik Veenendaal, to name only a few. Their more recent experimentations with concrete have helped introduce new mixes and techniques and thus creating unexpected ways of composing with concrete.

4.1.1. Primitive concretes (PC)

Throughout time, a wide variety of concrete-like materials and mixes have been developed and used by ancient civilizations, as is summarized in figure 3 (page 61).

Although the modern process of producing concrete results from intentional and manual labor, it has also occurred geologically in a spontaneous and unplanned manner in nature (Forty, 2013). The first types of geological concrete-like materials can be traced back as far as 12 000 000 BC in the Middle East where a limestone and oil shale spontaneous reaction formed what can be considered as the earliest natural deposits of cement compounds (Waever, Big Rentz, 2020). Other naturally occurring concretes were found on Graeco-Roman sites and in medieval England (Robinson cited in Cherry & Pevsner, 2002). To this day, such deposits can still be found in some regions of California (Robinson in Cherry & Pevsner, 2002).

The first PC structures were manufactured in 6500 BC Syria and Jordan; these were composed of a type of hydraulic lime-based concrete that hardens under water (Malinowski and Garfinkel, 1991; Gan, 1997). A few centuries later, in 5600 BC Central Europe (today's Yugoslavia), houses were built with a type of concrete floor (Vasavan, 2019). Some theorists even suggest that different types of concrete mixes were used to build the Egyptian Pyramids in 3000 BC (Campbell, 1991). These recipes were composed of mud and straw to form the bricks, in addition to gypsum, lime, clay, and sand to make the mortars (Gavriletea, 2017; Gan, 1997). Around that same time, Chinese cultures developed a form of cementitious materials to hold bamboo together; these were used to build boats as well as the Great Wall itself (Lin, 2011).

The use of substances to help bond together stones or bricks can be traced back to Neolithic Times (Gan, 1997). PC's journey continues in the Middle East around 1300 BC where coatings of fortresses and vernacular walls were made of a thin and damp coating of burned limestone (Gavriletea, 2017). This type of material marked the beginning of the development of cement, which is the binding substance that helps other materials adhere together by hardening with time (Taylor, 1997).

Further up the timeline, in 700 BC Jordan, groundwater seeping through silica was found to transform into a sandy volcanic ash pozzolanic material (Gan, 1997). A pozzolanic material is a hydraulic cement which generally reacts like cementitious substance when in contact with water (Taylor, 1997).

There is even some evidence of lime and ashes used as mortars in the Middle East (Draffin, 1976; Gan, 1997). The ancient Jordanians combined the volcanic ash deposits with lime and then heated them in pottery kilns, kept the concrete mix dry. These civilizations began to understand that excess water led to voids and weakness in the structures, which helped them optimize their techniques. That time period introduced the use of new building practices such as specialized tools such as the ones used for the stamping process in which stamps are pushed into the wet concrete and then removed, leaving a pattern (Draffin, 1976).

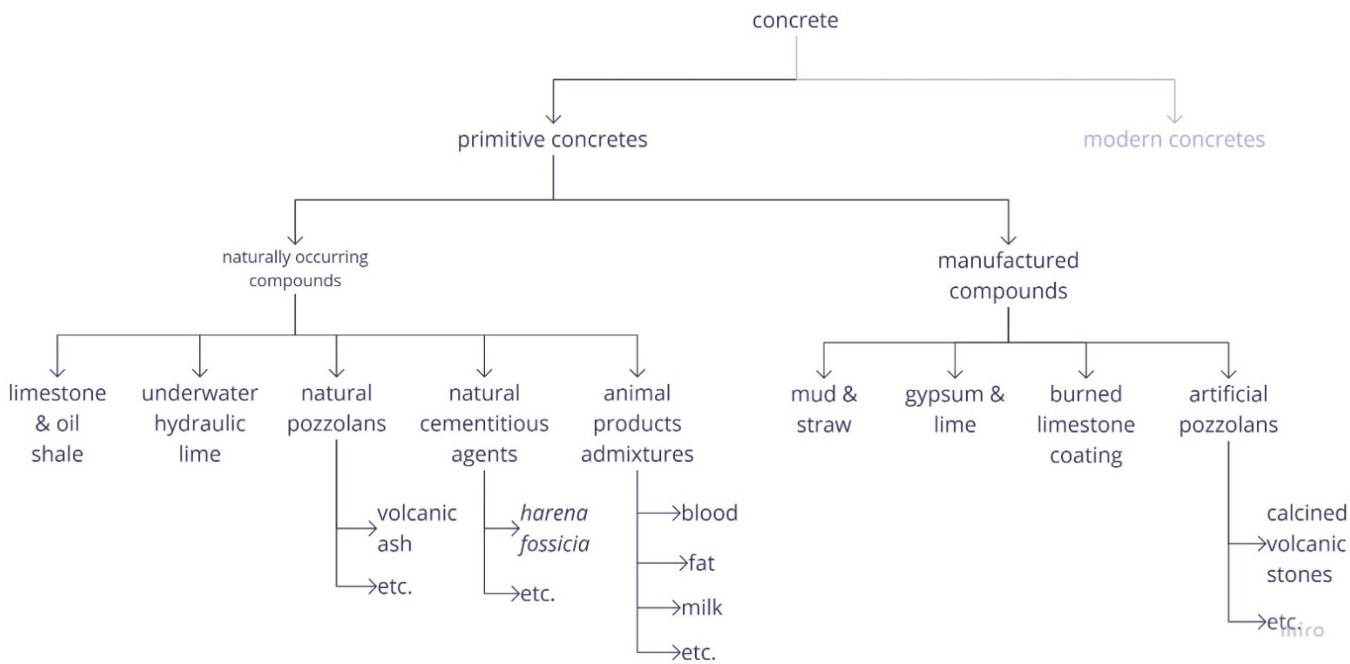
Following the Jordanians, the 600 BC Greeks also discovered a type of natural pozzolan known as volcanic ash, which developed hydraulic properties when mixed with lime (Gan, 1997). These types of materials were generally referred to as 'hydraulic setting cements' (Gan, 1997).

However, when it came to ancient civilizations utilizing PCs, the Romans took the lead. Around 200 BC Rome, with the use of cemented rubble, they developed a material remarkably close to MC in its composition (Gan, 1997). The Romans became known for developing some of the first artificial pozzolans such as *calcined kaolinite clay* or *calcined volcanic stones* (Delatte, 2001).

The first large-scale use of naturally cementitious building agents was documented and attributed to the Roman era (Gan, 1997). Cement was made from a naturally reactive volcanic sand known as *harena fossicia* which was thought to have helped preserve the structures across the centuries (Gan, 1997). In addition, different types of animal products such as fat, milk and even blood were used as early admixtures.

Moreover, one of the most important aspects of the Romans' contribution to concrete's history is the use of trade guilds. In fact, the Romans were the first to assign members of their community as responsible for passing down knowledge of materials, techniques and tools to younger apprentices (Jackson et al., 2014). Vitruvius, the most famous Roman engineer and architect, developed and documented detailed techniques to produce and build concrete cofferdams and vaults (Vitruvius, 1914). Since then, the Romans perfected their trade and were notorious for building architectural marvels that stand tall to this day such as the Colosseum (using lime mortars still holding together the bricks) and the Pantheon (with the largest still-standing unreinforced concrete dome in the world), to name a few examples (Gan, 1997).

However, with the fall of the Roman empire in 476 AD, there was a “gradual decline in the quality of the cement, mortar and concrete used in building construction” (Gan, 1997, P.4). Although concrete was still used as a construction material throughout the Middle Ages, its quality was far inferior to that of Roman cement (Gan, 1997). Consequently, there were no new concrete developments documented before the re-discovery of Vitruvius’s Ten Books on Architecture in the fifteenth century ‘*De Architectura*’ (Forty, 2013).



To summarize, PC can be grouped into two main categories: naturally occurring concrete-like compounds that are found in nature, and purposely manufactured ones that were combined, heated, and treated by mankind as can be seen in figure 2 below.

Figure 2. – Categorization of Primitive Concretes, T. Harb, 2020

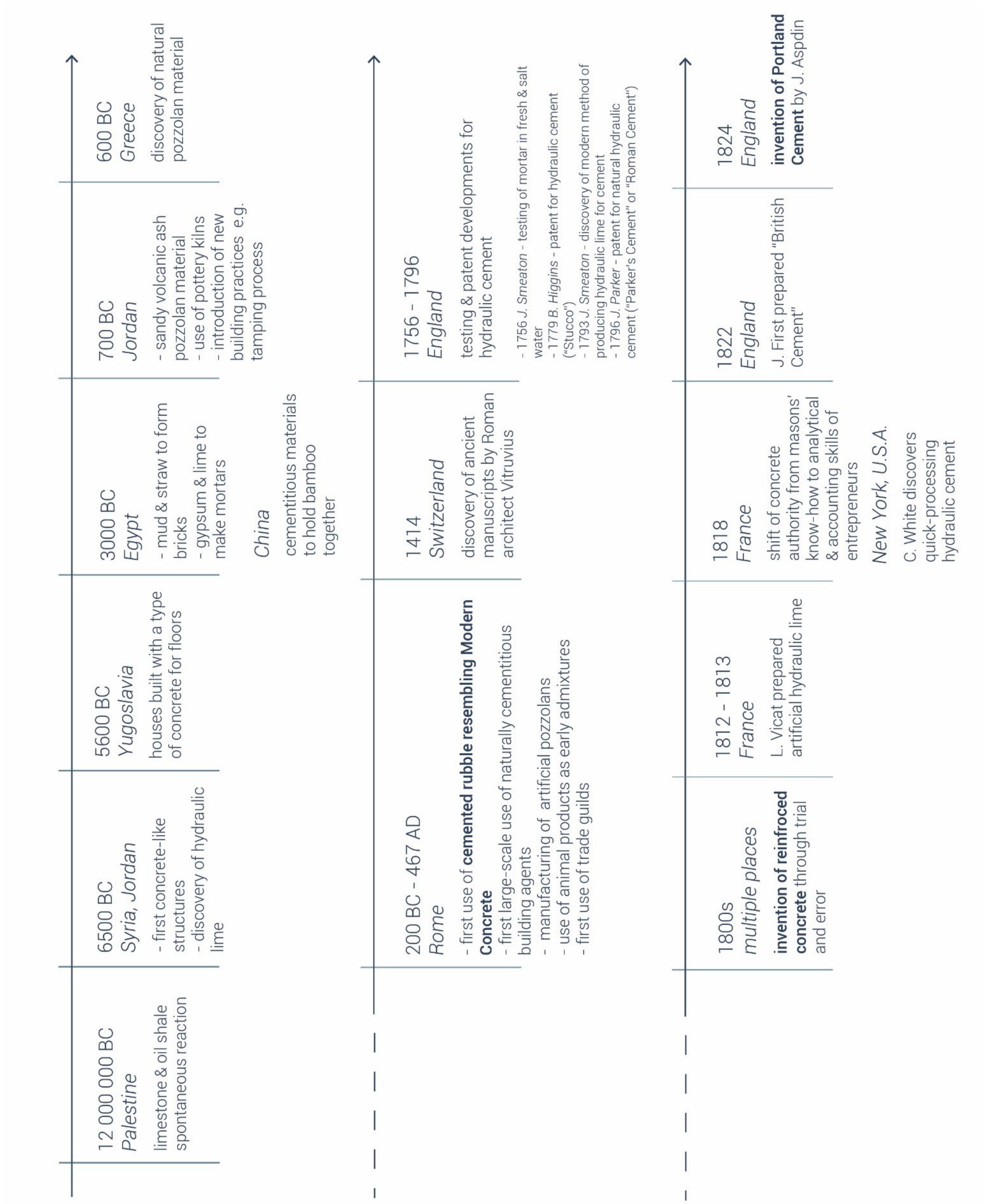


Figure 3. – Timeline of Primitive Concretes, T. Harb, 2021

4.1.2. Modern concretes (MC)

After nearly a century, in 1414 Switzerland, Vitruvius's ancient manuscripts were re-discovered in an old monastery library (Vasavan, 2019). They were then published to an audience of Renaissance thinkers in 1450 and later translated into many languages (Vasavan, 2019). However, despite their translation and distribution to the public, no remarkable concrete developments were documented throughout the following centuries.

We organized these MC mixes into two main categories: the first includes concrete mixes used for non-structural uses as seen in figure 4 below, and the second groups reinforced concretes, as seen in figure 5 (page 63). Generally, all MC mixes are mainly composed of a binding paste and aggregates: the binding paste includes a cementitious material, water, and other additives, admixtures, or agents; it is what allows for the fine and coarse aggregates to bind and adhere together as the mixture cures with time (Wang & Salmon, 1998/2017).

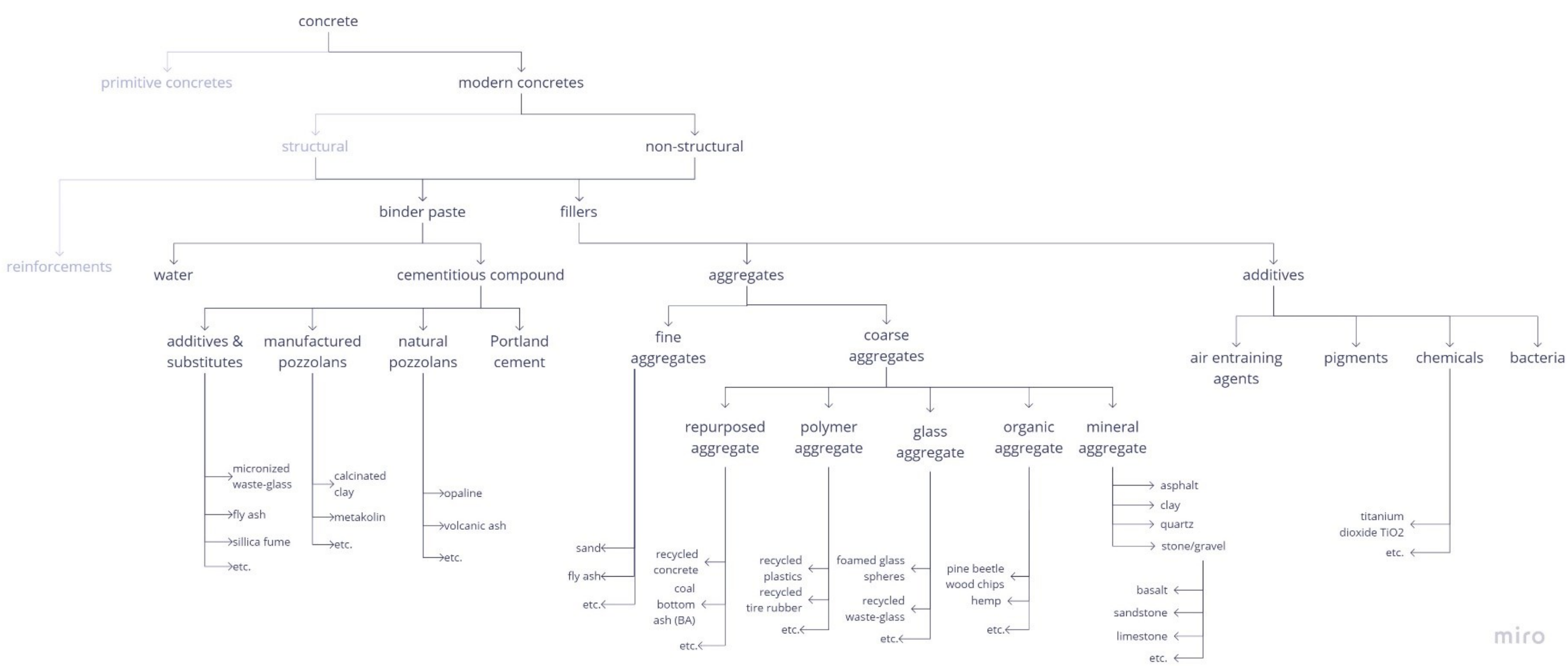


Figure 4. – Categorization of non-structural Modern Concretes, T. Harb, 2021

The addition of a type of reinforcement to the recipe leads to a more structural and performing concrete which is used for applications requiring high technical and mechanical performance, as well as extended durability (page 77).

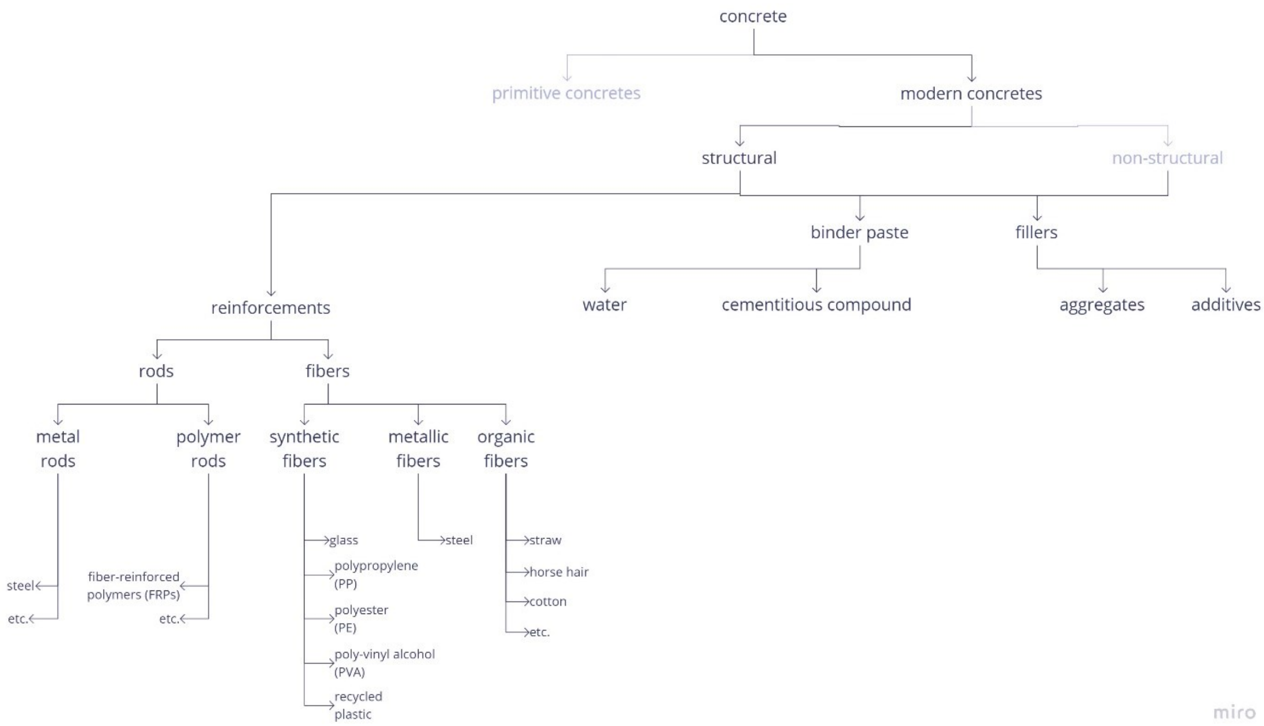


Figure 5. – Categorization of structural Modern Concretes, T. Harb, 2021

In the mid-to-late 1700s, the production of hydraulic cement marked an important milestone in the material's evolution: British engineer John Smeaton tested different types of clay and lime mixtures (Gan, 1997). This led to patented hydraulic cement technologies that were used in the construction of his Eddystone Lighthouse, which was described as "the foundation upon which our knowledge of hydraulic mortars has been built" as well as "the chief pillar of modern construction" (Draffin, 1979 cited in Gan, 1997, P.5).

The invention of **Portland cement** and the development of **steel reinforced concrete** in the 1800s were arguably two of the most important discoveries for the concrete construction industry. In their early developments, these technologies were thought to be invented several times, in different ways, in multiple places, by combining a variety of skills and expertise of many disciplines (Simonnet, 2005; Forty 2013).

> "Different regulatory regimes, different constructional cultures and differences in local labor markets have all contributed to variations in ways of doing concrete" (Forty, 2013, P.119-120)

The research, testing, and patenting processes were dispersed amongst a variety of groups: while chemists and engineers developed cement's recipes, industrialists commercialized its production. Furthermore, builders and entrepreneurs developed (through trial and error) concrete applications and perfected the techniques used to reinforce it with steel (Simonnet, 2005; Forty, 2013). These combined contributions have helped shape MC's know-how, becoming the state of the art since.

The 19th century marked an important milestone for concrete technologies with the invention of Portland cement in 1824. Although many have experimented with previous variants, and optimized later ones, the recipe is credited to J. Aspin who burned finely ground chalk and clay in a kiln until the carbon dioxide was removed, thus creating what is referred to now as cement (Gan, 1997).

> "Portland cement is made by heating a mixture of limestone and clay, or other materials of similar bulk composition and sufficient reactivity, ultimately to a temperature of about 1450°C. Partial fusion occurs, and nodules of clinker are produced. The clinker is mixed with a few per cent of calcium sulfate and finely ground, to make the cement. The calcium sulfate controls the rate of set and influences the rate of strength development. It is commonly described as gypsum, but this may be partly or wholly replaced by other forms of calcium sulfate." (Taylor, 1997, P.1)

Reinforced concrete recipes and techniques were first patented by W.B. Wilkinson in 1854 (Schmidt & Fehling, 2004). Throughout the mid to late 1800s, the evolution of reinforced concrete was further optimized through the works of pioneers such as W. Ward and T. Hyatt (U.S.A. and England), M. Allen and E. L. Ransome (U.S.A.), J. L. Lambot, J. Monier, A. Perret, and F. Hennebique (France), and G.A. Wayss (Germany), to name only a few (Collins, 2004). Most of these developments in reinforcement involved metal: specifically, steel elements (barbs, wires, meshes, structures, etc.) that were integrated, through trial and error, into the concrete mix.

As the use of reinforced concrete became increasingly popular as a construction material, it has been described by some as a *process* rather than a mere *medium* (Delhumeau, 1999; Simonnet, 2005). This is due to the fact that its ingredients are combined via the *process of human labour* (Forty, 2013). In fact, Hennebique, the first pioneer of reinforced concrete, famously said that "[…] reinforced concrete was the art of doing large things with small means" (Delhumeau, 1993, P.67).

According to Forty (2013), although the mixing and construction process can seem simple or primitive, concrete's reliability and durability has surpassed other mixed building materials such as rammed earth and mud. Its performance was predictable, which became a critical and important advantage as manufacturing and building norms were being established.

> "[...] reinforced concrete is more than a material, it is a totally new construction process which permits the realization of all kinds of forms, the solution of all constructional problems. It can appear under all kinds of costume. It is too general to have a proper physiognomy" (Edouard Arnaud, cited in Hennebique, 1901, P.87)

During the 20th century, concrete technologies evolved the most (Forty, 2013). With the industrial revolution and globalization, the demand for concrete applications grew rapidly in parts of in North America (across the U.S.A. and Canada), Europe (mainly France, England, Germany, and Italy) and Asia (specifically Japan and India) (Forty, 2013; Collins, 2004). Architects such as Perret and Hennebique, engineers such as Vicat, White, Brunel, Edison, Koenen, Aspin, and Le Chatelier, and builders such as Coignet and First pioneered concrete developments in novel applications (Simonnet, 2005; Forty, 2013).

According to Simonnet (2005) and Forty (2013), these technologies included **colored concrete**s, the use of **alternative aggregates** (e.g., rubber) as well as **air-entraining agents** that help increase resistance. The introduction of **ready-mixed** technology revolutionized the industry as concrete could be delivered directly to construction sites and poured in place (Forty, 2013). In addition, **prestressed concrete** took advantage of its compressive strength allowing it to withstand impressive loads that tend to reduce its size, making it strong under pressure. Later, architects and engineers introduced other techniques such as **cantilevers** to offer a new way to deal with load and support issues (Forty 2013), or **thin shells** to create dramatically thin hyperbolic structures (Veenendaal & West, 2011).

Furthermore, Forty (2013) draws a connection between concrete and war as the rise of the material's potential in the early 1900s coincided with World War I (WWI), and later, World War II (WWII). According to him, it is during that period that concrete acquired a political connotation which is usually associated with the radical left: in Eastern European countries such as Russia or Poland, and Western ones such as Spain or Britain, reinforced concrete was particularly seen as a medium that enhanced people's collective social consciousness. Later, during the postwar era, concrete was seen to become “part of a transatlantic dialogue” (Forty, 2013, P.116). The material’s universality was connected to the pursuit of an architectural cultural international style. In that period, concrete attained the peak of its political maturity as it became a “formidable weapon in the arsenal of the Cold War” (Forty, 2013, P.150).

In that context, Forty (2013) attributed concrete two roles: the first one was passive as concrete bunkers, missiles silos, aircraft hangars, and shelters were built to absorb blasts and protect from shocks and radiations. The second was more active from an ideological standpoint, as the communist East and the capitalist West tried to outperform each other when it came to building production and expansion.

The post-war reality called for reconstruction, and concrete was generally the preferred medium when it came to the “needs for speed, to not hamper economic recovery by diverting skilled labour away from other industries and into building production” (Forty, 2013, P.150). During that period, the advantages of **prefabrication** in the construction industry became increasingly evident:

> “Prefabrication in concrete rescued the social democracies from their political predicament, for it offered the prospect of building houses, hospitals, schools and roads fast, and with unskilled labour.” (Forty, 2013, P.160)

The rest of the twentieth century thus brought some of the most notorious concrete developments. In the 1960s, reinforced concrete as well as prefabricated panels increasingly gained in popularity in the West as well as in Europe and some parts of the East. Forty notes that “few, if any, other technologies have made the transition from West to East, from North to South, quite so completely as concrete”, thus becoming the building material of choice for both ideological and economical reasons (Forty, 2013, P.119).

Casting concrete directly on the construction site proved to be very practical and efficient in terms of time and resources, and thus **cast-in-place** became increasingly popular. In addition, new **polymer concrete** mixes were explored by replacing cementitious with polymers, offering new physical properties and enhancing technical performances. Experimentations with different types of new fibers emerged (e.g. steel, glass, and carbon fibers) lead to the introduction of **fiber reinforced concrete** (FRC).

As the urban growth continued to increase, different countries developed new technologies depending on the needs of their specific contexts. For example, Europe introduced **alkali-resistant glass fibers** in the 1970s, while Japan developed **self-compacting concrete (SCC)** in the mid 1990s helping reduce signs of deterioration.

In the middle-late 1990s in North America, **high-strength concrete (HSC)** and **high-performance concrete (HPC)** began to emerge helping improve compressive strength. These were soon followed in the late 1990s by **engineered cementitious compound (ECC)** mixes, which improved ductility, tensile strength, and repair; better ductility enabled a material to sustain high forces before plastic deformation, while improved tensile strength helps it withstand bigger loads which tend to elongate, making it strong in tension. Around the same time, France's **reactive powder concrete (RPC)** was becoming known for its high ductility and impressive compressive strength.

By the end of the 20th century, the worldwide brand of **Ultra-High-Performance Concrete (UHPC)** was created, covering a wide range of products (pages 76-79). Over the course of many years, multiple new recipes were patented using all sorts of fibers (e.g., natural and polymer), additives (mineral additives, cementitious additives, types of bacteria, chemicals, etc.), and agents (e.g., air entraining agents, etc.).

The timeline showcasing the most important milestones in MC's are resented in figure 6 as follows (page 68).

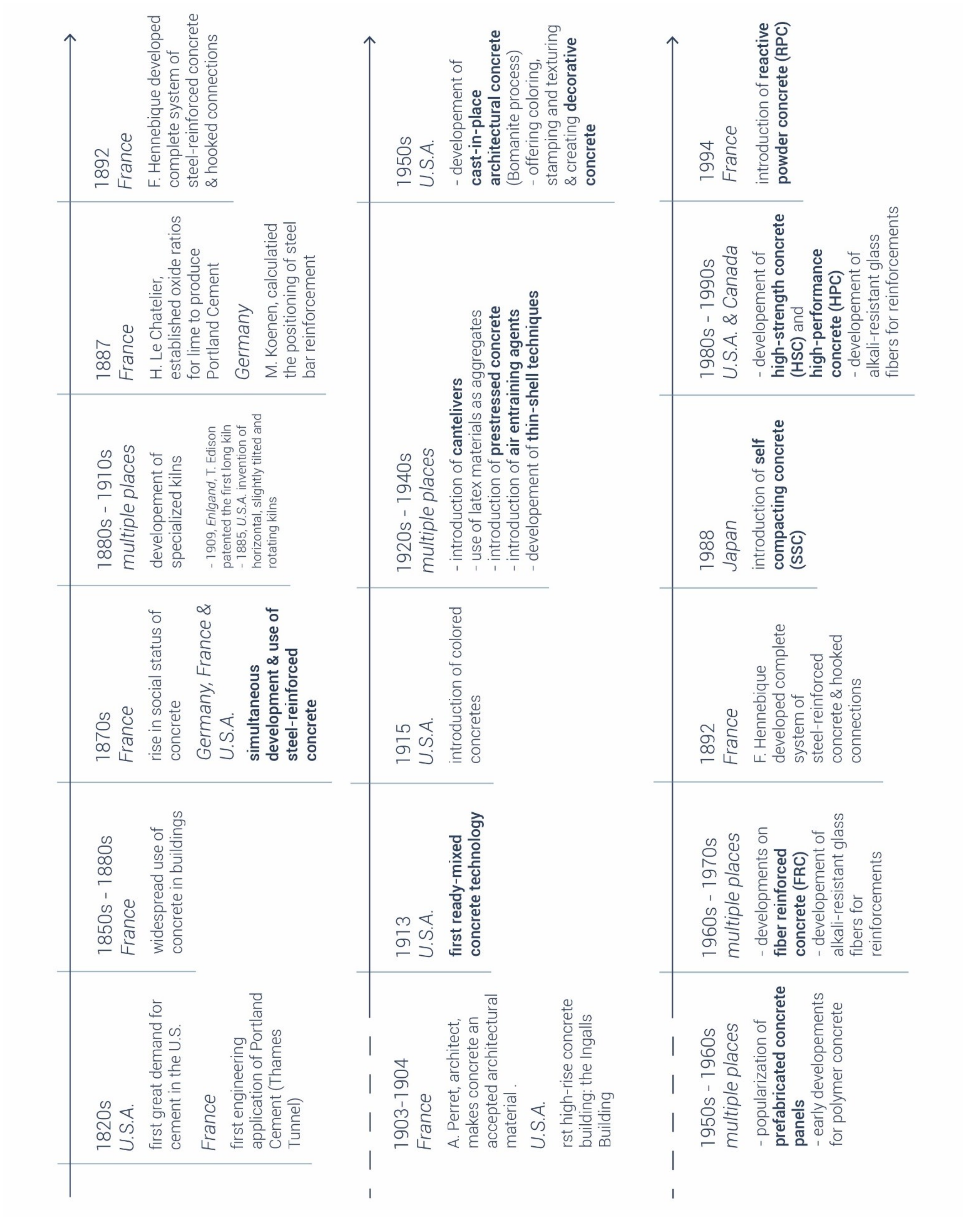


Figure 6. – Timeline of Modern Concretes, T. Harb, 2021

4.2. MC's main characteristics

4.2.1. Technical properties

Concrete's popularity[8] as a abuilding material can be directly linked to its "*low cost*, general *availability*, and *adaptability* to a wide spectrum of performance requirements" (Meyer 2005, P.2). On a technical level, concrete is thus known for its *high compressive strength*, however displaying a *lower tensile strength* compared to the former (Kromoser & Huber, 2016). In addition, some high-performance concrete recipes are "characterized by *excellent durability* due to negligible chloride-ion penetration, low mechanical abrasion, and very *high freezing-and-thawing resistance*" (Tangit-Hamou et al., 2015, P.41).

> "The economy, efficiency, durability, moldability and rigidity of reinforced concrete make it an attractive material for a wide range of [structural] applications" (Ferguson et al., 1988 cited in Mahzuz et al., 2011, P.381).

Due to its technical performance, the material is widely used in the construction of mega-structures and infrastructures which have withstood harsh conditions over long periods of time. For example, the Hoover Dam, completed in 1935 between the borders of Nevada and Arizona, utilized over 2 480 000 cubic meters of concrete. After testing samples in 1995, the concrete is said to be still curing and gaining in strength to this day, over 100 years after it was first poured (Wiltshire, 2010). In addition, a non-reactive aggregate was used, making the concrete resistant to alkali-silica reactions which usually cause rapid deterioration (Wiltshire, 2010).

4.2.2. Aesthetic properties

In its earliest applications, concrete was selected "primarily for financial, rather than aesthetic or semantic reasons" (Forty, 2013, P.205). Simonnet observes that:

> "Whether regarded as a process, by which a gloopy liquid turns rigid, or as a system, in which forces are transferred through the combination of steel armature with cement and aggregates, concrete is hard to visualize. While the process of concrete's setting can be explained chemically, and the transfer of forces analysed mathematically, neither leaves us with any satisfactory image of the material" (Cyrille Simonnet, 2005, cited in Forty, 2013, P.261)

[8] Popularity is understood here in terms of widespread use

In that sense, the aesthetic impact that concrete has on its users varies widely depending on the context (e.g., type of application, finishes, location, surroundings, expectations, and cultural background of the observer, etc.). In fact, these aesthetic associations are so complex and context-sensitive that a full section of our research is dedicated to understanding them.

In general, our findings revealed that concrete remains a *controversial* material for various reasons and is far from unanimously appreciated by all.

In its earliest apparitions, many architects were very *reluctant* to work with the material, judging it as "*intractable* and *repellent*" (Forty, 2013, P.49). As research shows, these emotions towards concrete may be due to the fact that people tend to compare it to other pre-existing[9] building materials (e.g., wood, steel, brick, etc.). Frank Llyod Wright even went on to describe it as a "*mongrel material"*, questioning its affiliations with traditional mediums such as stone, plaster, brick, tile, and cast iron (Wright, 1987, P.301).

Judging from our gathered testimonies (pages 119-127) and field observations (pages 135-154), prefabricated or casted concrete can indeed give the impression of being *impenetrable* and *indestructible*; its weight, density, and mass can be interpreted as it being *inflexible* and *monolithic*; it's natural grey color can make it appear *drab* and *depressing*; and its weathering with the passage of time can be seen as an *unpredictable, unpleasant,* and even *dangerous*.

Although these associations have a negative connotation, the research shows that others *embrace* and *celebrate* it. In fact, concrete's aesthetic appearance can *captivate the attention* - and in some cases the *devotion* - of designers, architects, poets, cinematographers, artists, historians, and writers, amongst many other profiles (pages 101-118). The material has a long history charged with dualisms (page 163) since its aesthetic appearance is known to trigger contradicting opinions and emotions.

However, by the end of the 20th century, the shift in attention from materials' appearances to their impacts on nature's resources and ecosystems "[...] made previous aesthetic concerns look trivial" (Forty, 2013, P.69).

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[9] 'pre'-existing in reference to building materials which were commonly used by the construction industry before the discovery and widespread use of concrete

4.2.3 Ecological properties

By the mid 1990s, the sustainability movement was gaining in momentum (Ceschin & Gaziulusoy, 2016; Sherwin, 2004). Concrete's popularity was linked to multiple environmental impacts and its ecological footprint was under scrutiny ever since (Mehta, 2002; Malhorta, 2000). Despite its aesthetic depreciation, concrete's practical and economical advantages made it *high in demand* as a building material and required the extraction of astonishing quantities of natural resources, including water, sand, aggregates, and cementitious materials. In fact, studies conducted in the past decade showed that the planet was producing a whopping 10 billion tons of concrete each year (Bilodeau & Malhotra, 2000; Mehta, 2002; Meyer, 2005). Different aspects have influenced concrete's ecological footprint:

Concrete binders most commonly include Portland cement, which is considered as one of the most polluting materials on the planet. The extraction and manufacturing of 1 ton of Portland cement is responsible for an equivalent 1 ton of Carbon Dioxide (CO_2) released into the atmosphere (Bilodeau & Malhotra, 2000; Mehta, 2002; Meyer, 2005; WBCSD, 2012). These quantities are catastrophic from an ecological standpoint as CO_2 is the most detrimental greenhouse gas, contributing directly to global warming (Oliver & Peters, 2020). CO_2 was measured to constitute up to 81% of total greenhouse gas emissions in 2018 (EPA, 2015) and the cement industry produced 7% of these emissions worldwide (WBCSD, 2012).

In addition, the concrete industry's water consumption is also cause for concern since the production and building process uses over 1 trillion gallons of water each year (Bilodeau & Malhotra, 2000; Mehta, 2002). These numbers do not even include the quantities consumed for concrete wash and curing water, which are considered as waste materials that need to be properly disposed and discharged (Sandrolini & Franzoni, 2001; Meyer, 2005).

Other studies revealed that demolition concrete from disposed structures, pavements, and roads constitute the largest single component of construction debris worldwide (Bilodeau & Malhotra, 2000; Mehta, 2002). This contributes directly to the planet's solid waste disposal problem (Chapman, 2015) as demolition concrete debris occupies a large fraction of the waste we produce (Meyer, 2005).

The cement industry is also one of the greatest consumers of sand, contributing directly to the depletion of natural resources (Edwards, 2015). Today, sand is the second most consumed natural resource after water (Gavriletea, 2017). However, it's renewal rate is far inferior to its consumption rate (UNEP, 2014). In fact, the world is facing a sand crisis where access has been increasingly scarce, all while improper mining is causing irreparable damages to various ecosystems (Gavriletea, 2017).

Similarly, the extraction and consumption of gravel - which is a popular concrete aggregate - is facing comparable challenges as the sand industry. Each ton of cement requires an approximate 6 to 7 seven tons of gravel (UNEP, 2014). The renewal rate is also struggling to keep up with its consumption rates, leading to another rapid decline in accessibility (Gavriletea, 2017; UNEP, 2014).

Finally, the extraction and production of cement and other concrete ingredients is known to be energy intensive. Although many countries (e.g., Japan) have looked into optimizing the process, studies show that it is extremely difficult if not impossible for that efficiency to be further improved (Bilodeau & Malhotra, 2000; Mehta, 2002).

These concerns have motivated further research into the development of alternative technologies in an effort to reduce the material's ecological impacts (page 83-85).

4.3. A change in paradigm

In recent years, a paradigm shift can be observed resulting in a change in mindsets and ideologies. According to the research, ideological changes can be either preconditioned by a crisis of some sort (e.g., climate change awareness), or be a direct resultant of it (e.g., the need for sustainability) (Kuhn, 2012). The ecological impact of modern society's unsustainable consumption habits is causing the exponential degradation of our ecosystems and our quality of life. These events call for an urgent shift in consciousness which preoccupies the global community "[…] if we are to meet the growing complexity of environmental, economic and socio psychological challenges in a timely fashion" (Gidley, 2008, P.25).

> "The profound transformation we are now witnessing has been emerging on a global scale over millennia and has matured to a tipping point and rate of acceleration that

> has radically altered and will continue to alter our human condition in every aspect. We must therefore expand our perspective and call forth unprecedented narrative powers to name, diagnose, and articulate this shift." (Gangadean, 2006, p. 382)

The pressing need to change has been pressuring society to assess and adjust lifestyles and habits. More specifically, the concrete industry - including its various stakeholders (pages 119-121) - is putting in place policies and actions to reverse those unsustainable practices.

And although discoveries emerging from a paradigm shift can contribute to change in either a constructive or destructive manner (Kuhn, 2012), progressive societies are preoccupied with the wellbeing of the people, and thus aim to influence positive change towards a better, improved state.

The sustainable development movement has been embraced and adopted by many disciplines and industries (Gidley, 2008), including design. In that sense, professionals from different fields are at the forefront of proposing alternative innovative solutions within an ecological agenda. However, our research has shown that sustainability considerations go beyond optimizing technical characteristics of materials to extend their life cycles. Today, new approaches can operate on different levels in order to satisfy the need for sustainability.

Design has the power to embody value subtly and durably in artifacts (Sherwin, 2004). It is that ability to increase attachment to urban artifacts - with the purpose of elevating their emotional durability in addition to their technical one - that interests us the most, amongst other aspects that we will detail in the discussion chapter.

4.3.1. Emotionally durable design

Sustainable design encompasses *emotionally durable design* (EDD) (Brezet, 1997; Mugge et al., 2009; Chapman, 2009; 2015). In today's technocentric materialistic society, products, spaces, and services seem to quickly lose their user's appreciation and are rendered deprived of value and meaning far too early in their life cycle.

> "It has been estimated that 78% of discarded products still function properly when replaced (Van Nes, 2003), and in some cases this is due to psychological obsolescence (when a product is discarded for reasons such as changes in users' perceived needs, desire for social status emulation, or new trends in fashion and style) (Cooper, 2004, 2010 cited in Ceschin & Gaziulusoy, 2016, P.123).

Here, the main factor influencing **product attachment** is time. In fact, some scholars have observed that seasoned objects and materials are seen to lose **user engagement** at an alarming pace (Chapman, 2015). By designing for precision and perfection, our society is creating unstable PAMEs that will fail at withstanding the test of time (Ashby & Johnson, 2016).

> "Within a context of rapid technological advances and quickly adapting user needs and values, a product that aims to satisfy or conform to particular user concerns may cease to deliver the initial experience in the later stages of the relationship." (Demir, 2008, P.141)

Chapman along with other scholars observe that in today's technocentric society, "products whose key value lies in the degree of newness are vulnerable to the glare of decay" (Chapman, 2015, P.131). However, ageing properties of a material can be further exploited through design to create new types of experiences with characteristics that evolve freely through time (Chapman, 2015). EDD can thus be seen as a strategic approach to sustainable design, impacting the user-object relationship by "embedding less transient and more enduring values within products" so the subject-object relationship can be further sustained with the passage of time (Chapman, 2015, P.27). This approach aims to "reduce the consumption and waste of natural resources by increasing the resilience of relationships established between consumers and products" (Chapman, 2009, P.142).

> "Emotionally durable design therefore provides a useful language to describe the contemporary relevance of designing responsible, well-made, tactile products that the user can get to know and assign value to in the long term" (Lacey, 2009, P.142)

This emotional-driven approach encourages a sustainable narrative when it comes to product and material experiences. This is achieved through the creation of more time-enduring narratives that promote the selection of evolving materials bearing the signs of time as opposed to inert and sterile ones (Chapman, 2015).

However, EDD has limitations to be considered (Ceschin & Gaziulusoy, 2016). Firstly, given that meanings are context-sensitive, they can vary greatly between different users, which makes it challenging for the designer to guarantee product attachment (Mugge et al., 2009; Chapman, 2015). Additionally, the level of attachment can vary depending on the product category (Mugge et al., 2009). In that same sense, not all products necessarily benefit from an extended longevity (Vezzoli & Manzini, 2008). And finally, the extended emotional durability of some products may clash with the economic expectations of some merchants whose main goal is to increase sales, making them reluctant to develop and sell them (Mugge et al., 2009). Therefore, there should be a nuance in the expectations when it comes to privately acquired artifact as opposed to publicly owned ones.

4.3.2. The aesthetic of sustainability

With this rising interest in sustainability, concepts such as the aesthetic of sustainability (AOS) have emerged, proving to be of high interest for design disciplines and can be seen as "a powerful means to influence and determine behavior, attitudes, and actions in a society" (Manzini, 1994, P.23; Saito, 2009). Governed by a more philosophical and social take on sustainability, the goal of this concept is to encourage new socio-cultural values and their resulting lifestyles (Zafarmand et al., 2003; Karana et al., 2013).

Variations of the concept have since been recorded (Karana et al., 2013) such as the "aesthetics of environmentally sensitive products" (Walker, 1995), "green aesthetics" (Saito, 2007), "sustainable aesthetic" (Branzi, 2008), "total beauty" (Datschefski, 2001), or "sustainable beauty" (Hosey, 2012), to name a few.

This approach to sustainability can be seen as both a challenge and opportunity for design as the balance between an artifact's environmental value and its aesthetic appeal can be difficult to achieve (Karana et al., 2013). Some scholars emphasise the importance of following the different forms that sustainable values can manifest through in a product (Vezzoli & Manzini 2008). For example, recycled paper is noticeably darker and rougher to the touch compared to regular paper, but these indicators are seen as a virtue by some since they display the material's eco-friendliness. While others see designing products that reflect environmental values as more *attractive* "[…] without simply making them conform to the popular taste which is for the most part not environmentally informed" (Saito, 2007, P.19).

The AOS ultimately investigates how products can demonstrate **positive sustainability credentials** through their materials (Karana et al., 2013), a characteristic that is of interest to our research (page 175).

4.4. Concrete technologies

This section of our chapter is an overview of recent concrete technologies which contribute to the material's evolution and perceptions. The term 'technology' is seen as a rich body of knowledge which can be applied through various techniques and can be described as "a way of doing something", thus going beyond the specific methods or tools (Franklin, 1999, P.82). The ones presented in this section were selected based on our research interests as they reflect the (emotionally and technically) sustainable criteria which we have described (pages 69-75).

Throughout history, civilizations have been optimizing material recipes and tools to create more performing constructions that can better withstand the test of time (Schmidt & Fehling, 2004). Today, we are still searching for ways to perfect material and technologies to build more performing artefacts which adhere to the evolving needs and lifestyles of society. In recent years, designers have been seen to experiment with new ways of *doing something* with concrete through theories, approaches, and practical techniques that have the ability to influence and improve the user experience.

We will look at some of the recent concrete discoveries and developments in terms of recipes, manufacturing techniques, and finishing in different types of uses and contexts. These will be used to investigate how design solutions can regulate the material's quality perception. We will be briefly describing them, as well as providing examples of recent projects in the fields of engineering, architecture, urban planning, interior design, product design, cinematography, photography, and art, amongst others.

4.4.1. Concrete recipes

There are various criteria that define an artefact's performance. When it comes to concrete constructions, there are mechanical and practical properties to consider such as strength, workability, and durability, as well as economic properties such as affordability (Schmidt & Fehling, 2004). When a material is described as 'high-performance', this usually refers to improved strength, workability, durability, or cost. With today's environmental awareness, the ecological performance has become as important to consider.

High performance concrete (HPC)

In the past years, multiple types and variations of concretes have been developed and optimized such as the noteworthy recipe that revolutionized the construction industry in terms of improved performance: **HPC**.

When the first applications for HPC emerged in 2004, it was described as "basically a new material" although it was still called concrete (Schmidt & Fehling, 2004, P.3).

Construction materials can have different designations depending on where and when they are being used; in that sense, multiple countries can be using the same material relatively, but with different names and definitions. To be labeled an HPC in the U.S.A. for example, the concrete must display "[…] freeze-thaw durability, scaling resistance, abrasion resistance, chloride penetration, compressive strength, modulus of elasticity, shrinkage, and creep" (Schmidt & Fehling, 2004, P. 5).

Nowadays, we can find multiple variations of HPCs, including UHPCs which primarily refer to concretes which have been reinforced with either rods or fibers. The most used reinforcement for concrete is steel - primarily in the form of rods, bars, or mesh. However, other types of materials are being used as reinforcement such as fiber-reinforced polymers (FRPs). In fact, researchers have recently developed 3D printed polymer structures (e.g., polylactic acid or acrylonitrile butadiene styrene) to be used as reinforcement, thus reducing the weight of concrete per mixture up to 33% (Salazar et al., 2020; Sertoglu, 3D Printing Industry, 2021).

Multiple types of fibers can be used in HPC and UHPC which can be organized in a simplified and non-exhaustive manner into different categories: synthetic fibers include metallic fibers (primarily steel fibers of various types), glass fibers (e.g., alkali-resistant (AR) glass fibers or glass reinforced plastic fibers GRP/Fiberglass), polymer fibers (e.g., PP, PVA, PE), and recycled plastic fibers, to name only a few. In addition, organic fibers include natural ones such as cotton, straw, or wood, whereas organic polymer fibers include carbon, as can be seen in our categorization of structural concrete reinforcements (figure 4, page 63).

This results in a wide variety of **fiber reinforced concretes (FRCs)**, for example glass fiber reinforced concrete (GFRC) (also known as glass reinforced concrete GRC), ultra high-performance fiber reinforced concrete (UHPFRC), or UHPGC, amongst others.

Ultra-High Performance Fiber Reinforced Concrete (UHPFRC)

One of the most ground-breaking inventions in HPC developments came with the introduction of Ductal®, an UHPFRC offering improved permissive, compressive, and flexural strength, as well as ductility (Schmidt & Fehling, 2004). From a practical standpoint, UHPFRC was lighter in weight compared to regular concrete mixes.

The material offered a superior aesthetic precision in comparison by achieving sharper and cleaner concrete edges and seams with complex molds. This new technology resulted from the combined effort of three contributors: construction materials manufacturer Lafarge, contractor in civil and structural engineering Bouygues, and chemical materials manufacturer Rhodia (Schmidt & Fehling, 2004), proving that innovations in material technologies benefit greatly from the combined skills and expertise of various disciplines and professions.

In recent years, we can find architectural applications of FRCs such as the perforated Ductal® panels in Rudi Riccioti's 2013 museum of European and Mediterranean civilization (MuCEM), as well as the 2021 Jean-Bouin stadium as seen in figure 7. In addition, we find high-quality pre-cast FRC slabs, plates, and panels which provide a sleek and precise finish such as seen in the European concrete company Reider Group's products concrete skin (½ inches thin concrete panels) or öko skin (concrete slats) as seen in figure 8 (Reider, 2021; ArchDaily, 2021).

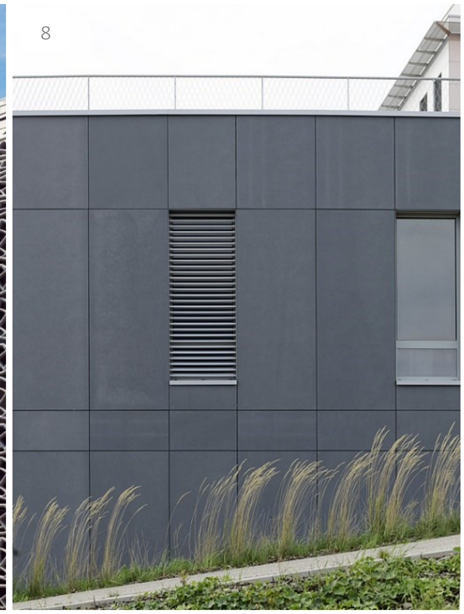


Figure 7. – Stade Jean-Bouin by Rudy Ricciotti - image by Sebastian Weiss from Behance.com (2021)

Figure 8. – Concrete Skin by Reider Group – image from ArchDaily.com (2021)

Graphene-reinforced concrete

Other researchers have successfully incorporated graphene into concrete which is defined as “a two-dimensional sheet of carbon atoms arranged in a hexagonal lattice” (Dimov et al., 2018, P.1). The graphene-reinforced material showed unprecedented enhanced mechanical properties, particularly in terms of ultralight strength (Dimov et al., 2018). Compared to other recipes, these properties include an increase in compressive and flexural strength, improved electrical and thermal performances, as well as a decrease in water permeability (Dimov al., 2018). Researchers were able to replace up to 50% of the required quantity of cement with graphene, making it an eco-friendly alternative to traditional cement.

Although other experimentations with nanoengineered cement with other sorts of additives (e.g., hexagonal boron nitride (hBN), graphite, carbon nanotubes, graphene oxide, etc.) have showed improved mechanical and thermal properties, the production processes revealed itself as complex and costly (Dimov et al., 2018), making it difficult to commercialize. Compared to other nanotechnologies, reinforcing concrete with graphene is considered non-hazardous, cost-effective (with the price of graphene decreasing), and eco-friendly by reducing the carbon emissions linked to the production of cement (Dimov et al., 2018).

Use of recycled materials in new concrete mixes

In recent years, in an effort to comply with the demands of sustainable development, studies investigating alternative materials that are capable of enhancing the ecological performance of concrete have gained in popularity.

> "Nowadays, solving environmental problems is an essential objective, and experts are more aware that economic and social development needs to be correlated with environment protection." (Gavriletea, 2017, P.17)

Therefore, strategies of substituting cement with by-products of other industries, or using recycled or waste materials as aggregates amongst other solutions are projected to drastically improve the industry's sustainability performances (Meyer, 2005). In terms of recycled and reused materials, recent studies have investigated the use of construction site debris, post-consumer materials such as glass, dredged materials, and recycled fibers, amongst others.

> "Closed loop recycling is the best sustainable method to re-use waste streams back into new production, as it will create energy savings, reduce the demand on primary mineral resources and divert materials away from landfill." (Taha & Nounu, 2008, P.14)

For example, recycled concrete from **construction and demolition debris** (C&D) can be used as coarse aggregates in new mixes (Ganiron, 2013; Meyer, 2005). **Post consumer glass** can be used as either coarse or fine aggregates, or, according to recent studies, resulting in a white HPC (high hardness and improved abrasion and chemical resistance) (Tangit-Hamou et al., 2018). **Dredged materials**, once treated, can be recycled as filler for concrete mixes helping improve some properties such as the freeze-thaw durability, amongst others (Detzner, 1995; Meyer 2005). Furthermore, the **wash water** used to clean the inside of concrete recipients during manufacturing can be treated and reused, offering multiple advantages particularly in areas of the world where access to water is limited (Chini & Mbwambo, 1996; Meyer 2005; Tsimas et al., 2011). In addition, given the global sand crisis we have previously mentioned, studies have investigated the replacement of sand with **mixed colour recycled glass san**d (Taha & Nounu, 2008), **non-biodegradable plastic wastes** (Ismali & Al-Hashmi, 2008), sugarcane bagasse ash (Sales & Lima, 2010), and even **quarry dust** or **stone powder** (Mahzuz et al., 2011).

Chinese design studio Bentu even proposes the reuse of **ceramic waste** as coarse aggregates in new concrete mixes, resulting in a unique aesthetic (with the exposed ceramics) and reducing energy consumption with the production of new aggregates (Bentu design 2021; de Klee, Dezeen, 2018). Further details on those solutions highlighting their main advantages or disadvantages can be found in annexed table 1 (pages 226-228).

In addition, other waste-materials and by-products of industries can be reused in concrete mixes such as waste wood, rubber tires, recycled carpet fibers (typically made of nylon), plastics waste, pulp, paper mill residuals, to name only a few (Mehta, 2002; Meyer, 2005).

> “The challenge is to identify situations where one person’s waste or by-product becomes another person’s valuable resource.” (Meyer, 2005, P.8)

Use of by-products of other industries as cementitious substitutes

In terms of cement substitutes, studies have investigated the use by-products of different industries such as **fly ash**, a residue from the coal industry, which can replace up to 100% of Portland Cement (Çolak, 2003; Meyer, 2005; Assi et al., 2018; Noe, Core77, 2020), in addition to **ground granulated blast furnace slag** (GGBFS), a by-product of the steel industry, offering replacements of up to 80% of Portland cement (Taylor, 1997; Meyer, 2005). Furthermore, **condensed silica fume**, a by-product of the semiconductor or silicon industry, is seen to enhance strength and durability, but comes at a higher cost (Meyer, 2005). Some studies have even investigated the use of **natural pozzolans** in combination with lime, offering higher strength in concrete mixes but requiring more energy and water in some cases (Taylor, 1997; Çolak, 2003). We have summarized some of these cement substitutes as can be seen in annexed Table 2 (page 229).

In addition, **micronized recycled glass** can replace up to 30% of Portland cement and results in an UHPGC with improved freeze-thaw and impact resistance properties, as well as lower heat absorption and permeability (Tangit-Hamou et al., 2016).

Concrete additives

Concrete mixes also include various types of additives and agents that help optimize its performances as seen in our categorization (figure 4, page 62).

For example, projects have included the use of a **photocatalytic concrete**, also referred to as ‘smog eating concrete’ as seen in figure 9, which offers self-cleaning properties minimizing maintenance cost and purifying the air in highly polluted areas (Mujkanović et al., 2016; Beeldens, 2020). Photovoltaic technology promises to optimize the energy consumption of buildings by combining UHPC panels with a semiconducting material which converts sunlight into electrical power (Hosseini et al., 2013; Luo et al., 2016).

Light-transmitting concrete (LTC) technologies include the combination of waste tempered glass aggregates with epoxy resin to be used in the road construction industry for visibility (Luo et al., 2016; Li et al., 2021), as well as including optical fibers or even plastic rods to provide transparency and energy saving advantages as seen in figure 10 (Kim, 2017; Navabi et al., 2021).

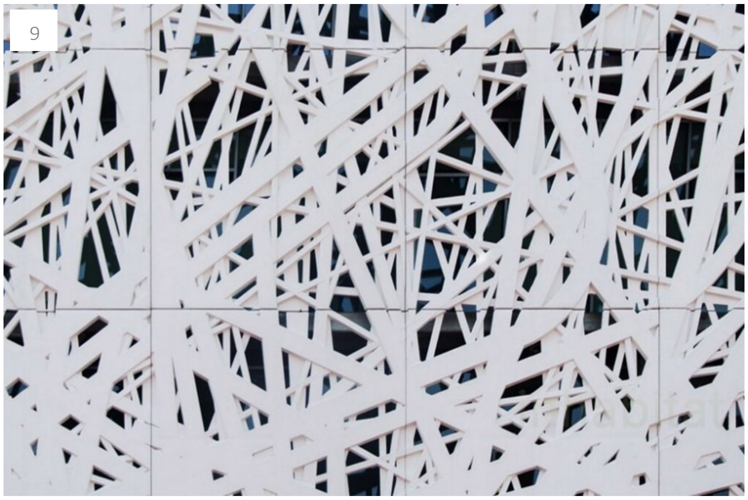
Photoluminescent concrete can help improve road visibility and serve as signalisation with the addition of photoluminescent pigments into the mix which absorb Ultraviolet (UV) radiations to radiate a subtle glow at night as seen in figure 11 (Suleymanova et al., 2020;). Furthermore, a technology allowing for biological growth (e.g., microalgae, fungi, lichens and mosses) on concrete surfaces promises a naturally evolving material with an unexpected aesthetic appeal requiring no maintenance as seen in figure 12 (ArchDaily, 2013; Dezeen, 2013).

When it comes to self-healing properties, a **biological concrete** has the ability to repair cracks with the help of a bacteria, thus extending the life service of artifacts while requiring little to no maintenance (Srinivasa et al., 2012; Talaei Khozani & Majid, 2014; Silva et al., 2015).

Some technologies provide **electricity conducting** properties, thus opening the doors to new applications for concrete (Logan, MIT News, 2021).

Whilst other technologies promise enhanced mechanical properties all while replacing up to 40% of Portland Cement through **nanoplatelets recovered from waste root vegetables** (Aouf, Dezeen, 2018).

Further details on those technologies which offer enhanced properties on technical, ecological, and aesthetic levels can be found in annexed Table 3 (pages 229-233).



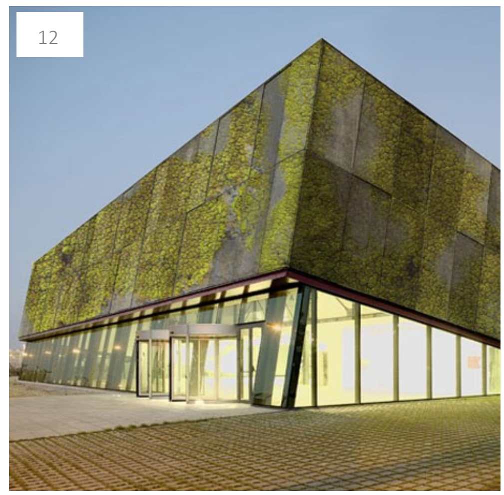


Figure 9. – Palazzo-Italia's smog eating concrete by Italcementi – image from InterestingEngineering.com (2019)

Figure 10. – Litracon's light-transmitting concrete – image from Dezeen.com (2008)

Figure 11. – Ambient Glow Technology (AGT)'s photoluminescent concrete – image from AmbientGlowTechnology.com (2021)

Figure 12. – Universitat Politècnica de Catalunya's biological concrete simulation – image from Dezeen.com (2013)

Alternatives to Concrete

Considering the environmental impacts related to the extraction and manufacturing of cement, several studies look into alternatives to traditional concrete recipes (Bhalla et al., 2008; Ishak & Hashim, 2015; Maddalena et al., 2018; Assi et al., 2018).

For example, some researchers are working on a **bio-concrete using two invasive species** (Japanese knotweed as the binder and American shells from signal crayfish as aggregates) which are combined with water and gelatine as seen in figure 13 (Hahn, Dezeen, 2021).

Others have created a **sustainable concrete-like material made from seashell waste** from the seafood and aquaculture industries combined with non-toxic natural binders such as sugar or agar as seen in figure 14 (Crook, Dezeen, 2020).

Furthermore, sustainable construction boards made from **cellulose residue found in paper mills** waste can be considered as a lightweight alternative to concrete or MDF construction panels (Hitti, Dezeen, 2020).

Other initiatives propose *K-Briq,* a **construction brick made from 90% construction waste** which displays better insulation properties than regular clay bricks (Aouf, Dezeen, 2020; KENOTEQ, 2021), in addition to **building blocks made from salt-water waste and by-products of potassium and bromine industries** (figure 15) (Carlson, Dezeen, 2021; Erez Nevi Pana, 2021).

Finally, in an effort to reduce the ecological impact of the construction and product manufacturing industries, other alternatives are being explored all over the world: we can find civil engineer S. Lambert's zero-waste brick made from human urine (Aouf, Dezeen, 2018); the fungi-based self-supporting structures developed by architect D. Hebel and engineer P. Block as seen in figure 16 (Frearson, Dezeen, 2017); or the eco-friendly, biodegradable, and lightweight bricks made from soil, cement (in reduced amounts compared to regular concrete mixes), charcoal, and organic luffa fibers developed by the researchers at the Indian School of Design and Innovation in Mumbai as seen in figure 17(Aouf, Dezeen, 2019), to name a few.

These technologies are further detailed in annexed Table 4 (pages 233-234).

Figure 13. – B. Kock and I.R. Moravia's bio-concrete tiles from weeds and crayfish shells – image from Dezeen.com 2021

Figure 14. – Newttab-22's Sea Stone concrete-like tiles from shells – image from Dezeen.com 2020

Figure 15. – E. Nevi Pana's sea salt Crystalline collection – image by Tom Ross from Dezeen.com 2021

Figure 16. – Karlsruhe Institute of Technology & ETH Zurich's fungi self-supporting structure – image from Dezeen.com 2017

Figure 17. – Indian School of Design & Innovation's Green Charcoal bricks – image from Dezeen.com 2019

4.4.2. Concrete manufacturing techniques

Traditionally, concrete is casted into a mold, usually described as 'formwork'. When needed, reinforcements are integrated to enhance structural performances, but the overall shape and surface finish of the casted material depends on the formwork as well as the recipe. When needed, multiple surface finishes can be applied, offering a wide variety of textures and appearances.

Traditional formwork

Concrete is a material that generally needs to be “molded”: it needs to be bound in time and space in order to cure and set.

Although the term “mold” suggests a certain rigidity and fixity, the verb implies the need to take actions resulting in a change (West, 2016). Since the beginning of its uses, concrete similar aesthetic vocabulary as the old used to form it (West, 2016).

PCs and MCs were traditionally formed using wooden formworks, although later steel was introduced. Wooden formwork could be composed of plywood, grooved wooden boards, timber posts, wooden beams, particle boards, engineering wood, or Medium Density Fiberboard (MDF), etc. (Forty, 2013).

In general, unfinished concrete will take on the physical characteristics of its formwork: as the liquid medium is casted into the mold and begins to cure, it takes on the texture of the framework by filling every cavity and reproducing the reliefs. In fact, Japanese concrete was known for its ‘wood-like’ character, as the wooden formwork was left intentionally imprinted on the surface, creating a textured board-marked concrete (Forty, 2013).

We can see the richness in terms of texture, grain, and tint variations added by the unfinished board-marked concrete in Christian Wassmann’s *Sun Path House* as seen in figure 18 (Brillon, Dezeen, 2017). Another recent example is the bamboo-marked concrete in VTN Architects’ 2014 *House For Trees* in Vietnam as seen in figure 19 (ArchDaily, 2019), or Tectoniques Architectes’ traditional timber formwork concrete house that was casted in-situ and colored with ochre dyes as seen in figure 20 (TectoniquesArchitectes, 2020). By using coarse aggregate as well as less water in the mixture, steel pins were utilized to intentionally create a pattern of small dots of rust once the plates were removed. The casting was manually vibrated to reach the “thick, imperfect end result”, thus showcasing concrete’s *crude, rustic*, and *textured* aspects (DesignBoom, 2020).

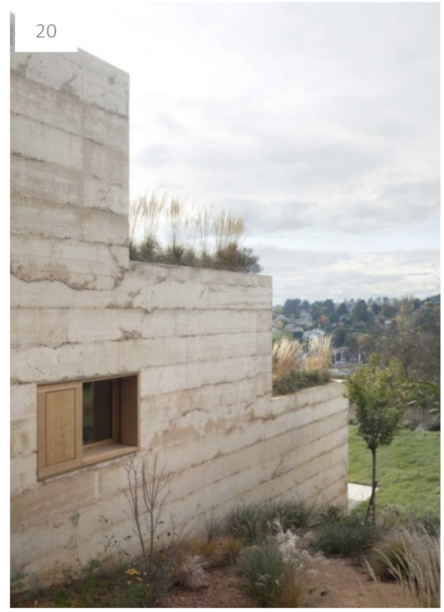


Figure 18. – C. Wassmann's Sun Path House - image by Lukas Wassmann, Todd Eberle & Casey Kelbaugh from Dezeen.com (2017)

Figure 19. – VTN Architects' House For Trees - image by Hiroyuki Oki from ArchDaily.com (2019)

Figure 20. – Tectoniques Architectes' house in Saint-Cyr-au-Mont-d'Or – image by Jérôme Ricolleau from Tectoniques.com (2020)

In the past years, designers and architects started embracing authentic material finishes, textures, and styles which were found in the industrial sectors (e.g., exposed piping and ducts, unfinished steel and concrete, stained glass, etc.). Projects have been integrating more *béton brut,* known as rough, raw, or exposed concrete. In many cases, the unfinished material becomes a design statement, a pivotal part of the concept. In fact, multiple projects showcase *béton brut* in interior applications such as the board-marked concrete in Luciano Kruk' *Casa H3* as seen in figure 21 (Luciano Kruk, 2021; Mairs, Dezeen, 2016) or in Ludwig Godefroy Architecture's *Merida House* as seen in figure 22 (ArchDaily, 2018). In addition, bare concrete and exposed infrastructures are increasingly found in projects where older buildings are refurbished. An example is Jarrín's *A Forest House in* a 1970s renovated building with its rough concrete ceilings and columns that were intentionally exposed as seen in figure 23 (Gibson, Dezeen, 2020).

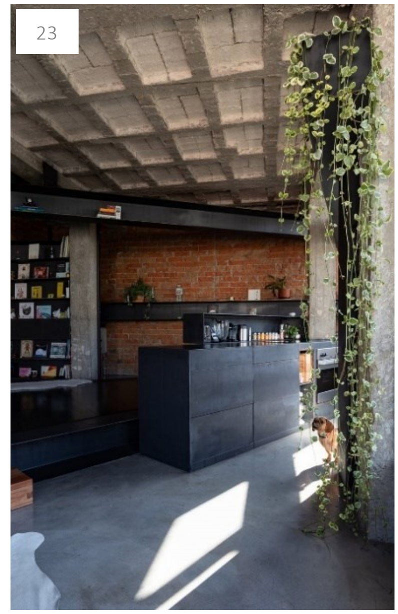


Figure 21. – L. Kruk's Casa H3 – image by Daniela Mac Adden from Dezeen.com (2016)

Figure 22. – Ludwig Godefroy Architecture's Merida House – image by Rory Gardiner from ArchDaily.com (2018)

Figure 23. – A. Jarrin's A Forest House - image by JAG studio from Dezeen.com (2020)

Wooden formworks have been successfully used for centuries to produce impressive concrete artifacts. Nonetheless, this manufacturing technique has its limits by restricting the medium. Some scholars argue that, for such an amorphous material, it is peculiar why concrete has been given such geometrical shapes (Burton & Schjeldahl, 1992; West, 2016). Architect Mark West (2016) suggests that concrete artifacts' orthogonality can be traced back to modern civilization's complex relationship with the right angle: since most artifacts are produced through single-axis machines (e.g., saw and rolling mills, extrusion mills, etc.), the calculations and analysis techniques commonly available followed that Cartesian X-Y-Z coordination system. As a direct result, most of our material culture, as well as the tools and methods we instinctively used, found themselves to be "saturated with this self-same orthography" (West, 2016, P.2). Some experts point out that:

> "It may be noted that although [reinforced] concrete has been used for over a hundred years and with increasing interest during the last decades, few of its properties and potentialities have been fully exploited so far. [...] the main cause of this delay is a trivial technicality: the need to prepare wooden forms." (Pier Luigi Nerci in Structures, 1956, P.95, quoted in West, 2016, P.4)

Concrete mixes are “wet, heavy, gloppy” and will virtually submit to any shape they are given, as long as it is possible to hold it in place as it cures (Burton & Schjeldahl, 1992).

Alternative formwork

Since then, others have ventured into the rediscovery of concrete’s plasticity as a “wet, sensual, and responsive” construction material, which promised to fundamentally alter its traditional forms and representations (West, 2016, P.4).

Fabric formwork

Fabric formworks came about after the Industrial Revolution, although it was briefly exploited in the Roman times by Vitruvius who proposed the use of woven reed baskets to cast cofferdams (Veenendaal et al., 2011). Throughout the 18^{th} and 19^{th} century, several individuals experimented with fabric formworks such as builder G. Lilienthal (U.S.A.), inventor J. Waller (Ireland), architect M. Fisace (Spain), and more recently architects Mark West (Canada) and Kenzo Uno (Japan).

The techniques developed use flexible materials such as textiles and polymers (e.g., rubber, nylon) as formwork and can be defined as: “a building technology that involves the use of structural membranes as the main facing material for concrete moulds. […] the material is highly flexible and can deflect under the pressure of fresh concrete. The resulting forms exhibit curvature as well as excellent surface finishes that are generally not associated with concrete structures” (Veenendaal et al., 2011, P.164).

> “[...] this simple change [flexible frameworks] demands a re-thinking of the entire “tree” of concrete architecture. The hard, flat, prismatic, world of cast concrete is suddenly, and effortlessly, transformed into soft and sensual curvatures that love the play of light. Heavy, expensive, rigid moulds, destined for the pyre or landfill, become light, efficient, inexpensive, and reusable membranes. Utility and beauty are met in the same body.” (West, 2016, p. xix)

Fabric formworks also offer other advantages such as cost savings on formwork materials, as well as reinforcement, which ultimately leads to reductions in transportation, storage, labour, and lower greenhouse gas emissions (Veenendaal et al., 2011; West, 2016). Thus, the line between sculptural and architectural became more blurred (Veenendaal et al., 2011) giving rise to new opportunities and uses.

Flexible formworks uses and applications

Flexible formworks allowed the creation of Tejo Remy and Renee Veenhuzien's *Concrete Chair* line which used rubber molds to create a soft appearance which is generally associated with ceramics of fabrics as seen in figure 24 (Etcherington, Dezeen, 2010).

Other examples include Janwillem Van Maele's graduation project, the *Mass III* side table, which was cast in a suspended fabric mold as seen in figure 25, as well as architecture students Kyle Sturgeon, Chris Holzwart and Kelly Raczkowski's *FattyShell* (v.01) as seen in figure 26 (Etherington, Dezeen, 2010). The structure was made by casting concrete between two sheets of stitched rubber that were strategically tensioned with cables on a wooden frame (Warmann, Dezeen, 2010).

Multiple alternative frameworks have been experimented with to imprint on concrete a wide variety of textures. In more recent years, Zaha Hadid Architects (ZHA) and the ETH Zurich research group have built a double-curved thin shell pavilion. In their project, a 3D-knitted fabric shell - using *KinCrete*, a new textile technology - was used as formwork to shape the curved concrete structure, allowing the surfaces to form without the use of traditional molds as seen in figure 27 (Walsh, ArchDaily, 2018; Block, Dezeen, 2018).

Figure 24. – T. Remy & R. Veenhuizen's Concrete Chair – image from Dezeen.com (2010)

Figure 25. – J. Van Maele's Mas III side table – image from Dezeen.com (2010)

Figure 26. – K. Sturgeon, C. Holzwart & K. Raczkowski's FattyShell (v.01) – image from Dezeen.com (2010)

Figure 27. – ZHA & ETH Zurich's Concrete Pavilion – image by Philippe Block via ZHA from ArchDaily.com (2018)

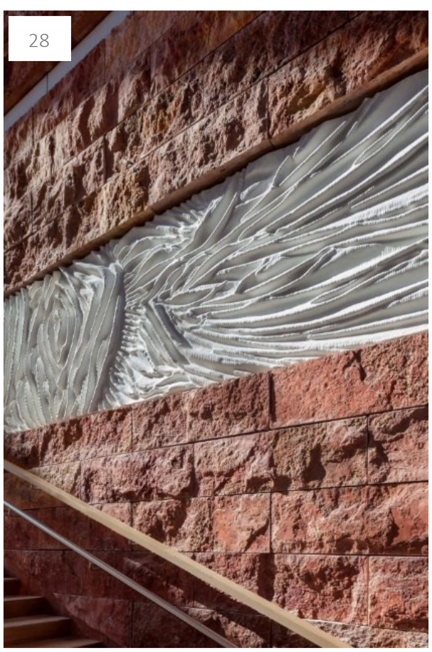
Inflatable molds

As mentioned previously, concrete is known for its high compressive strength, however displaying a lower tensile strength compared to the former. Yet, some experts agree that most concrete structures are not designed properly to optimize those properties, leading to a "low utilization of the material and require a big amount of additional reinforcement" (Kromoser & Huber, 2016, P.1). In order to take advantage of those properties all while reducing the amount of reinforcement required, some suggest the use of hollow or doubly curved structures such as thin shells even though the production process seems to be tricky and labor-intensive (Kromoser & Huber, 2016).

To create hollow concrete elements, experts have been developing since the late 1800s different techniques, including the Pneumatic Forming of Hardened Concrete (PFHC) (Hawkins et al., 2016). According to Krosomer & Kollegger (2015), this new cost-effective construction method consists in building concrete shells from a plane plate; pneumatic formwork helps bend the plate until the required curvature is formed. These systems can be used as a spacer within the structure to make it hollow, as an inflated membrane onto which the concrete is applied afterwards, or as a lifting device where the concrete is applied onto a flat surface which is then lifted. Researchers at Technische Universität Wien have successfully inflated multiple structures from flat to 3D, including the latest inflatable full-scale dome, using limited amounts of resources and time (Buitink Technology, 2021). Some consider this method as "[…] the most important innovation that modern construction has seen in many years" (Interesting Engineering, 2017).

Polymer molds

Other flexible materials are also used as formwork for concrete constructions such as polymer molds (e.g., rubber, silicone, etc.). For example, architecture firm Neutelings Riedjik Architects worked with experimental fashion designer Iris van Herpen on the *Naturalis Biodiversity Center* project to create concrete panels casted in rubber molds as seen in figure 28. Drawing inspiration from van Herpen's couture background and experimentations with materials and structural shapes, the designers were able to cast small-grained white marble aggregate concrete into rubber molds featuring complex organic shapes and textures (Ravenscroft, Dezeen, 2019). These molds were casted from an MDF board which was given the relief inspired from geological deposits through a computerized numerical controlled (CNC) device. The resulting concrete panels exposed a more fluid and 'natural' aspect of concrete, particularly in contrast to the other sleek UHPC modules composing the back façade as seen in figure 29.



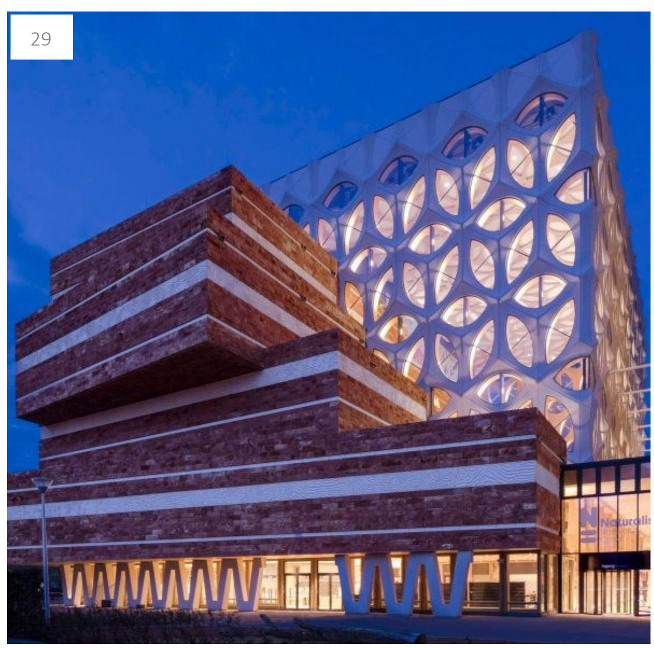


Figure 28. – Naturalis Biodiversity Center – image by Daria Scagliola & Stijn Brakkee from Dezeen.com (2019)

Figure 29. – Ibid

4.4.3. Alternative manufacturing techniques

Digital manufacturing

For many years, the construction sector has been lacking innovation in adopting progressive manufacturing technologies. However, recent trends in digitization and advanced automation as well as new material technologies and recipes have been revolutionizing other industries (e.g., manufacturing, agriculture) including the construction industry, helping better integrate digital fabrication into the conception and building process (Wangler et al., 2019).

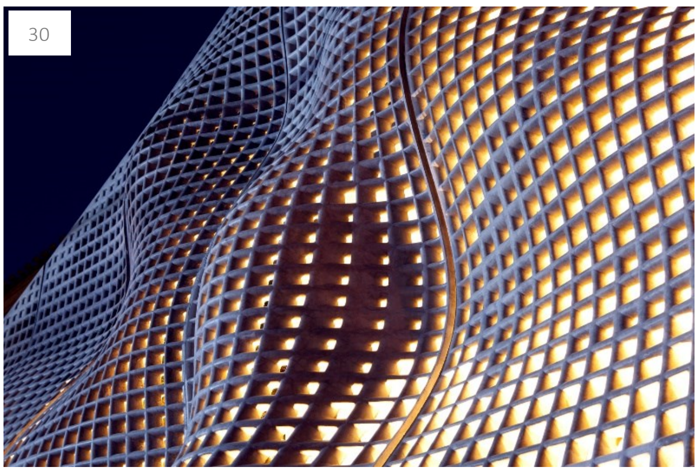
Digital fabrication uses digital modeling technologies to manufacture artifacts and includes many fabrication methods, from 3D-printing (three dimensional) to other additive production processes (Wangler et al., 2016). Economists have described it as the "third industrial revolution" with the promise to revolutionize production techniques worldwide across all fields and sectors (The Economist, 2012; Wangler et al., 2019).

According to recent studies, digital fabrication offers multiple advantages by opening the door for freeform designs (Wangler et la., 2016). As can be seen through our research, traditionally casted concrete artifacts are often associated with a monolithic dense mass. Digitally fabricated concrete artifacts however can have more delicate proportions, fluid shapes, intrinsic textures, and even translucent finishes.

For example, AntiStatics Architecture's *MaoHaus* includes an experimental UHPC façade that was built with single unit panels casted from CNC-milled molds with a mere 2 ¾ inches thickness as seen in figure 30 (ArchDaily, 2019). The curvature of the surface was generated through computer fluid-dynamics algorithms and was thus designed strategically to efficiently distribute the loads of the structure to the foundation, optimizing the use of the material (ArchDaily, 2019; AntiStatics, 2021).

Furthermore, digital fabrication offers higher precision by strategically placing materials where structural support is needed, thus leading to more sustainable constructions by reducing waste generation (Wangler et al., 2016). Other benefits include "increased construction speed, reduced costs for labor and formwork, and increased worker safety" (Wangler et al., 2016, P.67).

Another AntiStatics Architecture project demonstrating those advantages is the *Ou-river Crystal Boxes* restaurant exterior screens as seen in figure 31 (ArchDaily, 2020). The UHPC concrete blocks were cast from a simple two-part mold that was generated through precise geometric control and definition, creating a macro-scale *moiré* effect as the users pass by on the street level (ArchDaily, 2020; AntiStatics, 2021).



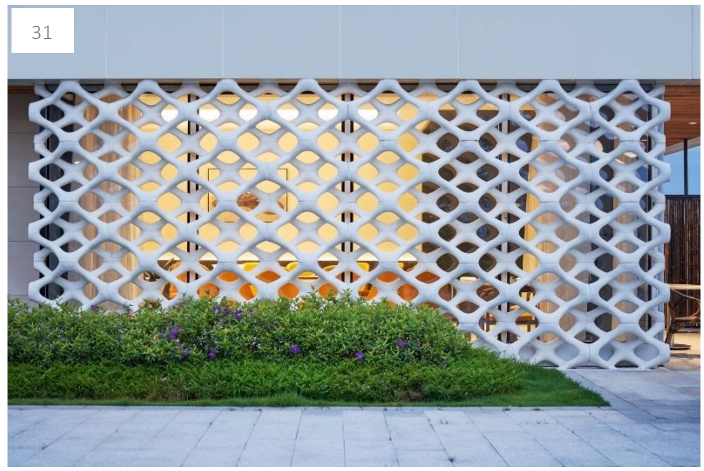


Figure 30. – AntiStatics Architecture's MaoHaus – image by Xia Zhi from ArchDaily.com (2017)

Figure 31. – AntiStatics Architecture's restaurant – image by Dachou Photography from ArchDaily.com (2020)

3D printing

3D printing is an automated additive manufacturing technique where layers of a material are added in a controlled and pre-programmed manner (Wu et al., 2016). In recent years, it has been finding its way into the construction industry as it offered many advantages in terms of "increased customization, reduced construction time, reduced manpower, and construction cost" (Wu et al., 2016, P.1). Subsequently, 3D printing concrete techniques have been experimented with and applied as recipes and methods are still being perfected (Wu et al., 2016; Freek et al., 2018). Some have gone to the extent of successfully reinforcing it, resulting in high ductility (Freek et al., 2018) while others have utilized the rheological properties of SCC (e.g., viscosity and yield stress) (De Schutter et al., 2008). SCC offers the advantages of being fluid enough to be pumped easily into the printer, and of hardening fast enough once the print head is detached (Shah & Lomboy, 2015). Such ongoing developments are opening the door for all kinds of structural applications.

Although additive manufacturing and rapid prototyping have been integrated into the daily operations of many industries (e.g., aerospace, automotive, robotics, etc.), 3D printing techniques have been used more conservatively in the construction industry as "there are some technical, economic and social challenges that need to be overcome to unlock and trigger all opportunities from 3D printing [...]" (Freek et al., 2018, P.25). However, many architects and designers have started to explore its possibilities through various applications.

In fact, the first 3D-printed houses were built within 24 hours out of recycled contrition and industrial waste in Shanghai, China in 2014. The Chinese company extruded a mixture of high-grade cement as well as glass fiber material (BBC News, 2014; DesignBoom, 2014).

More recently, during the 2018 Milan design week, Arup engineering firm, CLS Architetti architecture studio, manufacturer Italcementi, and Cybe Construction 3D-printed a concrete structure as seen in figure 32 (Jordahn, Dezeen, 2018). The project called *3d Housing 05* utilized recycled concrete from demolition site debris developed by Italcementi. Their intention was to demonstrate how 3D-printing concrete can be a cost-effective and efficient building technique using only "the exact amount of raw materials needed for each component, thereby reducing waste produced during construction" (Jordahn, Dezeen, 2018). In addition, ICON, a new construction company based in the USA, introduced one of the first permits for building a 3D printed concrete house; their goal is to commercialize and democratize 3D-printed homes from a sustainable perspective, particularly in response to the global housing crisis as seen in figure 33 (Peters, Fast Company, 2020; IconBuild, 2020).

Concrete 3D printing techniques have also been inspiring artistic installations as can be seen in ETH Zurich's *Concrete Choreography* consisting of a series of 3D-printed concrete columns as seen in figure 34 (Aouf, Dezeen, 2019).

Researchers and design professionals show great interest in 3D printing for multiple reasons: it eliminates the need for formwork and molds, optimizing the production process; it allows for the strategic use of the exact amount of material needed, eliminating waste; and it can help achieve complex designs and patterns that were unthinkable before, offering new opportunities for designers.

Figure 32. – Arup and CLS Architetti's 3D-printed house – image from Dezeen.com (2018)

Figure 33. – ICON's 3D-printed houses – image by Regan Morton photography from DesignBoom.com (2021)

Other hybrid technologies are also being looked at, combining casting techniques with digital manufacturing methods. For example, the ETH Zurich researchers developed a system called *Fast Complexity* that can transition seamlessly from casting to 3D printing concrete as seen in figure 35. This reduces the amount of concrete needed to create buildings, and with the intention of constructing much larger structural applications eventually (Ravenscroft, Dezeen, 2020).

In addition, the world's longest 3D printed concrete pedestrian bridge is being built in Nijmegen in collaboration with designer Michiel van der Kley (Sertoglu, 3D Printing Industry, 2021). The initiative called *The Bridge Project* is thought to break the current record held by the 86-foot concrete bridge built by Tsinghua University (Bridge Project, 2021; Michiel Van Der Kley, 2021).

More recently, ZHA in collaboration with ETH Zurich have erected Striatus, a concrete footbridge made from 53 hollow 3D-printed blocks known as voussoirs (Parkes, Dezeen, 2021). Their technology uses compression and gravity to hold the structure up without the need for reinforcement as can be seen in figure 36.

Figure 34. – ETH Zurich’s Concrete Choreography – image from Dezeen.com (2019)

Figure 35. – ETH Zurich’s Fast Complexity – image from Dezeen.com (2020)

Figure 36. – ZHA & ETH Zurich’s Striatus footbridge – image by Naaro from Dezeen.com (2021)

In order to optimize concrete recipes for 3D printing technologies, researchers are investigating the use of alternative additives such as desert sand, river-sediment ceramist sand, as well as concrete debris (as small, medium, and large aggregates respectively) (Bai et al., 2021; Hanarphy, 3D Printing Industry, 2021). Delft University of Technology researchers have been working with a calcined clay-based cement to perfect the mix in terms of flow consistency, buildability, and hydration properties for 3D extrusion (Chen et al., 2020; Sertoglu, 3D Printing Industry, 2021).

4.4.4. Surface finishes

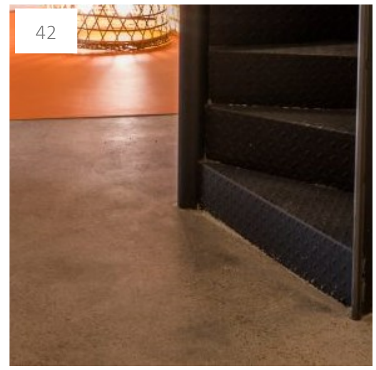
As an amorphous material that cures and hardens with time, concrete lends itself to a wide variety of surface finishes which can be achieved with the help of different types of equipment (Archtoolbox, 2021; The Constructor, 2021):

The most common finish in concrete applications is known as the **trowel technique** as seen in figure 37 offering a smooth and fine-leaved concrete surface which can be achieved through either manual tools (e.g., a flat steel blade attached to a handle known as a 'trowel'), as well as mechanical or automated tools.

Additionally, the **broom finish,** as seen in figure 38, can be used to provide a rougher texture, thus generating a slip-resistant surface, which is typically found on walking surfaces such as concrete sidewalks and pavements for example.

We also find concrete **stamping** as seen in figure 39, which is attained by pressing a stamp onto the freshly poured concrete to generate different patterns or to simulate other materials (e.g., tiles or stone). Another technique is **salt finished** traditionally found around wet areas (e.g., pools) where coarse rock salt crystals are applied on fresh concrete and washed off later, leaving a rough texture offering skid resistance as seen in figure 40. We also find the various methods of revealing concrete aggregates known as the **exposed aggregates finish** as seen in figure 41. This can be achieved through **polishing** the top surface of the concrete and then coating it with a **protection layer**. In addition, by applying a **penetrant chemical** with the help of specialized equipment, concrete surfaces can be ground to create a **glossy polished finish**, which is usually found in indoor applications as seen in figure 42.

Concrete can also be **colored** by either adding the pigment into the mix prior to casting or by applying pigments or staining agents directly to the dry surface as seen in figure 43. Concrete surfaces can be **sandblasted** (figure 44), **etched** (figure 45), **waxed**, and **marbleized**, to name only a few of the wide variety of concrete finishing techniques which offer unique textures and appearances.



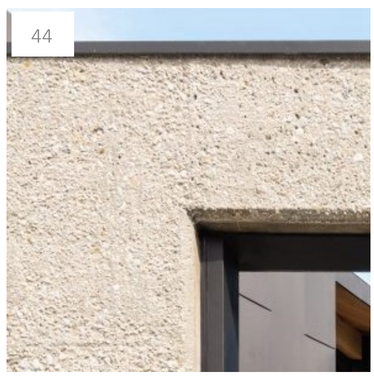


Figure 37. – Trowel Finnish – image from VicotriaConcreteSurfaces.com (2021)

Figure 38. – Broom Finish - image from VicotriaConcreteSurfaces.com (2021)

Figure 39. – Stamped finish – image from ImpressionsGroupOttawa.ca (2021)

Figure 40. – Salt finish – D. Adjaye's Ruby City Center – image by Dror Baldinger, courtesy of Ruby City & Ajaye associates from Dezeen.com (2019)

Figure 41. – Exposed aggregate finish – Estudio BRA Arquitetura's Casa Piraja – image by Maira Acayaba from Dezeen.com (2018)

Figure 42. – E. Jerez & B. Leal's Classroom – image courtesy of Javier Bravo from Dezeen.com (2021)

Figure 43. – Stained concrete, BBGK Architekci's Katyn Museum – image from Dezeen.com (2017)

Figure 44. – Sand-blasted finish, C. Wilkinson's home – image by Ema Peter from Dezeen.com (2020)

Figure 45. – Etched finish – image from TimberTown.ca (2021)

In that sense, depending on the intention and the treatment applied, concrete surfaces can range anywhere from smooth to rough, glossy to dull, monochromatic to colorful, etc., thus reinforcing the material's versatility in terms of aesthetic finishes.

4.4.5. Concrete maintenance and repair

In order to remedy to concrete defects which may occur with the passage of time, multiple repair techniques can be used in different fields of application.

Cracking in concrete is a common phenomenon. Some techniques help improve or extend the lifespan of concrete artifacts by either preventing cracks from appearing (e.g., plastic polymers applied on concrete surfaces), or by filling them with **epoxy injections** for example after they have formed (Silva et al., 2015). According to experts, surfaces displaying minor cracks can be easily remedied by applying an **overlay** layer (e.g., polymer modified Portland cement, silica fume concrete, etc.) (TheConstructor.com, 2021).

Other techniques include **routing and sealing,** which involves enlarging the crack and then filling it with a joint sealant; as well as **stitching,** which uses U-shaped metal staples anchored on opposite sides of the crack (TheConstructor.com, 2021). Additional techniques include **inserting reinforcement bars** at a 90-degree angle according to the crack plane and filling the hole with epoxy, or **prestressing** techniques which applies compressive strength in selected sections to help distribute the pressure more evenly (TheConstructor.com, 2021). Other methods include **grouting** which consist of filing the crack with another material (e.g., cement-based mixtures, low water content mortar, etc.) and then ramming and patting it into place (TheConstructor.com, 2021).

Furthermore, small holes in concrete surfaces can be repaired using a **dry-pack** method by packing a thick mortar (e.g., cement, sand, and water) into the hole, or a **synthetic patching** method consisting of brushing and troweling an epoxy-resin mortar onto the surface (Damsafety.org, 2021).

Yet, these techniques are labor-intensive, costly, and impractical due to the difficult if not impossible access to the damaged areas due to logistic or environmental conditions (Silva et al., 2015). In cases where more than a square foot of the concrete surface is judged damaged, the section is usually removed and replaced.

If anything, the existing repair techniques show that there is a tendency to want to fix concrete artifacts displaying signs of damage rather than discarding them and replacing them – which we will reflect on further in our discussion chapter.

4.4.6. Concrete applications

For this section, we have organized concrete artifacts according to the scale of their applications (see figure 36 below). We thus find large scale uses including infrastructures and edifices, as well as small scale ones including prefabricated modules, accessories, and furnishes. In addition, we find the installations category composed of smaller scale artifacts which can be multiplied and assembled to create larger ones.

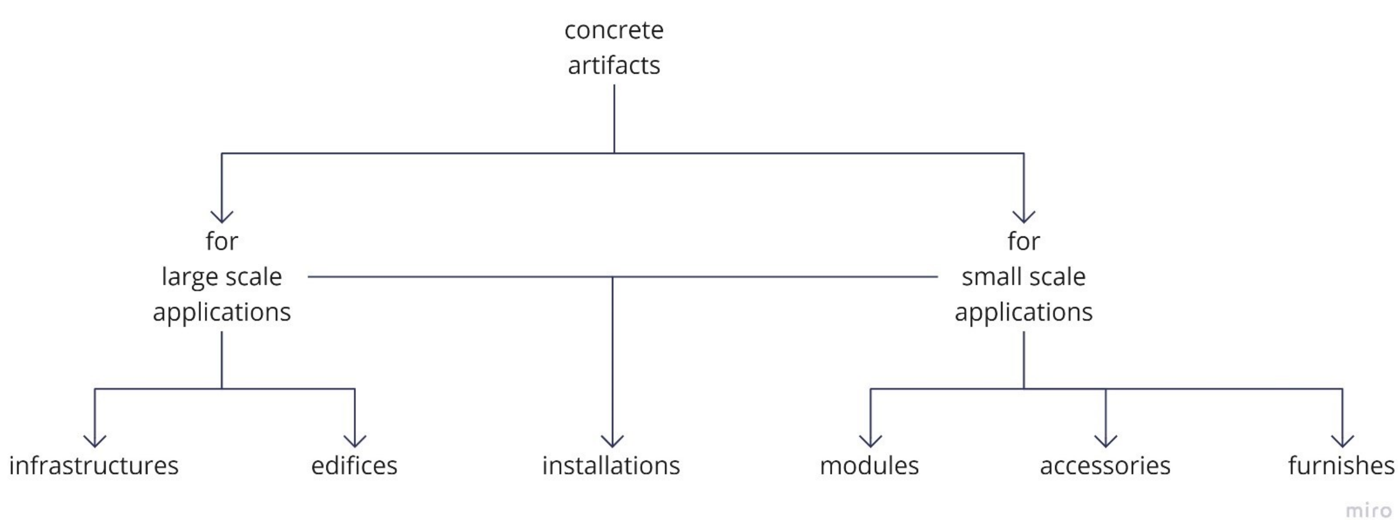


Figure 46. – Categorization of concrete artifacts – T. Harb (2021)

Large scale applications

As mentioned previously, concrete has been mainly featured in architectural and structural applications within the construction industry due to its technical characteristics (Hosseini et al., 2013) as seen in figure 47.

It remains the material of choice for infrastructures such as highways, roads, tunnels, bridges, coastal barriers, units for mass transportation, airports, airways, silos, water dams and waste management, power generation and transmission, telecommunication, etc.). The materials also widely preferred in the building industry as it is commonly used to build edifices in the commercial, residential, industrial, agricultural, and institutional sectors.

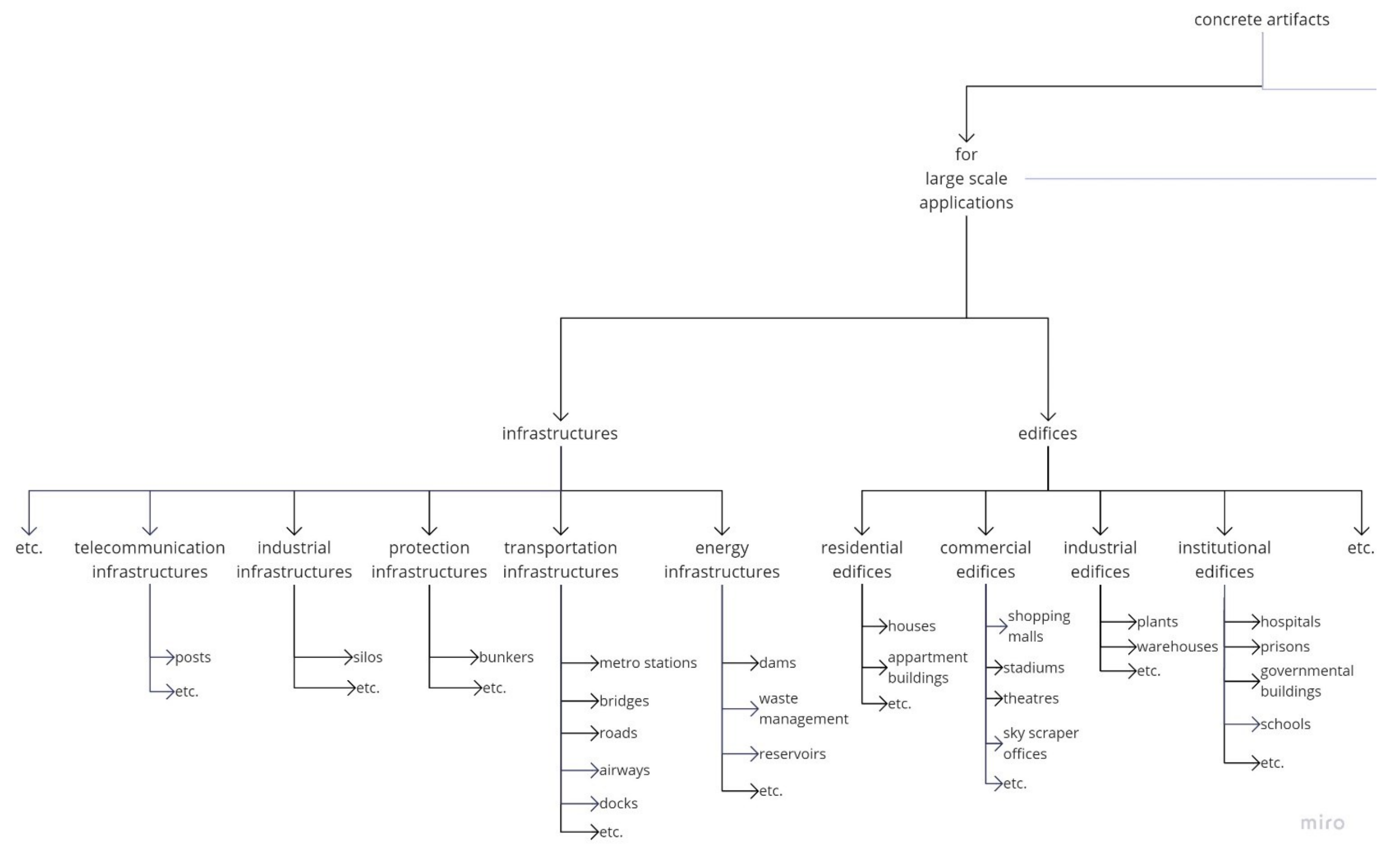


Figure 47. – Categorization for large scale applications of concrete artifacts by T. Harb (2021)

Although a wide majority of these structural applications feature concrete in its most standard morphology (e.g., monolithic precast or cast-on-site massive blocks), architects and designers have been exploiting the material's plasticity by giving it more organic shapes.

For example, in Northern Italy, MoDus Architects' undulating concrete tunnel emphasizes the material's fluid characteristics as seen in figure 48 (Block, Dezeen, 2020).

Another impressive example is the *Zeitz Museum of Contemporary Art Africa* by designer Thomas Heatherwick which was carved out of a pre-existing grain silo from the 1920s, following a destruction rather than a construction technique, utilizing 3D scanning algorithms to compose with the past as seen in figure 49 (Dezeen, 2017; ZeitzMocaa, 2021).

Lastly, we need to mention Snøhetta's underwater restaurant built in Norway with its 34 meters long sunken monolithic concrete tube which is partially submerged in the ocean (Crook, Dezeen, 2019). The architects explain that concrete was the perfect medium offering optimal resistance against the pressure of the water and waves as seen in figure 50.

> "The concrete has been left with an exposed, rugged texture to encourage algae and molluscs to cling on. Over time this will create an artificial mussel reef that helps purify the water, and in turn naturally attract more marine life." (Crook, Dezeen, 2019).

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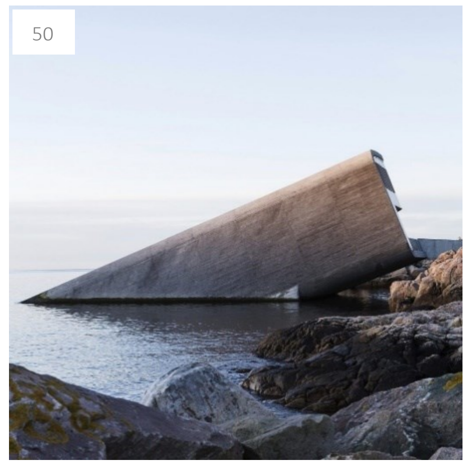


Figure 48. – MoDus Architects' curved tunnel - image by Leonhard Angerer from Dezeen.com (2020)

Figure 49. – T. Heatherwick's museum Zeitz MOCAA - image by Iwan Baan from Dezeen.com (2017)

Figure 50. – Snøhetta's semi-submerged restaurant Under - image by Inger Marie Grini from Ignant.com (2019)

Small scale applications

Concrete can be also found in smaller scale urban applications such as prefabricated artifacts made from modules, as well as furnishes that can be found both in indoor and outdoor contexts as we have proposed in figure 51.

We therefore find projects where landscape, architecture, and design firms collaborate with concrete manufacturers to create prefabricated accessories to furnish public and private spaces.

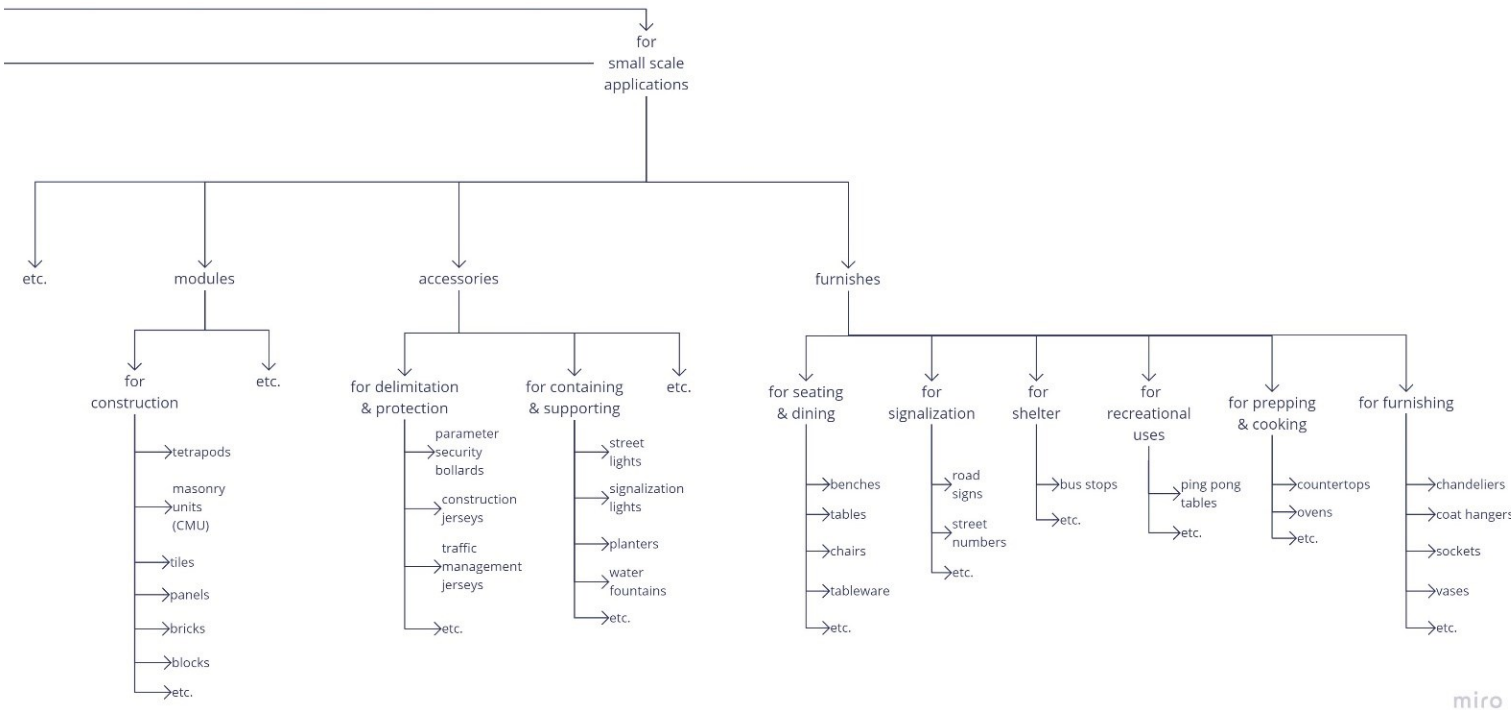


Figure 51. – Categorization for small scale applications of concrete artifacts by T. Harb (2021)

In addition, the smaller scale concrete modules can be assembled to create larger scale installations as we have organized in figure 52 below.

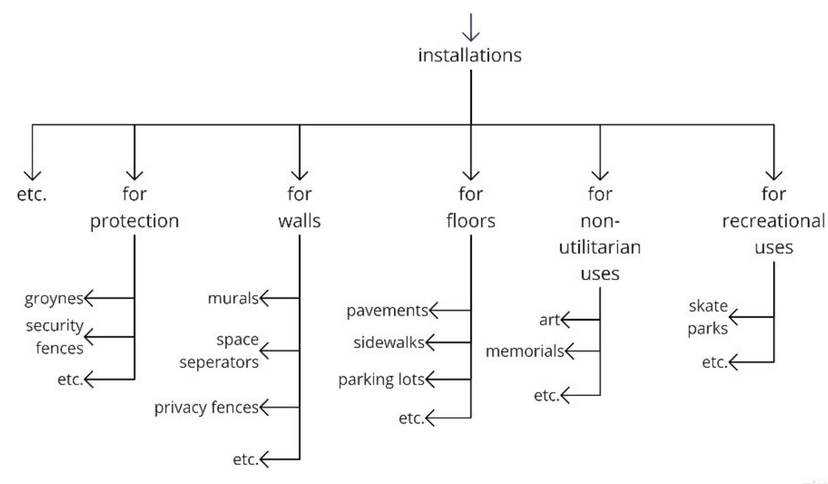


Figure 52. – Categorization for installations types of concrete artifacts by T. Harb (2021)

The examples presented in this section highlight a selection of concrete artifacts that are far from the ordinary, and which display the material in new and unexpected aesthetics.

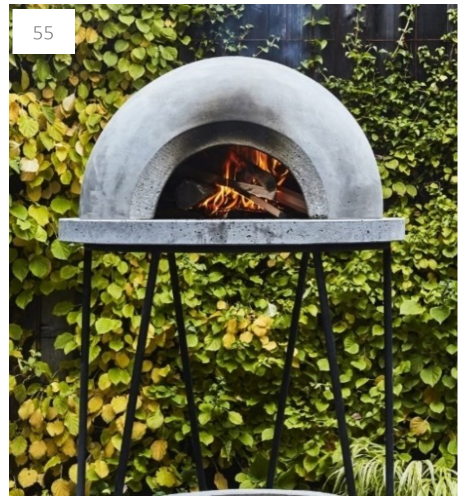
For example, Danish design firm Gjøde and Partnere Arkitekter's movable white concrete planter *TreePot* offers a form language that is simple and iconic which is usually more associated with ceramics (figure 53) (Gpark, 2012).

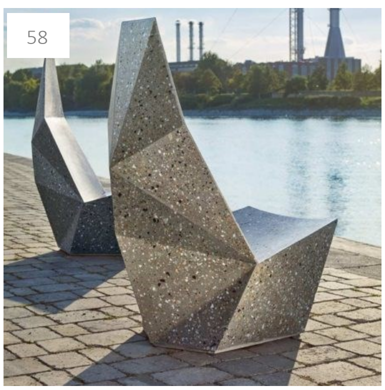
Another example is the Montreal-based design & manufacturing firm m3béton specializing in Ductal® products. According to their website, the low-porosity, low-thickness, low-maintenance, and anti-graffiti material is ideal for outdoor applications, and is said to age gracefully (m3béton, 2021). Their *Table de Ping Pong* spans over 2 meters with a mere 1-inch thickness (figure 56), and their *Feuillus* outdoor vegetation support structure has the sole purpose of offering support for climbing plants in urban spaces (figure 54).

AtelierB, another local design and manufacturing firm, offers a collection of concrete floors, panels, counters, and furnishings (AtelierB, 2021). They promote concrete as a "noble material" using their expertise and techniques and offer furniture such as The *Brikabrak* bench, the fire-resistant baking appliance *Chibouki* pizza oven (figure 55), and their *Pink Punk Table* doubling as a dining table and using ultra-high performance fiber reinforced concrete with a ¾ to 1½ inch thickness, similar to the one made by m3béton (AtelierB, 2021).

Architect Murray Barker and artist Laith McGregor propose two *Monoliths* tables: the lighter-colored one includes copper inlaid details and green pebble aggregates on its surface (figure 57), whilst the darker one is tinted black with iron oxide pigments (Morby, Dezeen, 2016).

Many designers have developed concrete furniture utilizing different recipes, manufacturing, and finishing techniques: Designer Alexander Lotersztain's QTZ collection, produced by Hungarian manufacturer IVANKA showcases the manufacturer's expertise in experimental concrete technologies by demonstrating a rich variety of surface finishes such as pigmentation and exposed aggregates (figure 58) (DesignBoom, 2016). Inspired by Great Britain's 1950s brutalist architecture, designers Thomas Musca and Duyi Han created a collection of geometric reinforced concrete furniture with strategically placed voids to reduce the weight (figure 59) (Cassius Castings, 2021; Klein, Dezeen, 2020). Another example is London design studio Raw Edges' concrete seating system *Steps* which utilizes precast concrete's replicability, forming an inviting urban texture with its smooth surface finish (figure 60) (Raw-Edges, 2021; Yalcinkaya, Dezeen, 2017).





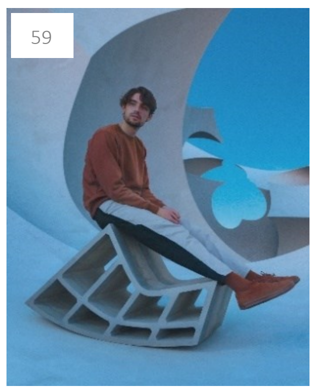


Figure 53. – Gjøde and Partnere Arkitekter's TreePot – image from Gpark.dk (2012)

Figure 54. – M3béton's Feuillus – image from m3beton.ca (2017)

Figure 55. – AtelierB's Chibouki wood-fired Oven – image from atelierb.ca (2021)

Figure 56. – M3béton's Ping Pong Table – image from m3beton.ca (2017)

Figure 57. – M. Barker & L. McGregor's Monoliths ping pong tables – image by Abigail Varney from Dezeen.com (2016)

Figure 58. – A. Lotersztain's QTZ Collection – image by IVANKA from Landezine-award.com (2021)

Figure 59. – T. Musca and D. Han's Rockitto Chair – image by Dui Han from Dezeen.com (2020)

Figure 60. – Raw Edges' concrete armchairs – image from Dezeen.com (2017)

Home furnishes

New experiments with admixtures, aggregates, pigmentation, and surface finishes have opened the doors to new and more subtle applications in interior spaces. These require less structural performance thus motivating many designers and architects to introduce concrete into the interior space.

The projects of Italian concrete manufacturers Cimento® offer a wide range of concrete products from panels, floors, and outdoor facade coverings all which display a sleek aesthetic due to the 90% content of mineral aggregates which are mixed into the cement binder (Cimento, 2020). They have collaborated with Italian design firm Parisotto + formenton architetti for example, to produce multiple concrete furnishes including the *Torcello* bench (figure 61), the *Zitella* stool, and the *Giudecca* table (figure 62) (Archiproducts, 2021). They have also collaborated with designers Defne Koz and Marco Susani to create the *Lido* bench and stool collection (figure 63) (Cimento Collection, 2021; Koz Susani Design, 2021), as well as designer Gordon Guillaumier for the *Cannaregio* concrete dining tables, chairs, armchairs, sofas, and poufs collection (figure 64) (Archiproducts, 2021).

> "[...] With its almost velvety tactile effect, the concrete skin highlights the softness of the lines, softening the hardness of the classic concrete furniture. Finally, the use of two-color coatings creates a play of contrast in the volumes that makes pure forms vibrate." (Gordon Guillaumier, Archiproducts, 2021)

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Figure 61. – Parisotto + formenton architetti's Torcello Bench – image from Prodeez.com (2021)

Figure 62. – Parisotto + formenton architetti's Giudecca table – image from Prodeez.com (2021)

Figure 63. – D. Koz & M. Susani's Lido bench – image from ArchiPorducts.com (2021)

Figure 64. – G. Guillaumier's Cannaregio collection – image from ArchiProducts.com (2021)

Other examples displaying concrete's aesthetic versatility in indoor furnishings include Bower Studio's *Melt Chair* which can be seen to 'drape and fold over' its metallic base (figure 65), thus evoking "a fluidity that isn't usually associated with the material" (Gibson, Dezeen, 2020). In that same sense, Jerome Byron's curved concrete stools celebrate the liquid aspect of concrete with playfully pigmented GFRC (figure 66) (Gibson, Dezeen, 2020). The pigmented concrete is placed to dry slightly onto a flat rubber mold before being curved with a U-shaped woodwork (Gibson, Dezeen, 2020). We can also find Sment's *Gestalt furniture* which was made from a polished pigmented concrete that was made to simulate sculptural stone (figure 67) (Winston, Dezeen, 2018).

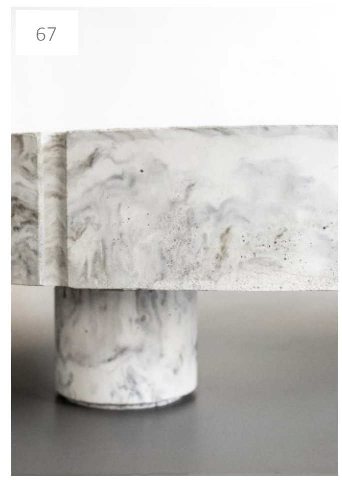


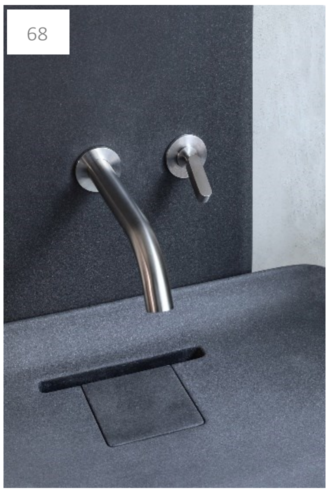
Figure 65. – Bower Studio's Melt Chair – image from Dezeen.com (2020)

Figure 66. – J. Byron's curved stools - image by Samuel McGuire from Dezeen.com (2020)

Figure 67. – Sment's Gestalt Furniture collection – image from Dezeen.com (2018)

Furthermore, concrete is increasingly used in countertops and paneling of all sorts. More recently, it's been making its way into people's homes in the form of washbasins, sinks, and bathtubs. For example, architect Marco Merendi and industrial designer Diego Vencato created a collection of stain and dirt resistant concrete artifacts for bathroom brand Agape in collaboration with Italian firm Gypsum (Griffiths, Dezeen, 2019). The *Petra* collection was featured on the longlist for the Dezeen Awards in 2019 and showcases a high-performance concrete called Cementoskin which was dyed with oxides as it was mixed to create a wide range of tones (figure 68) (Griffiths, Dezeen, 2019). Similarly, we can find AtlerierB's concrete sinks with a less sleek and more natural surface finish (e.g., exposed air bubbles and edge imperfections), coated with their “natural, non-toxic, water-based sealant” (AtelierB, 2021). In this example, concrete’s surface imperfections are an intentional part of the design concept (figure 69).

With sustainability as a guiding force in their designs, England-based company FORMED offers an aesthetically versatile range of concrete basins which are “80% recycled by weight and fully recyclable at the end of its life” (figure 70) (FormedConcreteBassins, 2021; DesignMilk, 2021).



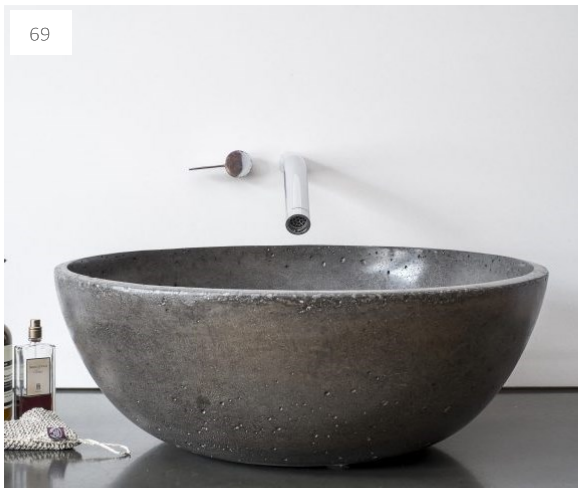


Figure 68. – M. Merendi & D. Vencato’s Petra collection – image from Dezeen.com (2019)

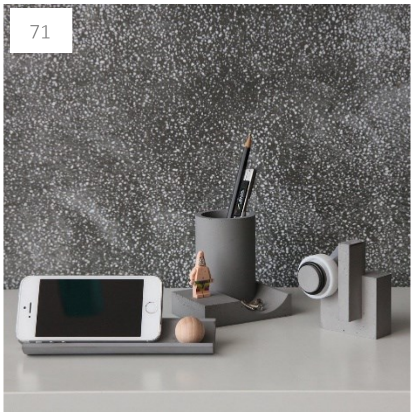
Figure 69. – AtelierB’s Large Bowls collection – image from AtelierB.ca (2021)

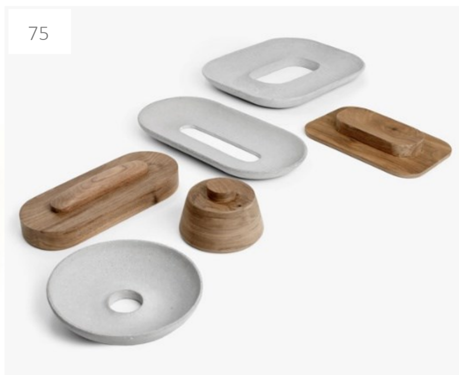
Figure 70. – Formed Concrete Basins’s Arc wash basins – image from FormedConcreteBasins.com (2021)

Smaller scale applications in interior spaces include 22Studio’s *Concrete Stationary* line of office accessories inspired by urban architecture (figure 71) (Ignant, 2019). Other examples include THINKK studio’s *Workaholic* concrete lamps (figure 72) and Allstudio’s Aperitivo pigmented concrete vase (figure 73) (Chalcraft, Dezeen, 2012; AllStudio, 2021).

Designer Nir Meiri introduced concrete in tableware with his plates and platters concepts (figure 74) (Nir Meiri studio, 2011; DesignBoom, 2011), while Spanish Mexican studio LaSelva their concrete plates for Mexican homeware brand Más, in addition to other concrete home accessories featuring vases, trays, and candle holders, in collaboration with designer Iván Zúñiga (figure 75) (LaSelva design studio, 20121; Brillon, Dezeen, 2016).

We also find AtelierB's dishware, as well as their concrete trays and wall hooks collections (figure 76) (AtelierB, 2021).





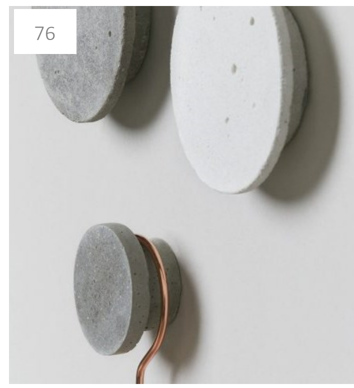


Figure 71. – 22Studio's Stationery collection – image from Ignant.com (2019)

Figure 72. – THINKK Studio's Workaholic collection – image from Dezeen.com (2012)

Figure 73. – Allstudio's Aperitivo vase – image from AllSutdio.com (2021)

Figure 74. – N. Meiri's Concrete Plates – image from DesignBoom.com (2011)

Figure 75. – image by Sergio Bejarano from Dezeen.com (2016)

Figure 76. – AtelierB's Hooks – image from AtelierB.ca (2021)

Figure 77. – Sekhina's concrete sockets – image from Sekhina.com (2021)

Finally, in an effort to substitute the use of non-recyclable and non-durable plastics in electrical accessories, Hungarian design brand Sekhina proposes a line of concrete switches and sockets as an "aesthetically pleasing alternative to plastic" (Dezeen, Hitti, 2020). This type of application takes advantage of concrete's insulating and non-flammable properties, in addition to being as environmentally friendly as possible by eliminating the use of synthetic resins and contaminants (Dezeen, Haiti, 2020; Sekhina, 2021). Interior designers - who are increasingly drawn to concrete finishes (e.g., walls, floors, etc.) - usually tend to want to "hide switches and sockets as they blunt the general aesthetics of their work” (Gábor Kasza cited in Hitti, Dezeen, 2020). Concrete sockets thus almost becoming an accent piece - similarly to plaster moldings - as a more integral part of the interior design concept and overall style (figure 77, p.110).

Other applications

When concrete was first being developed as a construction material in the late 19th century, it was mostly seen as a “low-grade substance suitable for foundations and retaining walls” (Forty, 2013, P.169). Back then, the literature showed that it was difficult to imagine concrete in more pristine or noble applications.

Concrete and artifacts of spirituality and remembrance

However, changing ideologies, practices, and uses have affected concrete’s identity and people’s perceptions over time (Forty, 2013; Simonnet, 2005; Collins, 2004). In that sense, concrete’s *durability* was being celebrated by architects such as Perret and Coignet in France, and Lascelles and Pulham in Britain, by featuring the material in more iconographic or symbolic applications, transcending its techno-economic appropriateness. Since then, concrete could be increasingly found in artifacts of spirituality (e.g., churches, mosques, temples, etc.), as well as artifacts of remembrance (e.g., memorials, shrines, etc.).

Amongst such applications, we find Perret’s 1923 *Notre Dame du Raincy church* in France (Ghiuzan, New Church Architecture, 2014), or Le Corbusier’s 1955 *Notre Dame du Haut* church featuring its iconic curved exposed-concrete roof (Dezeen, Winston, 2016).

More recent examples include the stepped concrete temple designed by Toru Kashihara Architects as seen in figure 78 (Astbury, Dezeen, 2019), the mosque by Candalepas Associates as seen in figure 79 (Dezeen, Han, 2019), the chapel by Cavagnero (Dezeen, McKinght, 2018), as well as the *Shonan Christ Church* by Takeshi Hosaka Architects as seen in figure 80 (ArchDaily, 2021).

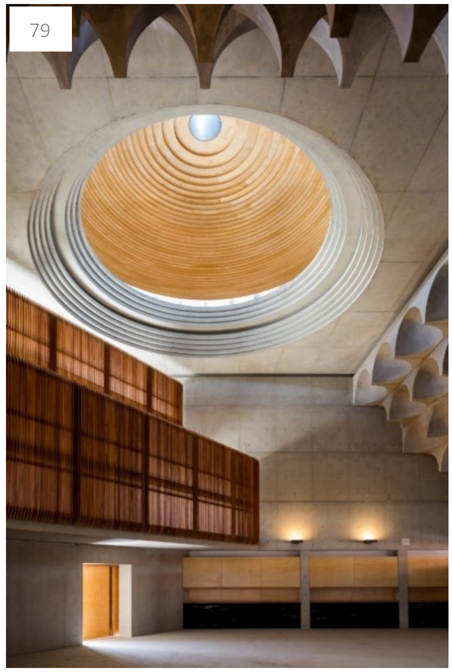


Figure 78. – T. Kashihara’s Shoraku-Ji temple – image by Takumi Ota from Dezeen.com (2019)

Figure 79. – Candalepas Associates’ mosque - image by Brett Boardman from Dezeen.com (2019)

Figure 80. – Takeshi Hosaka Architects’ Shonan Christ Church – image by Koji Fuiji/Nacasa&Partners Inc. from ArchDaily.com (2020)

Additionally, although in a post-war era concrete was considered “the material of *oblivion*”, it somehow became the default medium for memorials of modern times (Forty, 2013, P.198).

> “It is the creation of monumental works that the use of concrete fully justifies itself” (Joray, *Le Béton dans l’Art Contemporain*, 1977, cited in Forty, 2013, P.202)

Concrete’s associations with *inertness, brutality,* and *indestructibility* charged it with symbolisms and iconographies. The material was thus heavily featured in post-war as well as modern artifacts of remembrance such as the notorious *Holocaust Memorial* in Berlin by Eisenman and Happold (figure 81) (Baldwin, ArchDaily, 2020), as well as the *Lady Diana Memorial Fountain* in London by Gustafson Porter + Bowman (figure 82) (ArchDaily, 2004), or the upcoming *Memorial for the victims of Covid19* in Uruguay by Platero (figure 83) (WorldofArchitecture.com , 2020).

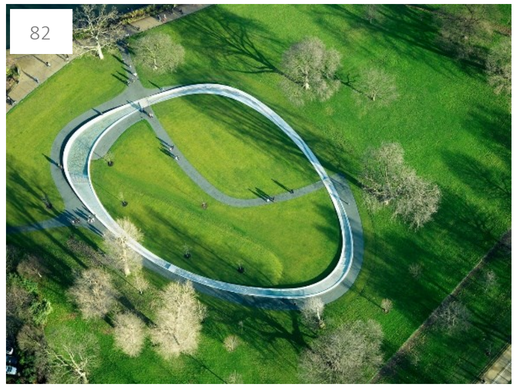


Figure 81. – Eisenman & Happold's Holocaust Memorial – image by Flickr user dalbera licensed under CC BY 2.0 from ArchDaily.com (2020)

Figure 82. – Gustafson Porter + Bowman's Diana, Princess of Wales Memorial Fountain – image by Jason Hawkes from ArchDaily.com (2004)

Figure 83. – G. Platero's memorial for the victims of the Covid-19 in Uruguay – image by Gômez Platero from WorldArchtecture.org (2020)

Concrete in non-utilitarian applications

Since its earliest developments, concrete as a medium has also been attracting the attention of other disciplines lending itself to more exploratory, poetic, and artistic uses. These types or artistic applications have also helped attribute to the material other significances and symbolism.

> "Think about concrete in all the diversity of the applications, not just those controlled by architects and engineers, but to deal with its presence everywhere, whether in the work of self-builders, sculptors, writers, politicians, entrepreneurs, photographers or film makers" (Forty, 2013, P.9)

In fact, some of the predominant movements and styles in the late 1920s - such as the Bauhaus in architecture and the Avant-Garde in art - displayed enthusiasm and curiosity for new materials (Forty, 2013; Collins, 2004). As the widespread use of concrete coincided with those movements, the material's aesthetics attracted the attention of sculptors, photographers, and cinematographers, amongst others, and was thus feathered in multiple projects.

For example, we find artist Bruce Nauman's 1965 *A cast of the space under my chair* (figure 84) (Kroller Muller, 2021). Today, a wide variety of artworks exploit the different features concrete has to offer. For example, Liliana Ovalle's 2017 collection of narrowed objects *En Concreto* was inspired from architectural artifacts (figure 85) (Press, Ignant, 2017), design studio Tiipoi's 2018 *Siment* collection drew inspiration from Indian urban infrastructures (figure 86) (Gibson, Dezeen, 2018), and Klemens Schillinger's 2019 *Landmarks* concrete tabletop pieces collection was influenced by ancient Greek and Mayan structures (figure 87) (Wade, Ignant, 2019).

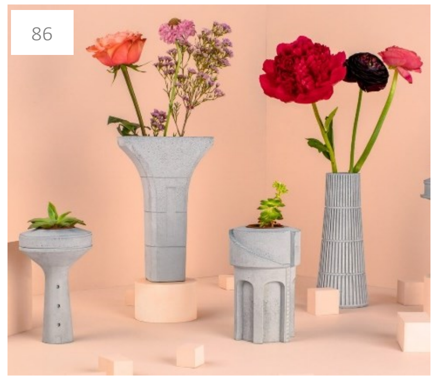


Figure 84. – B. Nauman's A Cast Of The Space Beneath My Chair - image by Kroller Muller Museum from krollermuller.nl (1981)

Figure 85. – L. Ovalle's En Concreto collection – image by Liliana Ovalle from Ignant.com (2017)

Figure 86. – Tiipoi's Siment collection – image from Dezzen.com (2018)

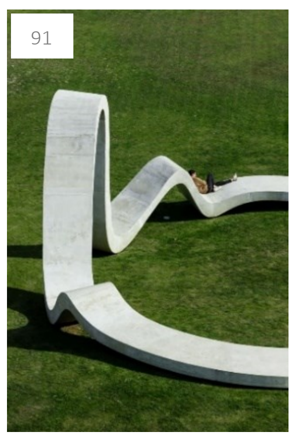
Figure 87. – K. Schillinger's Landmarks series – image by Leonhard Hilzensauer from Ignant.com (2019)

Concrete also lents itself to various scales and formats within the arts too. For example, Bram Vanderbeke's 2018 *New Primitive* collection featured concrete waste blocks treated with stone wax to create Neolithic-looking furnishes (figure 88) (Yalcinkaya, Dezeen, 2018), while Julia Olanders' 2019 *Betweenness* project combined concrete with insulation foam to create vases and recipients (figure 89) (Julia Olanders, 2019).

Venturing into larger formats, we find Matter Design's 2019 whimsical *Walking Assembly* developed in partnership with multinational building materials company CEMEX (figure 90) (Dezeen, McKnight, 2019). The massive jigsaw concrete blocks were inspired from megalithic architecture and were designed to "demonstrate the potentials of moving mass with joy" (Clifford cited in McKnight, Dezeen, 2019). Made of massive masonry units (MMU), the designers experimented with densities and centers of gravity to demonstrate the possibility of erecting structures without the use of heavy machinery (McKnight, Dezeen, 2019).

In urban art, we find numerous examples of installations including architecture studio FAHR's 2018 textured concrete circle bench *LOOP*, which was meant to be an organic meeting place democratizing the green space between the campuses of the University of Porto (UPTEC) (figure 91) (ArchDaily, 2019). Another example features the ongoing architectural project *Saya Park* designed by Álvaro Siza Vieira and Carlos Castanheira's studios which began in 2018 (Ignant, 2021; Zaxarov, ThisIsPaper.com , 2020). *Saya Park* consists of an art pavilion, chapel, and observatory celebrating unfinished board-marked concrete's monolithic beauty and the sensorial experiences it offers (figure 92).

> "The texture of the wooden formwork is printed onto the concrete, in another gesture that relates the artificial material to its natural setting." (Zaxarov, This Is Paper, 2020)



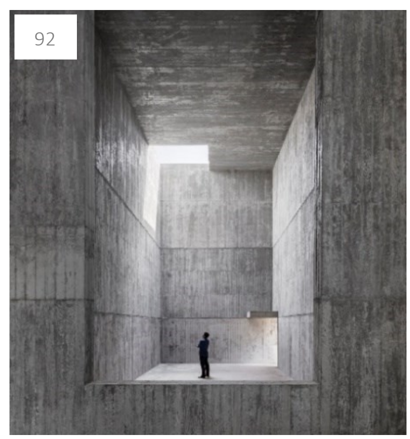


Figure 88. – B. Vanderbeke's New Primitive – image from Dezeen.com (2018)

Figure 89. – J. Olanders' Betweenness project – image from Dezeen.com (2020)

Figure 90. – (bottom left) Matter Designs' Walking Assembly - image by Matter Design Inc. from matterdesignstudio.com (2019)

Figure 91. – FAHR 021.3's loop – image by Joao Morgado from DesignBoom.com (2019)

Figure 92. – Alvaro Siza + Carlos Castanheira's Saya Park – image by Fernando Guerra from ThisIsPapper.com (2020)

Concrete in photography and cinematography

Twentieth century concrete artifacts have attracted the attention of many photographers such as Lucien Hervé for example, who was known to be Le Corbusier's favorite photographer in the late 1940s (Beer & Hervé, 2004), or American landscape photographer Ansel Adam with his *Hoover Dam* photographs in the 1940s, as well as other concrete infrastructures (Turnage, The Ansel Adams Gallery, 2016). In fact, post-war concrete buildings have been indeed the subject of interest of many, particularly with the rise and fall of brutalist architecture.

For example, we can find the recognizable works of German photographers Bernd and Hilla Becher with their recognizable back-and-white photographs of industrial structures through a vantage point in the 1960s (Blumberg, Britannica, 2015), as well as English photographer Simon Phipps' works on the brutalist concrete buildings of modernist British architecture in the late 1960s (Simon Phipps, 2021; Mickey Hartley, 2021).

Old and new concrete elements have been captured the more recent works of architectural photographers such as award-winning Sebastian Weiss whose work celebrates concrete aesthetics and beauty in urban centers in his series Dramatis Personae II for example (figure 93, page 117) (Le Blanc, 2020).

We also find Australian architectural photographer Rhiannon Slatter who focuses on the "stark beauty and ubiquity of concrete" as well as questions the material's popularity in her latest series entitled 'Concrete' (figure 94, page 117) (Ignant, 2019).

Lastly, we find Stefano Perego and Roberto Conte who are known to feature concrete in their creations as they explore both Modernist[10] and Brutalist[11] architecture, using photography as historical storytelling (figures 95-96, page 117) (DesignBoom, 2021; RobertoConte.com, 2021), and the list goes on.

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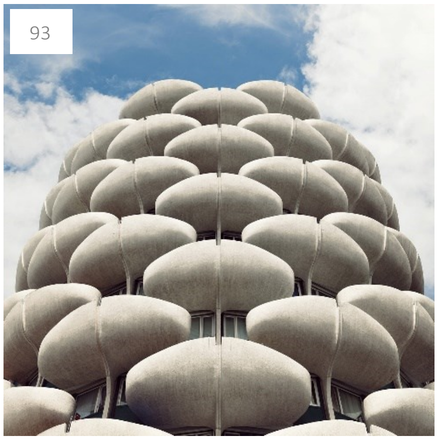
[10] Modernist architecture is a movement based on functionalism (e.g., that *form follows function* mentioned on page 12) which emerged in the early 20th century (Rowe, 2011). It was mainly characterized by constructions using innovative technologies and new materials, notably reinforced concrete, amongst others (e.g., glass, steel, etc.).
[11] Brutalist architecture emerged in continuation with the Modernist movement in the post-war mid 20th century and was characterized by large-scale monolithic masses (Mould, 2016). As mentioned previously, poured concrete was by far the material of choice for this movement as it manifested in minimalist and structural shapes.



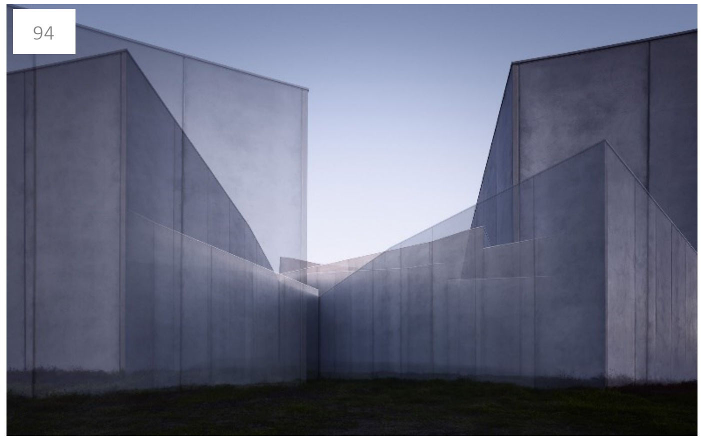


Figure 93. – photograph by Sebastien Weiss of Choux de Créteil in France, from his series Dramatis personae II – image from LeBlanc.com (2017)

Figure 94. – photograph by Rhiannon Slatter of series Concrete – image from Ignant.com (2019)

Figure 95. – photograph by Stefano Perego of Housing Complex Pegli 3 Aldo Luigi Rizzo (1980-1989) in Italy, image from DesignBoom.com (2021)

Figure 96. – photograph by Roberto Conte of Cultural Heritage Institute, nicknamed the Crown of Thorns, in Madrid, image from RobertoConte.com (2021)

In cinematography, concrete undoubtedly carries symbolic and aesthetic values that are being exploited by the film industry. In fact, many motion pictures plots revolve around the material.

For example, Adrian Pasdar's 2000 film *Cement* (featuring torture inside an iron box being filled with cement) highlights concrete's slow yet destructive curing strength which is used to control subjects psychologically and physically.

Concrete is undeniably associated with the urban world as demonstrated in multiple examples, such as Ricky Staub's 2020 movie *Concrete Cowboys,* where the term refers to the African American community originating from the American megacity Detroit. In this double entendre, concrete refers to *urban culture* in general as well as the African American community more specifically.

In Craig Zahler's 2018 *Dragged Across Concrete*, concrete is very predominant in the walls and floors of prisons which were notoriously used as a *medium of security and control* for being *unbreachable* from the inside. In that same sense, based on James Dashner's 2009 novel, the 2014 movie *The Maze Runner* proposes an experimental world that is sealed off by massive concrete walls (Bryan, Motion Pictures, 2014).

> "[in] scenes set against concrete, men are tested, and sometimes destroyed." (Forty, 2013, P.61)

Furthermore, as mentioned, concrete is a characteristic material of Brutalist architecture; by consequence, people make connections with social injustice or disorder.

Stanley Kubrick's 1971 *A Clockwork Orange* as well as Ben Wheatley's 2015 *High Rise* feature concrete brutalist buildings representing a dystopian experience, creating an ambiance for violence and punishment (Scovell, Little White Lies, 2018; Nedomansky, FilmScalpel, 2021). In that same sense, Denis Villeneuve's 2017 *Blade Runner 2049* embraced brutalist concrete as an appropriate backdrop for his dystopian Los Angeles and Las Vegas (Nedomansky, FilmScalpel, 2021) as seen in figure 97 below.

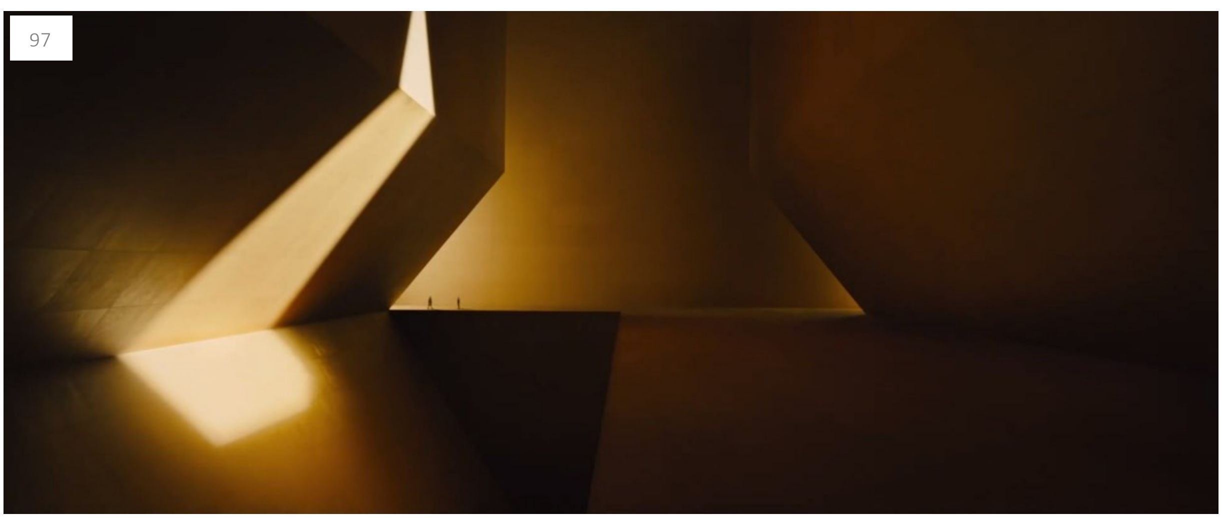


Figure 97. – Render for D. Villeneuve's Blade Runner 2049 92017) trailer – image from FailedArchitecture.com (2021)

Lastly, concrete's qualities seem to be celebrated and showcased today as adding a sensorial and experiential value to properties as seen in BBC's 2017 The World's Most Extraordinary Homes documentary series where British architect Piers Taylor and presenter Caroline Quentin continuously boast the material's aesthetics.

4.5. Perceptions of concrete

Throughout the literature review, we realized that concrete experiences extend beyond the interaction with artifacts due to its rich history and influence on various sectors (including political, spiritual, cultural, social, and artistic aspects). Therefore, materials and artefacts can be perceived very differently by the individuals that interact with them depending on their personal experiences.

4.5.1. Concrete actors

Today, design's focus has shifted from the product of the project to its actors and their user experience (as previously described on pages 13-14) (Findeli & Bousbaci, 2005). This brings us to the concept of concrete **actors**: the various human entities experiencing the artifact in its context through their sensory modalities, whether it is done consciously or subconsciously (Morin, 2014). In our research, all concrete users or actants are included under the encompassing term "actors" (Findeli & Bousbaci, 2005; Latour 2011; Morin, 2014).

Concrete artifacts can evoke unique and varied significations to different actors. The complex nature of these associations (e.g., positive, or negative) is influenced by where, when, and how the interaction with the material or its artifact happens. Based on a phenomenological approach, theses perceptions are non-static and can thus gain new meanings and evolve as values and ideologies change (Graumann, 2002). In that sense, things that might have been disliked by some in the past can become cherished by them today.

Quality perceptions and judgments also depend on the type of actor interaction. These interactions can be either **passive** or **active** (Osgood et al., 1957):

On the one hand, is experienced in a passive manner without a direct interaction with the material. These passive interactions include for example riding a bicycle on the concrete pavement, going down a flight of concrete stairs at a of metro station, or walking into an industrial building or office with concrete walls, floors, beams, etc.

On the other hand, some interactions are much more intimate where users directly – and sometimes intentionally - experience the material through their sensory modalities. These include interactions such as pouring concrete into a mold, sitting on a concrete bench, leaning against a concrete wall, etc.

Our research has allowed us to distinguish different concrete actors which we have organized into three groups depending on their type of interaction or relationship with concrete. These include the **stakeholders** (including design professionals, decision-makers, building and construction professionals, and maintenance professionals working with or around concrete); the **observers** (including the researchers, scientists, and other professionals or amateurs passively studying or looking at concrete); and the **end users** (directly or indirectly interacting with concrete artifacts).

Firstly, we find the various stakeholders called to work with the material. For example, the **design professionals** including architects, designers, urban planners, and engineers, amongst other disciplines, which prescribing concrete in their projects. Although these actors actively work with/around concrete, their interaction is more of a passive one as they are not necessarily living and experiencing the artifact they have designed on a daily basis. The incentives to prescribe the use of concrete can vary from valorizing its unique aesthetic and sensorial qualities, to prioritizing its techno-economic practicality, and so on.

Then we can find the **decision-makers** signing-off on or investing in projects that use concrete. Their relationship with concrete can be considered as passive as they play a decision-making role. These actors include local authorities such as municipalities, government investors or representors, private clients, etc. In addition, the motivations behind their actions are mostly economy driven as they are more concerned with technical and practical aspects (e.g., budget, labor required, performance, frequency and cost of maintenance needed, etc.).

Then there are the **building and construction professionals** shaping concrete. These actors play a more hands-on active role when it comes to the mixing, manufacturing, casting, finishing, and assembling processes. They include the plant workers, builders, manufacturers, entrepreneurs, artists, and some extend to amateurs using concrete for personal purposes (e.g., recreational experiments, renovations, etc.). These types of actors tend to interact actively with the raw material as opposed to the final artifact created.

Furthermore, there are the **maintenance professionals** cleaning or preserving concrete artifacts. These actors actively interact with the material within the line of their responsibilities as they directly handle the concrete surfaces and elements in order to clean or preserve them. They include the city workers of all kinds (e.g., maintenance workers cleaning corporate buildings) and can extend to artifacts preservers such as conservators employed by heritage, historic, or cultural industries, or art centers and archives, etc.

We can need to consider passive group of users which we labeled as the **observers**. These actors include the individuals or entities having studied concrete, or those who have found meaning and inspiration in the material and its applications through time. For example, historians, scientists such as geologists or mechanical and chemical engineers, poets and writers, political and religious leaders, cinematographers, art critics, and more.

Finally, we can find the different **end users** who are directly interacting with the artifact - these types of actors are the focus of design disciplines. One way or another, we are all end users: beyond our professional vocations, we are all citizens of the world that we create. We are constantly, and at least subconsciously, interacting with concrete through the use of the streets, buildings, services, etc. that surround us. In that sense, the end users include the citizens in their daily commutes and urban activities, the visitors passing through, the tourists sightseeing, the homeless, the street performers, etc. The experiences we have can differ greatly due to multiple factors: first, we come from different age groups and generations (e.g. infants, children, adults, and seniors; or baby boomers, millennials, gen X, etc.). Then, we can identify with different genders (e.g., female, male, nonbinary, etc.). In addition, we come from different cultural backgrounds and ethnicities (e.g., values, traditions, manners, rules, beliefs, etc.). And lastly, we have a wide spectrum of physical and cognitive abilities and disabilities (e.g., use of wheelchair, sensory overload, etc.).

These considerations add layers of complexities are impossible to quantify but need to be considered when discussing the perceptions of concrete artifacts. As mentioned before, our study does not quantitatively measure perceptual qualities but rather observes variations and differences that have occurred over time, and thus based on a historical, documentary, and mediatic review.

4.5.2. Concrete's semantic qualities

We have chosen to highlight some of concrete's perceptual qualities which were extracted from a literature review overlooking manuscripts, books, journals, articles, conferences, websites, exhibits, comment sections, and blog entries, amongst other sources (pages 25-28). Our intention is to gather diverse opinions and appreciations which concrete has evoked in order to observe how they have changed.

We base ourselves on the assumption proposed by psychologist and behaviorist Charles E. Osgood and his colleagues, that **semantic space is bipolar** (Osgood & Suci, 1955; Osgood et al., 1957; Bentler, 1969). In that sense, when it comes to different user perceptions of quality, we firstly identify and define them (this is the author's choice based on frequency and impact in literature review), then we present them according to oppositional terms. Although generally the terms tend to be antonyms, our findings show that it is not always the case. We have used complimentary adjectives which are closely related to the main semantic quality (e.g., *sensuous* also includes adjectives such as *beautiful* and *pleasant* in its semantic boundaries, etc.). The full semantic mapping can be found in annexed Table 5 (pages 234-239).

The literature review showed that concrete was prone to carry sometimes contradicting meanings and associations as Forty explains it: "[...] to say that concrete has a tendency to 'double', to be two opposite things at once, is not a particularly original observation'" (Forty, 2013, P.11). Thus, concrete tends to fluctuate between different **semantic categories** - sometimes situated on opposite ends of the same semantic space - depending on the context.

> "From many of the usual category distinctions through which we can make sense of our lives - liquid/solid, smooth/rough, natural/artificial, ancient/modern, base/spirit - concrete manages to escape, slipping back and forth between categories." (Forty, 2013, P.10-11)

In addition, the research showed that while some qualities are intrinsic to the material's physical properties (e.g., its technical and mechanical *durability* as opposed to its *weakness*), others are more extrinsic as a result of its manufacturing and finishing process (e.g., its *beauty* as opposed to its *dullness* in terms of textures and finishes).

Therefore, in an effort to shed some light on concrete dichotomies, we have complied the collected semantic attributes, and then organized them according to 9 themes. This helped us review later on the changing ideologies and trends relating to the perception of quality of concrete artifacts in various contexts.

These semantic qualities include:

The perception of concrete's beauty

The research revealed that some have experienced *displeasure* and *unpleasantness* when it comes to concrete. For example, historian David Lowenthal said that "concrete becomes more *ugly* every passing year" calling it "*greasy*" and "*squalid*" (David Lowenthal cited in Forty, 2013, P.52). In addition, concrete has been described as "*harsh*" (Banham 1966, P.124), while others mention the "*distaste*" that some have experienced (Forty, 2013, P.41). However, other testimonies show a trend towards more positive views when it comes to its beauty. For example, concrete's *aesthetic pleasantness* can be observed when architect Ernest Ransome refers to its "*inherent beauty*" (Ransome cited in Collins, 2004, P.62), while architecture scholar Réjean Legault mentions the "*original beauty* of reinforced concrete" (Legault, 1997, cited in Forty, 2013, P.27). Concrete pioneer Auguste Perret even called it "much *more beautiful* and *more noble* than natural stone" (Perret, cited in Forty, 2013, P.82). In more recent examples, Forty goes on to describe its "*sensuous* and *tactile* properties" (Forty, 2013, P.281), while architect Mark West repeatedly referred to its "*wet, sensual,* and *responsive*" aspects (West, 2016, P.4). Furthermore, comments sections of design websites and blogs have revealed the public's appreciation of concrete. For example, comments on Marco Merendi and Diego Vencato's' *Petra* collection (page 109) include impressions such as "I'm *not* *a fan* of concrete but in this case looks *beautiful*" (@Sylvia Sanchez, Dezeen, 2019) or "concrete is the *best material*" (@Aigoula48, Dezeen, 2019). Other comments on Heatherwick's Zeitz MOCAA by designer (page 103) included "*seriously remarkable*" (by @Steve Leo, Dezeen, 2017). Finally, readers commenting on MoDus Architects' undulating concrete tunnel (page 103) displayed positive remarks such as "the only problem will be people wanting to stop for selfies with the tunnel entrances" (by @Bubba10, Dezeen, 2020) or "*extremely handsome*" (by @Felix Amiss, Dezeen, 2020), and so on.

The perception of concrete's luxury

Concrete is more often than not considered as *cheap*. The rare mentions of *prestige* were the ones of design professionals attempting to "*redeem*" or to "lift the medium out of its base associations" (Forty, 2013, P.169). It is usually seen as *non-luxurious* given that some felt that "the work of making concrete carries *little prestige*" (Forty, 2013, P. 225), and that it was "regarded as a *low-grade* substance" (Forty, 2013, P. 169), raising concerns of "*cheapness*" during its early developments (Winiger, 1957 cited in Forty, 2013, P. 185,). In fact, concrete was even considered to be "one of the *new technologies of poverty*" since third world countries found it to be an a*ccessible* and *affordable* building solution (Forty, 2013, P.40). However, this *cheapness* was also considered to be a "*virtue*" in the context of religious buildings as "[...] many cheaply built churches, it was said, would serve the purposes of religion better than a few magnificent ones" (Winiger, 1957 in Forty, 2013, P.185).

The perception of concrete's durability

In its early developments, the public opinion seems to perceive concrete as *fragile* due to exposure to harsh conditions as it was seen to *not resist* "humidity and frost in the long run as durable as we believed" (Pekka Pitkanen cited in Forty, 2013, P.53). However, the material is usually praised for its ability to "produce *durable* and *salubrious* structures" (Forty, 2013, P.225), lending itself to the "*resistance of forces*" (Forty, 2013, P.169). In fact, some even called it a "medium of *defense*" in reference to its *reliability* in terms of *protection* (Charles Reilly cited in Forty, 2013, P.178), while others emphasised its *ability to resist* fires and bombs (Simonnet, 2005 cited in Guillerme, 2007, P.3), amongst other forces.

The perception of concrete's warmth

Concrete is more often seen as *cold* and *depressing* as opposed to *warm* and *inviting*. In fact, due to its grey color, concrete can be seen as "*dreary*" as Forty puts it. Philosopher Gaston Bachelard even went on to describe it as a "*hostile* […] *cement cell"* (Bachelard, 1948, P.96), and it has been referred to as the "*material of oblivion*" when discussing its relationship with memory (Forty, 2013, P.198). In general, concrete seems to be more associated with *sadness* and *emotional distance*. However, more recent comments consider ageing concrete to be "a *natural* and *aesthetically pleasing* characteristic that influences its appearance in a *graceful* manner" (IVANKA, 2021). Pigmented concrete has opened up the door to new aesthetic appreciations as concrete is considered "*lush*" (@Darcy_lane_designs commenting on @formedconcretebasins's Instagram on October 20th, 2020), or "so *fresh*" (@tranquilbeautyuk commenting on @formedconcretebasins's Instagram on October 11th, 2020). In that sense, interior design websites and blogs mention that "despite its texture and colors which would make a space feel *cold* and *not exactly cozy*, concrete can be used in numerous ways and, in the right combination, a home can have concrete features and still be *warm* and *inviting*" (Ganea, Home Edit, 2013).

The perception of concrete's reliability

Although it is possible to calculate with precision the mechanical performances of reinforced concrete, it seems that the medium is nonetheless regarded as *unpredictable* and *difficult to control*. It is even seen as "*high maintenance*" by some (Srinivasa et al., 2012, P.392) and difficult to calculate ("*incalculable*") by others (Simonnet, 2005 in Guillerme, 2007, P.2). Some concrete manufacturers even add a disclaimer to protect themselves against this unpredictability such as "objects will *differ slightly* in terms of colour, texture and porosity. Concrete products *change slightly* over time, potentially becoming darker on contact with air and humidity" (AtelierB, 2021). However, what is considered here an aesthetic unpredictability is further discussed later (pages 140-142). Nevertheless, concrete is still considered to be "an *exact* material, which resulted in *precise* structures" (Forty, 2013, P.288).

The perception of concrete's naturalness

Opinions and conceptions on what should be considered *natural* or *artificial* (synthetic) are not clear cut, and our research showed that concrete tends to fluctuate between the two. On the one side, concrete is mostly composed of natural ingredients - most of which can be *found in nature* - and is mixed and given a shape through craftsmanship and human labor. Similarly to natural artifacts, concrete is *imperfect* "in its *failure to be perfect*" (Paul Andreu cited in Marrey & Hammoutène, 1999, P.209). It can be "*alive"* from a mechanical standpoint (West, 2016, P.5) as "when [it is] formed in a flexible mould, concrete begins life as a *wet and flexible* system, behaving precisely as a *natural, biological* structure might" (West, 2016, P.4). In that sense, concrete is seen to not "[...] fully conform to the expectations of synthetic materials in that it *lacks their perfectibilit*y" (Barthes, 1957, translated by Rosalind, Kraus and Hollier, 2005, P.51). On the other side, it is considered *synthetic* because it is *made by man* and is an "*non-natural*" material as an "*industrially derived product"* (Paul Andreu cited in Marrey & Hammoutène, 1999, P.209). Concrete is also seen to *"resist nature*" all while being "*plundered from nature*" at the same time (Forty, 2013, P.68). Some even go on to observe how concrete has "*displaced" nature* all while creating a new one called "*'urban nature*' - here, […] created through the agency of concrete" (Gandy, 2002, P.61).

The perception of concrete's plasticity

On the scale between rigid and amorphous, concrete is usually regarded as being *monolithic* and *rigid*. It has been described as "[...], *massif, inélastique*, [...]" by some (Simonnet, 2005 in Guillerme, 2007, P.2) since it is casted in traditional wooden formworks which are likely to be "*flat, straight* and built with 90-degree joints" (West, 2016, P.4). However, alternative manufacturing techniques (e.g., 3D printing, flexible formwork) have recently led to new quality perceptions in terms of its "*plasticity*" and "*flexibility*" (West, 2016, P.4). In that sense, new technologies are allowing cured concrete to express its *fluidity* with more *organic* forms as it has been described as "an *amorphous* material" (West, 2016, P.4) which is "able to *flow* and fill a mold, and upon hardening sustain a load" (Wangler et al., 2016, P.67).

The perception of concrete's practicality

Although previously regarded as "aesthetically *limiting*" (Forty, 2013, P.243), reinforced concrete has particularly proven to be "a totally new construction process which permits the realization of all kinds of forms, the solution of all constructional problems. It can appear under all kinds of costumes." (Edouard Arnaud cited in Hennebique, 1901, P.83). In recent years, it seems that concrete is generally regarded as a "*versatile"* material (Forty, 2013, P.296) in terms of the "economy, efficiency, durability, moldability and rigidity" of its applications with reinforcement (Ferguson et al.,1988 cited in Mahzuz et al., 2010, P.381)

The perception of concrete's omnipresence

Finally, although some have seen "*fair-faced* concrete as *'insignificant'* [and] 'hardly anything'" (Pekka Pitkanen cited in Helsinki, 2003, P.281), many more agree that concrete is *omnipresent* in today's world as "[...] attempts to make concrete behave as if it were a *colourless*, *recessive*, non-substance invariably turned out to have the opposite result" (Forty, 2013, P.286); The material is seen as "one of the most *meaning-attracting* substances there is […] Its very '*neutrality*' makes it an *Aladdin's cave of signification*" (Forty, 2013, P.286). Concrete is "[...] given a *presence*, one that is full knowing about, and engages with, ambivalence, towards modernization" (Barthes, 1957, translated by Rosalind, Kraus and Hollier, 2005, P.51). Today, concrete "is *everywhere*" (Jacques Tati, Playtime, 1967). If it was "meant to be *invisible*, it is *unmissable*" (Forty, 2013, P.281), and it "completely *dominates*" landscapes (Pekka Pitkanen in Forty, 2013, P.281).

4.6. Concrete and imperfections

Technological progress has offered an unprecedented degree of reproducible precision, allowing the mass production of seemingly 'perfect' artefacts. Beauty is thus expressed through "a sense of being flawless, while appearances have become more important than essence and substance" (Karana et al., 2013, P.147).

Western cultures' interest in the immaculate perfection of the material world is leading to a **dominating aesthetic model prioritising precision and purity while shunning imperfections**

(Karana et al., 2013). This standard is ultimately leading to premature **aesthetic obsolescence** (Walker, 2006; Burns, 2010). Some see this as being a result of the post World War II marketing policies encouraging rapid economic growth (Packard, 1960; Papanek, 1984; Zafarmand et al., 2003). We have thus become a materialistic society as we “commonly represent and communicate the fabric of our egos through objects” (Chapman, 2015, P.54).

> “The 20th century witnessed a steady societal migration away from deep communal values toward a fast-food culture of nomadic individualism and excessive materialism; today, empathy is consumed not so much from each other, but through fleeting embraces with objects.” (Chapman, 2015, P.26)

Furthermore, we seem to require that those objects remain in pristine condition for us to care about them enough to preserve them. Some scholars explain that the ”[…] aesthetic obsolescence of products fueled by ‘innovation’ for more ‘attractive’, ‘distinctive’ and ‘individual’ characters in the market (Norman 1988), is the result of a ‘market-led-design’ system […] rather than solely the products aesthetic particulars” (Zafarmand et al., 2003, P.176). Others support that aesthetic obsolescence can be seen as a side effect of our ego-centrical consumerism habits: the now worn-out artefacts that we have produced seem to fail to satisfy our need for exciting new experiences (Chapman, 2015, P.24).

In their quest for perfection, **consumers tend to discard objects displaying signs of wear and tear rather than fixing and preserving them**. These non-sustainable behaviors fill our landfills with perfectly functional yet slightly worn-out objects (Chapman, 2005). Concrete artifacts are particularly vulnerable to these premature disposal habits as landfills are overflowing with construction and demolition debris: concrete composes the single largest component in the world’s solid waste disposal problem (Meyer, 2005).

According to Chapman (2015), traditional concepts on product life cycles propose rendering objects more durable through resilient materials technologies and robust design engineering. With these modern technologies, we strive to create robust artefacts enabling us to construct a “synthetic futurescape” which is “immune to biological decay” (Chapman, 2015, P.54). This is seen as a system-focused approach to sustainability by some (Zafarmand et al., 2003). However, one could question what is the point of producing indestructible products if our landfills are overflowing with “durable goods” - which can be seen as a sign of the failed empathy towards these discarded yet still functional products (Chapman, 2015, P.54).

As one of the most commonly used materials, concrete is particularly concerned with these questions. Concrete monuments were created to last for centuries, yet most of them seem to exponentially lose the appreciation of the public with the passage of time. This type of material outlives our desire to withstand the harsh test of time, and this “illusion of control” thus generates “waste as one of its first predicaments” (Chapman, 2015, P.55).

However, emotionally durable approaches, as described earlier, transpose the ephemeral world of technocentric design. This is possible through focusing the research’s energies on a richer domain of emotionally durable experiences which can combat against prematurely discarded functional ‘waste’. Empathy and value can be added by considering metaphysical factors transcending physical ageing, thus avoiding material immunity. Therefore, EDD can influence the product's appreciation, and consequently its duration of life.

4.6.1. Embracing imperfection

In some cultures**, a new material aesthetic is slowly emerging which embraces imperfections and signs of graceful deterioration**. Ageing is considered an inevitable outcome for any material surface as it naturally loses its initial qualities (Karana et al., 2013). These traces of use are seen by some as a “record [of] their experiences”, allowing the actors “[...] to look back upon the captured records and reconfigure the recordings in order to replay what actually happened” (Karana et al., 2013, P.150). Manzini describes the cultural dimension acquired by ageing material surfaces as “an ability (or not) to stand the test of time by recording transitory signs with (or without) losing value to people” (Manzini, 1994, P.39). Here, ageing material surfaces are seen to gain appeal and value, contrary to many dominant Western views.

As a response to the redundant perfection of mass production, industrial design practices developed an interest in imperfection (Ramakers, 2002). In addition to aesthetic attributes promoting product sustainability (Zafarmand et al., 2003), qualities such as *personalisation, customisation, uniqueness, craftsmanship,* and *diversity* are being considered in contemporary design to better represent people's individuality and to promote emotional attachment (¡Viva la diferencia!, 2018). Some even go to the extent of intentionally reintroducing defects in products through manual labor and craftsmanship (Ramakers, 2002). Although these types of motives can be judged as deceptive practices, we can see the movement battling standardisation gaining in popularity.

Held in 2018 in Madrid, the *¡Viva la diferencia!* exhibition curated over 30 projects celebrating singularity and diversity in all forms of design. One of the first contenders of this movement was Italian designer Gaetano Pesce, celebrating the idea of '*malfatto*' - or badly made objects - since the 1970s (Connections By Finsa, 2019). Throughout his designs, Pesce recognized the expressive and symbolic potential of imperfections, and the uniqueness they bestowed on products (Karana et al., 2013). Other examples such as Hella Jongerius's *B-Set* dinnerware were described as "plates with a soul" (Scoouwenberg, 2011). In these products, imperfections were seen to bring a *unique* and *distinctive* character to each dish, adding to their appeal.

Other scholars have identified what can be called the 'naturally unplanned' (von Bonsdorff in Light & Smith, 2005). This notion includes elements of the natural environment that have an effect on the built one (Light & Smith, 2005). They also refer to "the way a building is "worn'' through contact with human bodies as part of the natural unplanned" (von Bonsdorff in Light & Smith, 2005, P.17). As the built environment is perceived here through the interaction of culture and nature, the naturally unplanned encapsulates the effect of time that inevitably appears on the world we build (Light & Smith, 2005).

Zen aesthetics

Although the interest in imperfection is slowly gaining in popularity in Western and European countries in the past few years, Eastern cultures have been advocating for it for centuries. In fact, Japanese culture's vision has always revolved around the acceptance of transience through the aesthetic principles associated with Zen.

Zen is a philosophical and ritualistic tradition of mindfulness originating with the transition of Buddhism from China to Japan in the 12th century (Lomas et al., 2017). Today, Zen principles are seen to have transcended rituals and artistic pursuits to constitute a more general 'way of being' (Hisamatsu, 1971). The encapsulated ideas and principles in Zen aesthetics are meant to be applied to improve well-being and quality of life (Lomas et al., 2017). Throughout time, Zen aesthetics became often referred to as 'Japanese aesthetics' due to the extent of their pervasive influence on Japanese culture (Keene, 1969).

Many scholars have studied the principles inherent to Zen aesthetics, however the most widely used are the ones identified by Japanese philosopher Shin'ichi Hisamatsu (Lomas et al., 2017; Purser, 2013; Hisamatsu, 2971). These include: **kanso** referring to 'beauty in elegant simplicity' (Purser, 2013, P.40); **fukinsei** which means asymmetry (Hisamatsu, 1971); **koko** translated as austere sublimity (Lomas et al., 2017); **shizen** translating to naturalness (Hisamatsu, 1971) or the avoidance of pretence or premeditation (Purser, 2013); **daisuzoku** or freedom from habits, routine, and the conventional (Lomas et al., 2017); **sei-jaku** which can be translated as stillness, purity and tranquillity (Hisamatsu, 1971; Lamos et al., 2017); and finally **yu¯gen**, the most challenging to translate, which can be understood as profound grace (Parkes et al., 2018) all while carrying mysterious depth and obscurity (Lamos et al., 2017; Suzuki, 1959/2019).

Although all these principles are of equal importance and serve as inspiration for design doctrines to this day, the most relevant to this research are fukinsei referring to irregularity and koko referring to beauty in ageing.

Fukinsei

Fukinsei is considered to be the epitome of Zen aesthetics as it reflects the natural world's inherent irregularity (Lamos et al., 2017). It is seen to transcend its faithfulness to nature by expressing the 'perfection of imperfection' (Purser, 2013). This irregularity is "inherently 'unstable', thus capturing the dynamic and continually changing nature of the organic world" (Lamos et al., 2017, P.8). These ideas remedy the impossible and harsh standards of perfection we have imposed on our body, our mind, and the resulting world we have created. In that sense, appreciating the irregular allows us to "embrace the good, and the good enough, and celebrate its beauty" (Lamos et al., 2017, P.9).

Koko

To further our understanding of the principle of austere sublimity, Koko finds beauty in elements that are aged or seasoned (Walker, 2011; Lamos et al., 2017). This principle is seen to include aspects of the worn-out, weathered, faded, or showing signs of decay due to ageing such as cracks, crackles, and scars (Hvass, 1999, translated by Walker, 2011).

Wabi-Sabi

According to Watts (1957), koko is also closely related to one of the three main "perceptual-emotional moods" evoked by Zen: Wabi Sabi. It is the quest for the unique and unconventional, the sense of beauty in transience and impermanence (Juniper, 1967/2003). In that sense, Wabi Sabi encourages a non-judgmental and appreciative approach that finds beauty and value in the seasoned imperfect objects. It is a compassionate and empathetic view on life, one that shifts the attention of the user from the new and shiny to the used and familiar (Knight & Ricciardelli, 2003; Lamos et al., 2017).

Kintsugi

The aesthetics of Koko and Wabi Sabi have transposed to processes such as the ancient Japanese ceramic repair technique known as Kintsugi: broken ceramics are reassembled together while highlighting the breakage instead of concealing it by mixing precious powdered metals in - usually gold (Keulemans, 2016). The defaults are thus emphasised and celebrated as a formative part of the artefact's life journey (Chittock, 2020). The craft art of kintsugi finds beauty and added value in the blemishes all while encouraging mending and repairing.

This ancient technique can be seen applied in many contemporary fields today: one example is Victor Solomon's repaired Kintsugi Court in Los Angeles (figure 98) (Hahn, Dezeen, 2020). Another example is the golden highlighted concrete cracks of architecture studio TANK's Xchange Apartment floor (figure 99) (Frearson, Dezeen, 2016).

Figure 98. – V. Solomon's Kintsugi Court – image by Shafik Kadi from Dezeen.com (2019)

Figure 99. – TANK's Xchange Apartment – image by Kenta Hasegawa from Dezeen.com (2016)

Patina

In engineering, ageing (or fatigue) is defined as progressive yet irreversible alterations resulting from usage and the passage of time (De Vreugd, 2011). However, the type and pace of ageing depends on the conditions and the nature of the material itself (Karana et al., 2013). However, whilst some materials tend to degrade with time, others are seen to mature through "maintaining or improving certain qualities" (Karana et al., 2013, P.150). Therefore, the social values affixed to material ageing are sometimes contradictory and "deeply genre dependent" (Chapman, 2015, P.131). For example, ageing metals such as copper and bronze display the "luster of a noble patina" which is added by the oxidized surface (Lowenthal cited by Saito, 2007). Patina has been used to describe the natural and sometimes intentional graceful ageing of high-quality materials (e.g., leather, wood, etc.) through the progressive formation of layers of tarnish causing pleasurable aesthetic changes on the material surface.

Patina can be thus seen to somewhat dictate the narrative linking both the semiotic and semantic aggregate of material experiences. It seems to affix more value to the ageing artifact, and to generate more attachment. Some scholars go on to suggest that "when a person is attached to an object, (s)he is more likely to handle the product with care, to repair it when it breaks down, and to postpone its replacement as long as possible" (Mugge et al., 2009 cited in Desmet & Hekkert, 2007, P.1). This explains why some worn-out artifacts are considered *antiques* (as opposed to *waste)* and are desired and pursued by collectors. Some even go on to artificially recreate fake signs of wear and tear (e.g., discoloration, scratches, fading, etc.) onto the surfaces of some products to give them a 'vintage' look which is seen to add to their value (e.g., aged denim).

Another interesting view on patina is brought forward by art and design professor Tom Fisher (2004) as he proposes that wear creates surfaces that are defined by use as opposed to design. The superficial patterns created by wear are thus idiosyncratic, depending on the user, their actions, and the environment, which are conditional factors that can be cultural, individual, or geographical (Fischer, 2004). These worn-out material surfaces tend to accumulate more dirt and particles, and by consequence become embedded in the texture of the artifact, drawing more attention to it and are likely to become of interest to the user (Fischer, 2004).

These patterns of wear can be of high significance to the user and can also be referred to as 'indexical signs of use' in the terminology of Peircean semiotics (Hawkes, 1977/2003). In that sense, the mapping and portrayal of ageing in artefacts and their materials can be seen as the 'signs of life' and 'clues of use' that show the embodiment of the subject within the object (Chapman, 2015). This indication of the artifact's secret life is seen to greatly influence the user experience, adding value through the discovery and appreciation of the superficial scars of use.

In order to better understand why a material like concrete is perceived the way it is, it was helpful to take a look at why other common materials are associated with different qualities. Materials experts Elvin Karana, Owain Pedgley, and Valentina Rognoli (2013) propose these different perceptions based on the intrinsic and extrinsic sensorial, aesthetic, cultural, and mechanical properties of some mediums. They briefly present the example of associated perceptual qualities based on a material's dominant property as such:

> "Wood is literally *warm* to the touch and therefore perceived as *inviting* and *cozy*, whereas stone or steel are generally *cold* to the touch and thus tend to be perceived as more *distant*. These latter materials are, on the other hand, relatively *heavy* and would for that reason also be regarded as *high quality*. Similarly, light materials have a tendency to be considered *cheap*. Next, when a material is *rough*, people will perceive it as more *natural* than when it is *smooth*, and *transparent* materials are most likely, or should we say naturally, seen as *fragile*. Finally, *soft* materials are mostly regarded as being *alive* where *hard* materials are considered *dead*." (Karana et al., 2013, P.9)

For example, one can therefore assume that *rigid* and *heavy* materials are often seen as *distant* and *dead* but can also convey *quality* and *durabilit*y, while *soft* and *warm* materials are generally associated with being *alive*, *natural,* and *inviting*, and so on.

In addition, the notion of maturity in terms of ageing is interesting as it usually refers to natural materials such as wood, paper, stone, or leather. On the one hand, these materials are seen to acquire sensorial characteristics with time that allows them to have "an aura of antiquity and preciousness" (Karana et al., 2013, P.151). Others link this to the fact that some of those materials were once considered "alive" and are therefore "in possession of an innate ability to deal with time" (van Hinte, 1997, P.152). Artefacts made from those materials are thus seen to age 'well' by gaining more value through transience (Karana et al., 2013).

This explains how, in some cases, the accumulation of patina embeds objects with a *distinctiveness* that elevates them beyond the "bland anonymity of a mass-produced world" (Chapman, 2015, P.132). Signs of wear and tear add history and value to the product, making it more *appealing* and more *desirable*, whilst other materials such as ceramics are seen to be simply "*inert* to the passage of time" (Saito, 2007, P.153). However, more often than not, the accumulation of patina tends to devalue artifacts, which seems to be the case when it comes to concrete. Another obvious example is plastic which is notoriously seen to age badly compared to other materials. We will further look into why ageing concrete is judged harshly in our discussion chapter (pages 157-158).

4.7. Field observations

In order to validate the findings, we conducted empirical observations of concrete artifacts in the urban context. These were organized and grouped following three emerging themes: firstly, shedding a light on concrete's general **omnipresence** in the urban world, as well as its **relationship with nature**; secondly, highlighting the material's **natural tendency to display signs of ageing** (e.g., stains, cracks, crumbles, etc.); and lastly, showcasing concrete artifacts' relationship with different types of uses and **misuses** (e.g., acts of vandalism, etc.).

In addition, we have selected two projects featuring concrete modules at two different scales. They have been chosen based on their relevance to the latter themes of our observations. Both artifacts, although of architectural and infrastructural scales, are composed of smaller concrete 'modules' which have been multiplied and assembled. This modular approach is of more relevance to industrial design which is generally concerned in prefabricated products and services at a human scale.

Therefore, as an example of concrete's premature ageing, we present Metabolist architect Kisho Kurokawa's Nakagin Capsule Hotel in Tokyo, Japan. Additionally, in order to look into concrete's uses and misuses, we use Atlantic Industries Limited's (AIL) precast retaining panel walls used in the construction of the Turcot interchange in Montreal, Canada.

4.7.1. Concrete's omnipresence

First and foremost, one of the most notable revelations that came from our empirical observations was that concrete was *omnipresent* and *used ubiquitously* in urban, interior, and product design, as well as the arts and other sectors.

Concrete elements could be easily spotted within the landscape in the vast majority of the situations and contexts. We found concrete elements in larger infrastructures such as retaining walls, bridges, and foundations (figures 100-102).

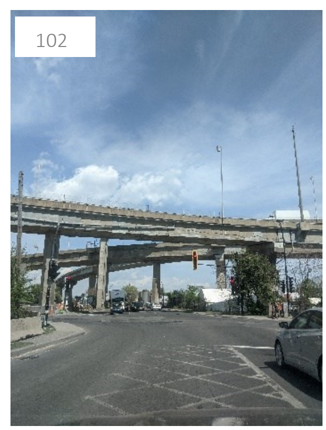


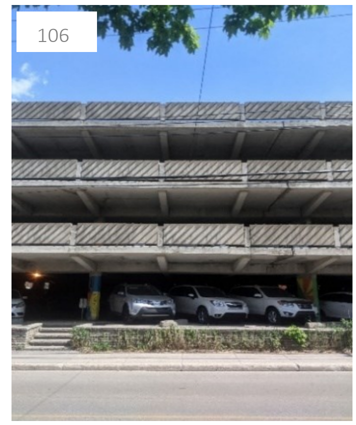
Figure 100. – bridge & overpass, image by T. Harb, Montreal, CA (2019)

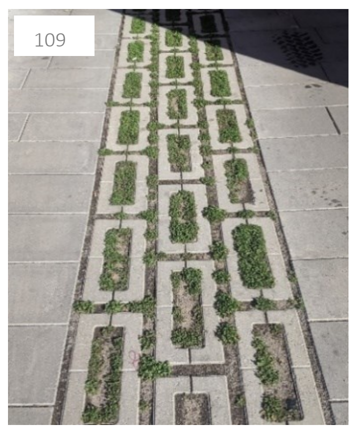
Figure 101. – water management structure, image by T. Harb, Charlottown, N.C. (2019)

Figure 102. – overpass & sidewalk, image by T. Harb, Montreal (2021)

At a medium scale, the material was found in multipliable elements including smaller precast concrete modules that were multiplied to create larger installations such as water banks, separation walls, façade panels, and more (figures 103-106).

Whereas at a smaller scale, concrete lent itself to a wide variety of urban products such as furnishes (e.g., benches, planters, etc.) or more technical artifacts (e.g., bases for various products, pavements, permeable slabs, or tiles, etc.) (figures 107-110).





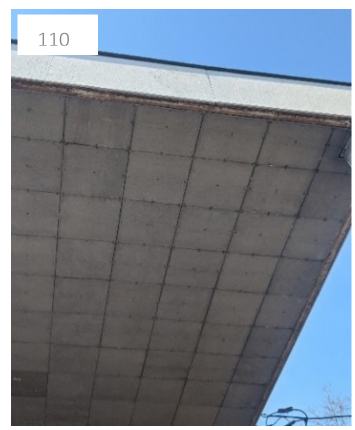


Figure 103. – concrete bridge flooring, image by T. Harb, Montreal, CA (2020)

Figure 104. – concrete jerseys, image by T. Harb, Montreal, CA (2021)

Figure 105. – concrete building, image by T. Harb, Singapore (2017)

Figure 106. – concrete parking, image by T. Harb, Montreal, CA (2021)

Figure 107. – concrete modules, image by T. Harb, Montreal, CA (2020)

Figure 108. – concrete bench, image by T. Harb, Montreal, CA (2021)

Figure 109. – concrete pavement, image by T. Harb, Quebec City, CA (2021)

Figure 110. – concrete panels, image by T. Harb, Beirut, Lebanon (2019)

Another general observation was made: no matter how ubiquitous concrete is, the material usually succumbs to nature's manifestations (figures 111-114). These include the inevitable exposure to nature's elements including natural sunlight and Ultra-Violet (UV) lights, precipitation in the forms of rain, hail, or snow, wind, fauna and flora, etc. Concrete surfaces also bore signs of exposure to pollutants (e.g., smog, carburant gas, etc.) causing fading in color or to staining, particularly if the concrete mix was a lighter color.

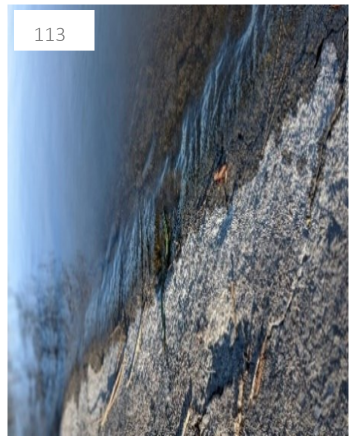


Figure 111. – vines on concrete wall, image by T. Harb, Beirut, Lebanon (2019)

Figure 112. – planter section , image by T. Harb, Montreal, CA (2019)

Figure 113. – concrete slab in water, image by T. Harb, Montreal, CA (2020)

Figure 114. – concrete jersey under snow, image by T. Harb, Montreal, CA (2020)

Whether the nature-concrete relationship is synergic or dualistic depends on the context, the design approach, and the stakeholders' intentions. In some instances, the natural manifestations are tamed and controlled by mankind through constraints and delimitations (e.g., allocated space for green manifestations), or through continuous maintenance work (e.g., cutting and containing plants from growing beyond their allocated space) (figures 109 & 112).

Whilst in other instances, nature seemed to be left to roam more freely, whether intentionally (e.g., finding pleasure and value in letting nature dominate the artifact), or through neglect (e.g., lack of resources for maintenance efforts) (figures 115-119).

Figure 115. – water on concrete, image by T. Harb, Montreal, CA (2021)

Figure 116. – vines climbing on concrete structure, image by T. Harb, Montreal, CA (2021)

Figure 117. – grass between concrete tiles, image by T. Harb, Beirut, Lebanon (2019)

Figure 118. – moss between tiles, image by T. Harb, Tokyo, Japan (2019)

Figure 119. – moss and fungi on concrete walls, image by T. Harb, Kawasaki, Japan (2019)

And yet, in other situations, it seems that the design intentions of the artifact planned ahead for nature's elements. The artifact's design seems to anticipate natural manifestation's need to be unchained and thus by allowing it space to grow freely without disrupting functionalities (figures 120-123).

In most of these cases, nature enhances the aesthetic experience of the artifact, making it more *beautiful* and *pleasurable*.

Figure 120. – grass growing between blocks, image by T. Harb, Tokyo, Japan (2019)

Figure 121. – Park Royal Hotel, image by T. Harb, Singapore (2017)

Figure 122. – rainwater canals integrated into pavement, image by T. Harb, Tokyo, Japan (2019)

Figure 123. – slot in concrete for grass, image by T. Harb, Tokyo, Japan (2019)

4.7.2. Concrete's surface imperfections

As was mentioned previously, concrete surfaces are known to display superficial signs of wear and tear uncontrollably and randomly. These signs were particularly easy to find throughout our field observations and consisted of cracks, stains, and surface imperfections in the form of air bubbles and irregularities, to name only a few (figures 124-134).

Examples of cracked and stained concrete surfaces were particularly observed in older infrastructures (e.g., bridges and tunnels) (figures 126 & 133). They include natural cracking or staining due to curing, ageing, or other external (but predictable) factors.

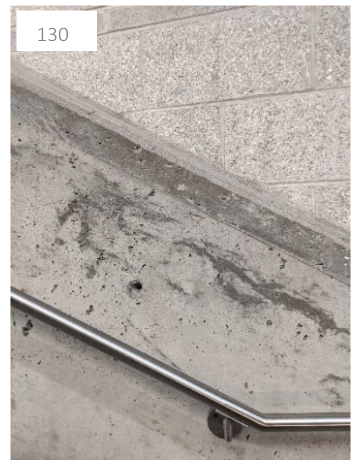
Some superficial cracks seemed to be the result of cheaper mixes, inadequate manufacturing techniques, or poorly executed repairs and maintenance works (figures 125 & 126). These patchworks seemed to be either done hastily with inappropriate techniques or due to neglect.

However, we also found other more structural cracks which tend to be more dangerous from a technical and safety aspect as they compromise the structural integrity of the concrete artifact (figure 132). These types of crack seemed much deeper, going through the whole volume as opposed to lying on the superficial top.

Some superficial stains observed were due to the unfortunate placement of other elements within the design such as metallic plug-ins, details, or features (figures 124, 128, 129 & 134). In addition to add-ons, recesses and crevices seem to lead to a similar effect. These types of interruptions within the concrete surface tend to leave drainage stains due to exposure to rain or freeze-thaw, amongst other reasons.

Additionally, some rust stains were commonly found on concrete surfaces (figure 124). These usually result from the exposure of sections of the steel reinforcement within which oxidises.

Lastly, multiple concrete artifacts showed signs of accelerated weathering such as crumbling and flaking (figures 126 & 133). These signs were most apparent on products with sharper edges (e.g., stairs). In addition, they were particularly found in instances where the artifact has been neglected (e.g., little to no maintenance, difficulty of access, etc.), poorly maintained (e.g., use of inappropriate mediums to clean), or exposed to particularly harsh conditions (e.g., freeze-thaw, snow removal operations involving heavy machinery and road salt, etc.).



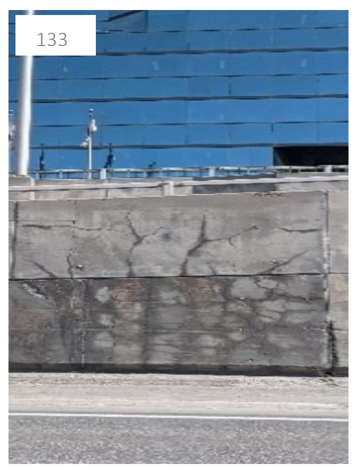


Figure 124. – metal stain & air bubbles, image by T. Harb, Montreal. CA (2020)

Figure 125. – surface imperfections & irregularities, image by T. Harb, Montreal, CA (2019)

Figure 126. – surface deterioration exposure/poor maintenance, image by T. Harb, Montreal, CA (2020)

Figure 127. – air bubbles, image by T. Harb, Beirut, Lebanon (2019)

Figure 128. – efflorescence, image by T. Harb, Montreal, CA (2021)

Figure 129. – stains from creases & cavities, image by T. Harb, Tokyo, Japan (2019)

Figure 130. – surface imperfections & stains, image by T. Harb, Kyoto, Japan (2019)

The case of Kisho Kurokawa's Nakagin Capsule Hotel in Tokyo

Kisho Kurokawa's Nakagin Capsule Hotel built in Tokyo-Japan is a revolutionary example of a controversial building construction. In order to further investigate the perception of ageing concrete, we have looked into the case from sociocultural and techno-economical aspects, systematically comparing when it was initially built in 1972, versus today.

Socio cultural context

Kurokawa was one of the protagonists of the Metabolism movement in architecture which focused on the dynamic adaptability, growth, and evolution of buildings and their designs (Kurokawa, 1977). Between the 1950s and the 1970s, the movement's ideas dominated architectural discourses in Japan by exploring methods to reconstruct the ravaged cities post World War II (Smithson, ArchPaper, 2019). The Nakagin Capsule Hotel was then built on the southern fringe of Ginza area of Tokyo in 1972 with the intent to emulate a living organism (Kurokawa, 1977).

Today, Ginza is known as one of Tokyo's priciest neighbourhoods, home, attracting businessmen and shoppers from all around the world (Ouroussoff, The New York Times, 2009). Since its construction in the early 70s, the city's neighborhoods have changed greatly, and the Capsule Hotel seemed to be failing to fulfil its initial intentions.

Techno-economical context

Kurokawa's innovative construction called for 140 prefabricated concrete capsules that were stacked and installed onto two interconnected central concrete cores with surprisingly only 4 high-tension bolts. The units expanding from the basement to the second floor were made with a traditional reinforced concrete mix whilst the upper levels used lightweight concrete. The assembly time on each capsule took merely 3 hours, and the main intention was for them to be removable and replaceable as needed. The towers were thus assembled in a whopping 30 days (ArchEyes, 2016).

The building earned much praise and admiration for its design ingenuity. The seemingly perfect white concrete blocks with their iconic circular windows offered a striking contrast with the towers' surroundings and contributed to its unusual beauty (figures 135-136). Kurokawa's intentions in regard to the temporality of the building was rooted in Japanese history: artefacts and landscapes built with 'natural' materials were seen to have an attractive ephemerality to them with their unpredictable lifespan (ArchDaily, Sueiven, 2011). In that sense, the Nakagin Capsule Tower promised great potential by building "vertical megastructures to which prefabricated, replaceable units would be attached, keeping Tokyo compact and making it possible to renew buildings without tearing them down." (Nakamoto, Nikkei Asia, 2020).

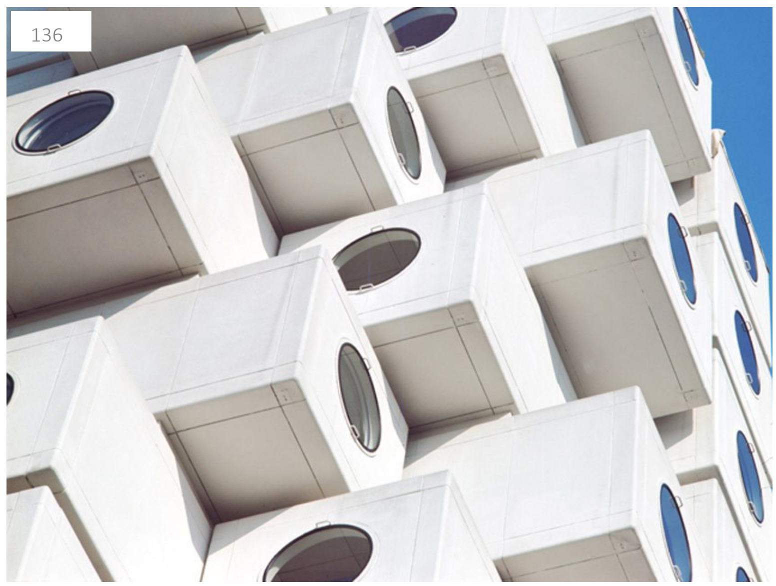


Figure 135. – Kurokawa's Capsule Hotel in 1972 – image by Noritaka Minami from ArchEyes.com (2016)

Figure 136. – Kurokawa's Capsule Hotel in 1972 – image by Noritaka Minami from ArchEyes.com (2016)

However, Kurokawa's intentions did not withstand the harsh test of time. After only 50 years, the building as well as the exterior of the tower were neglected and never maintained. This naturally led to multiple complications, including leaking and weathering problems. These manifested in the daunting appearance of the concrete façades - an inconspicuous sign that the building has fallen into despair (ArchDaily, Sueiven, 2011). Although the capsules were built to be replaced, not a single one had been removed. And while certain residents and architecture preservers tried to repurpose or restore some units, most of their efforts fell short as they were met with resistance from the investors and other stakeholders:

> "[…] postwar architecture is still treated with a measure of suspicion by the cultural mainstream, which often associates it with brutal city housing developments or clinical office blocks. Partly, too, it has to do with the nature of housing blocks in general. They are not sexy investments; they do not feed an investor's vanity or offer the cultural prestige that owning a landmark house does." (Ouroussoff, The New York Times, 2009)

As seen in figure 137 photographed in 2017, the unflattering ageing of the concrete surfaces is poignant from afar (Ronene Bekerman, Bertrand, 2015).

Figure 137. – Kurokawa's Capsule Hotel in April 2017 – image by PhotoMavenStock from Shutterstock,com (2021)

What was once considered a revolution in Metabolist architecture is now an example of a failed relationship between the design intentions and the sociopolitical realities of the urban world. As the first decade of the century passed, the costs of maintenance were becoming too great of a burden for the investors and stakeholders (Smithson, The Architect's Newspaper, 2019). The tower was facing multiple calls for demolition supported by some of the owners and managers.

Activists and organizers interested in its architectural heritage have been fighting to preserve the tower, arguing that it is one of the rarest examples of Metabolist architecture (The Architect's Newspaper, Smithson, 2019). The building was described as "gorgeous architecture; like all great buildings, it is the crystallization of a far-reaching cultural ideal. Its existence also stands as a powerful reminder of paths not taken, of the possibility of worlds shaped by different sets of values." (Ouroussoff, The New York Times, 2009). Today, as the building is pending demolition, 50 out of the 140 capsules have been removed and documented by the Nakagin capsule tower building preservation/regeneration project, while one of the capsules is being displayed at the museum of modern art in Saitama (Barandy, DesignBoom, 2021).

Unfortunately, the case of Kurokawa's Nakagin Capsule Tower shows that the visions of the architect, designer, or city planner are rarely mirrored by all the actors involved (e.g., the citizens and other stakeholders). Additionally, the material and its artifact's behavior through time has transcended the initial design intentions (with cultural, social, economical, and environmental developments in mind). This proves to show that although the material is the outer 'skin' of the artifacts and does not always represent its overall condition, function, and value, they are perceived as intrinsically linked: their quality perceptions and associations are extremely hard to distinguish and separate.

4.7.3. Concrete & vandalism

In addition to natural (as well as premature) signs of ageing, other aspects influence concrete's aesthetic appearance such as the different uses (and misuses) artifacts are subjected to by their actors. These include different physical misuses as well as intentional destruction of property. We observed that multiple concrete surfaces were subject to acts of art expression or vandalism, primarily under the form of graffiti or tags.

According to Roos (1992), vandalism is based on two fundamental viewpoints giving it a rational basis: the first assumes that it is situational whilst the second believes that it is motivational. Situational vandalism considers "that opportunities and possibilities in the built environment are the essential factor explaining variations in the prevalence of vandalism"; while motivational vandalism "grows out of a strong inner motivation and of a need by the perpetrators" (Roos, 1992, P.73). The first view blames the design of the artifacts (which affords being disrupted or destroyed), while the second blames the psychology of the perpetrator (who has a need or desire to disrupt or destroy).

> “[...] the original meaning of vandalism was to plunder and lay waste symbols and environments of a civilization. Today, the concept is primarily associated with damage and graffiti in the urban environments of industrial societies” (Roos, 1992, P.75)

There are a wide variety of motives that can lead to acts of vandalism such as the need to achieve ceremonial or ritualistic change, or in response to the defamation of a specific culture’s values, to name only a few (Goffman, 1967). In that sense, certain elements of the built environment can hold different symbolic meanings and values for the residents, the visitors, the homeless, and the city developers. Acts of vandalisms can be used to “mark and reshape that environment [...]” (Roos, 1992, P.75). However, today’s understanding of vandalism sees it as a “temporary act performed sporadically under certain circumstances. It does not involve continuous activity that could give rise to a certain type of identity. The vandalism act is responsive and, therefore, changeable and temporary” (Roos, 1992, P.78).

Others consider graffiti as a form of artistic expression which generally aims to transgress an existing sociopolitical order (Hojer in Tygstrup & Ekman, 2008). Whether composed of graphic tags, drawings, words, proverbs, truisms, jokes, or obscenities, graffiti is “very self-aware of its transience” as it assumes that it will be erased or replaced (Hojer in Tygstrup & Ekman, 2008).

Different cultures and societies entertain varied views on graffiti: what was once restricted and illegal in some contexts is now tolerated or even celebrated in others. Today, cities around the world have embraced graffiti as an artform allowing cultural expression. Places such as New York, Melbourne, Bogota, Los Angeles, Paris, São Paulo, Buenos Aires, Berlin, Bristol, London, Stockholm, and Montreal to name a few, have not only legalized graffiti in some sectors, but have also created art exhibits and festivals showcasing this urban artform.

For example, England-based graffiti artist Banksy has been showcasing through his stencil street art various political and social themes since the late 1990s: amongst his numerous installations, we can find his ‘Young Girl Covers Swastika’ mural placed next to a former refugee centre in Paris, which was shut down earlier by the French government (figure 138) (FRANCE 24, 2018; @banksy, Instagram, 2018). Another example is his ironic ‘Graffiti Is A Crime’ mural left in New York in 2013 (Widewalls, 2021; @banksy, Instagram, 2013), as well as his 2019 mural featuring a migrant child wearing a lifejacket in Venice as a clear political statement following the war in Syria (figure 139) (@banksy, Instagram, 2019).

Figure 138. – Banksy’s Migrant Soup Kitchen at Porte de la Chapelle – image by @banksy from Instagram.com (2018)

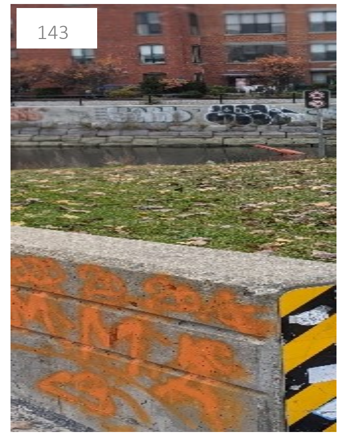
Figure 139. – Banksy’s Migrant Child in Lifejacket at Venice – image by @banksy from Instagram.com (2019)

In addition, Montreal has been home to several recurring graffiti festivals (MURAL and Under Pressure festivals) celebrating what is referred to as ‘urban’ or ‘street’ art (MTLblog, 2021).

Despite the city’s supportive attitude towards graffiti art with designated surfaces for artists to create murals, we still find graffiti in the form of tags and even obscenities in some instances. And although there is not enough evidence supporting that concrete surfaces in particular fall victim to these types of acts of vandalism, our observations allowed us to document multiple incidents of vandalised concrete artifacts (figures 140-147).

Although most of the surfaces observed could be considered ‘old’, ‘unmaintained’, or ‘damaged’ prior to the layer of vandalism, some even included ‘new’ and ‘well-kept’ surfaces were still subjected to tagging and vandalism. These mirrored the previously mentioned observation made by Roos (1992).

In some situations, we even managed to document city workers painting over the graffiti - with a shade of grey that doesn’t even match the aged concrete’s shade. Some seem to have considered the clean up act as an enticement to vandalise again: the uniform paint proved to be the ideal primer preparing the canvas for their tags (figures 145-147).



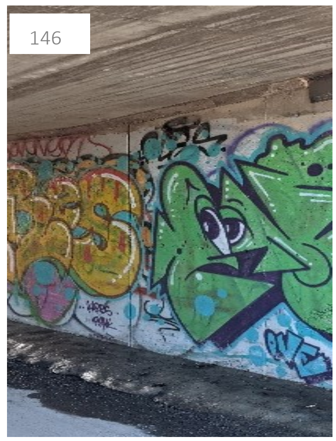


Figure 140. – graffitied old concrete, image by T. Harb, Montreal, CA (2020)

Figure 141. – graffitied old concrete, image by T. Harb, Montreal, CA (2020)

Figure 142. – graffitied old concrete, image by T. Harb, Montreal, CA (2020)

Figure 143. – graffitied recent concrete, image by T. Harb, Montreal, CA (2020)

Figure 144. – graffitied old concrete, image by T. Harb, Montreal, CA (2020)

Figure 145. – primer over graffitied concrete, image by T. Harb, Montreal, CA (2020)

Figure 146. – new graffiti over grey primer, image by T. Harb, Montreal, CA (2020)

Figure 147. – close up of new graffiti over grey primer, image by T. Harb, Montreal, CA (2020)

The case of AIL's Retaining Wall System for the Montreal Turcot Interchange

The concrete panel walls observed within the Turcot interchange project in Montreal, Canada are part of urban furniture or infrastructures, and thus falls under the responsibility of city officials. As opposed to our previous example, which was privately owned as part of the public space, these artifacts don't necessarily trigger personal attachment as they are shared by many actors and are generally less respected or preserved by their users. Their upkeep is also subjected to governmental budgetary constraints in terms of cost of maintenance.

Socio-cultural context

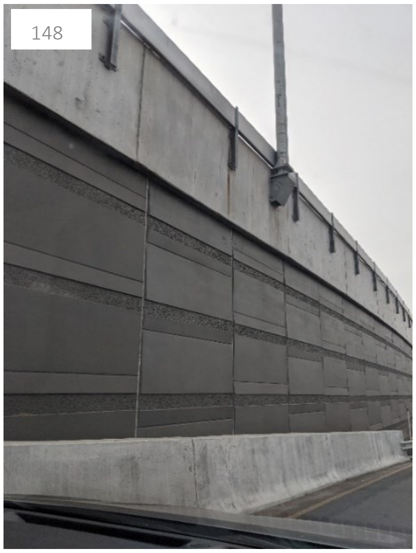
Montreal has a long-standing history with construction work: citizens have always complained about crumbling road infrastructures while enduring the resulting ill-organized, poorly executed, and never-ending construction work. The ongoing road work situation has been causing Montreal citizens and visitors frustrations and deceptions for many years. Recently, the Turcot (300,000 vehicles daily), the Champlain (160,000 vehicles), and many others of Montreal's roads, water infrastructures, and sewer networks have been under renovation and construction in an effort to optimize them (Ville.Montreal.qc.ca, 2021).

Techno economical context

In 2015, the Ministry of Transport of Quebec (MTQ) mandated the reconstruction of the Turcot interchange as part of the multi-year, multi-billion-dollars project. It consisted in progressively building a highly complex three-level-stack interchange that links major highways and bridges in the Montreal area (AIL, 2019).

The goal was to replace the old concrete infrastructures (including walls, overpasses, poles, beams, roads, etc.) which had poorly deteriorated, as well as optimize and expand the existing interchange. This is the largest construction project to take place in Quebec and was estimated to require millions of cubic meters of concrete (Kennedy, On-SiteMag, 2020). The project was led by the design-build consortium of KPH-Turcot, a partnership between multiple organizations and enterprises specializing in infrastructure design, manufacturing, and construction (AIL, 2019).

As part of the project, the retaining walls are composed of 8 types of precast concrete panels featuring different horizontal patterns. The assembled retaining walls were featured in multiple sections of the large project (figures 148-150). The large panels (3x1.5 meters) were covered with a specialized anti-graffiti coating post-installation (AIL, 2019) and featured a dark-grey concrete mix. While all wall panels had lateral sections separating their length at seemingly random intervals, some featured a smooth finish (figures 150, 153 & 156), while others featured a combination with a more roughly textured one (figures 148 & 149).



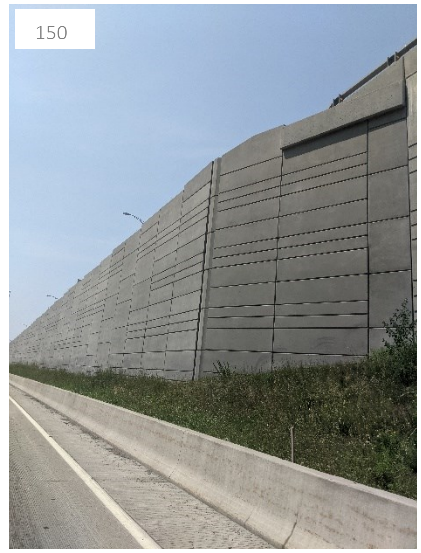
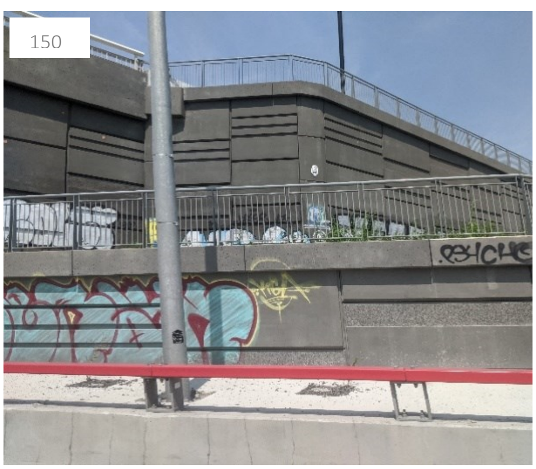


Figure 148. – Turcot interchange, wall panels post-installation in pristine condition, image by T. Harb, Montreal, CA (2020)

Figure 149. – Turcot interchange ,close up wall panels post-installation in pristine condition, image by T. Harb, Montreal, CA (2020)

Figure 150. – Turcot interchange, wall panels post-installation in pristine condition, image by T. Harb, Montreal, CA (2020)

Once assembled, the concrete panel walls remained in pristine condition only for a few days. Shortly after their installation, graffiti tags progressively appeared. Eventually, almost all of the retaining walls were plastered with tags (figures 151-153).



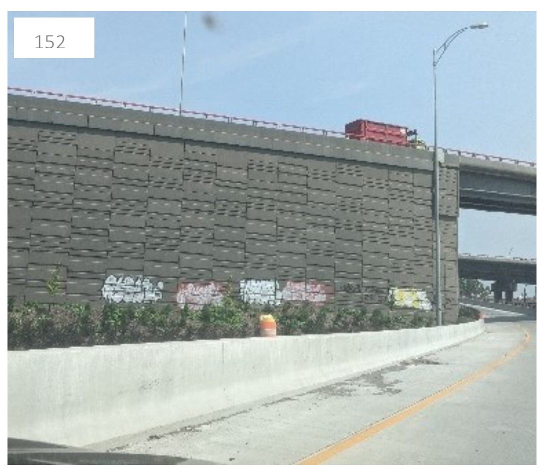


Figure 151. – Turcot interchange, graffiti tags on wall panels, image by T. Harb, Montreal, CA (2021)

Figure 152. – Turcot interchange, graffiti tags on wall panels, image by T. Harb, Montreal, CA (2021)

Some seem to have gotten removed and cleaned, leaving distinct darker traces on the surface (figures 153-156). In other instances, new graffiti tags could be observed on top of the cleaned surfaces (figure 150 & 154).

Figure 153. – Turcot interchange, traces of graffiti clean up, image by T. Harb, Montreal, CA (2021)

Figure 154. – Turcot interchange, traces of graffiti clean up with new tags on top, image by T. Harb, Montreal, CA (2021)

Figure 155. – Turcot interchange, traces of graffiti clean up, image by T. Harb, Montreal, CA (2021)

Figure 156. – Turcot interchange, traces of graffiti clean up, image by T. Harb, Montreal, CA (2021)

4.7.4. Trends observed

The research has revealed that concrete is omnipresent in the urban context and is featured in artifacts of various scales and complexities, from infrastructure buildings to furniture. These artifacts co-exist with natural manifestations (e.g., flora, precipitations, etc.), which can contribute further to their premature degradation due to exposure.

In addition, concrete always displays signs of imperfections that can be either the result of the manufacturing and curing process (e.g., bubbles, stains, superficial cracks), or premature deterioration (e.g., neglect, poor maintenance, prolonged exposure, etc.), depending on the environment and circumstances.

Concrete artifacts - similarly to other urban materials and surfaces - bare the traces of their various uses: while some are harmless and cause subtle and normal wear (e.g., sitting on a concrete bench), others can accelerate its deterioration and fatigue (e.g., vandalism). Little efforts are made to prolong the life of these artifacts through maintenance and repair. In fact, some of the repair techniques only invite more misuses (e.g., painting over a graffiti tag with a grey primer invites more graffiti), while other mending methods unintentionally draw the attention to the default (figures 157-159).

Figure 157. – repairs on concrete crumbling, image by T. Harb, Montreal, CA (2021)

Figure 158. – repairs on concrete cracks, image by T. Harb, Montreal, CA (2020)

Figure 159. – grey primer paint over graffiti tag, image by T. Harb, Montreal, CA (2020)

In addition, different types of urban artifacts featuring other materials (e.g., steel, asphalt, bricks, glass, etc.) are frequently subjected to misuses and vandalisms (160-162).

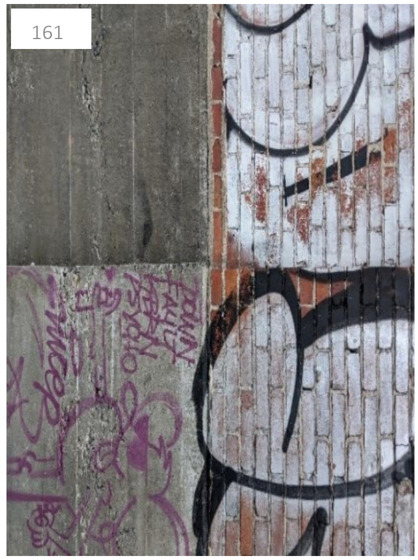


Figure 160. – (left) graffiti tags on steel plates & posts, image by T. Harb, Montreal, CA (2020)

Figure 161. – (middle) graffiti tags on bricks, image by T. Harb, Montreal, CA (2020)

Figure 162. – Graffiti tag on glass & vandalised glass, image by T. Harb, Montreal, CA (2021)

Our observations showed that flat surfaces which are slightly out of sight (e.g., underpasses, alleyways, tunnels, etc.) were usually the ideal target for acts of vandalism. Even less-accessible artifacts also bore signs of vandalism, thus adding to the act of defiance by proving that nothing is out of reach.

In that sense, all urban artifacts and surfaces can be the target of misuses given the right circumstances, whether they are made of concrete or other urban materials, old or new, accessible or inaccessible, etc. These observations raise questions about the perceptions of value and the motives behind them and made us wonder how design can help defer these types of behaviors.

The following chapter of our research is meant to discuss these results, as well as proposing some design considerations which can help elevated the experience of concrete artifacts.

Chapter 5 – Discussion

After presenting the current state of the art to answer our first & second research questions (*How have concrete technologies and applications evolved?* and *What are the perceptual qualities of concrete artifacts?*), this chapter will discuss some critical aspects in an attempt to provide insight into our third research question (*What influences those perceptual qualities - particularly when it comes to its ageing?*). The key findings revealed through the research and discussed in this section include:

1. Concrete can be perceived in contradicting ways (e.g., *rigid* yet *fluid*) as perception is subjective and context sensitive. Different factors can influence it including marking socio-political events (e.g., World War II). Concrete can hold multiple meanings and connotations depending on *when* and *where* it is being appraised, and *who* is doing the appraisal. Examples of those meanings, the aesthetic pleasure they generate, as well as the emotions they evoke will be discussed using Desmet and Hekkert's PAME framework (2007) (section 5.1. page 156).

2. Concrete's quality perceptions are influenced by its technical performance on one side, and its aesthetic and ecological properties on the other. Although the material offers multiple advantages, the research shows that it prematurely deteriorates. In addition, its ecological footprint across its lifecycle is cause for concern. Its aesthetic perception as well as ecological impact will be discussed based on the documentary review (section 5.2. page 164).

3. Design disciplines play a significant role in the conception of the future urban world considering the changing lifestyles and emerging needs brought by population growth and densification. Design has therefore the ability and the responsibility to better compose with urban materials' ageing process in mind. We will discuss the added value in designers' material knowledge and how it can help improve product attachment and encourage more sustainable consumption habits (section 5.3. page 167).

4. The increased use of concrete seems to be inevitable in the near future. Yet, new technologies have been emerging, leading to novel technologies and more sustainable practices. Some are even seen to aid design professionals to better compose with ageing materials (e.g., the need to create more sustainable artifacts). From a feminist ethics perspective, being aware of the field of possibilities brought by sustainable and innovative design is of great value for design practitioners conceiving for the world of tomorrow. We will thus highlight design aspects and considerations which can add value to artifacts, rendering them more appreciated by their users (section 5.4. page 169).

5.1. The experience of concrete

In this section, we will give examples of concrete artifacts experiences by applying the PAME framework proposed by Desmet & Hekkert (2007). The purpose of using the framework as an analytical tool is to "[...] distinguish patterns, both in the types of affective product experiences and in the processes that underlie these experiences. These patterns can be of value for designers as they can be used to facilitate their intention to 'design for experience,' that is, attempts to deliberately influence the experiential impact of new designs" (Desmet & Hekkert, 2007, P.8).

MC's evolution coincided with various socioeconomic, political, cultural, and environmental changes following marking events such as the Industrial Revolution, World War I and II, population growth, globalization, urban densification, and climate change, to name only a few. Since the versatile material lent itself to many types of applications, a wide variety of actors were called to interact with concrete, actively or passively. The appraisal of the material therefore differs greatly depending on the actor (e.g., cultural preferences, generational beliefs, environmental circumstances, educational background, etc.) as well as the circumstances (e.g., geographical positioning, architectural style, historical timeframe, etc.). For example, while a private investor may associate a pragmatic value to concrete (e.g., concrete is *cost-efficient*), an interior designer might be more interested in its semantic meaning (e.g., concrete is *inviting*), etc.

The research revealed a changing paradigm as evolving technologies have transformed the way design professionals look at the material and compose with it. For example, new applications in home accessories such as tableware, or more eco-friendly recipes such as fly-ash concrete, have opened the door to the exploration of a **new concrete aesthetic**. It is important to note that aesthetic appreciations are also cultural ones. Therefore, the observed changing paradigm is one that has been constructed by a dominant culture (John & Gordon, 2009).

With this broadening field of possibilities, never-imagined solutions are emerging, thus transforming the quality perception of concrete artifacts. The experience of concrete artifacts can be thus understood through a PAME framework (Desmet & Hekkert, 2007), which considers these 3 dimensions:

1. the aesthetic pleasure (or displeasure) produced
2. the meanings associated
3. the emotional response generated

5.1.1. The aesthetic appraisal of concrete

The aesthetic experience of concrete is linked to its capacity to generate sensory pleasure by delighting our bodily senses. The lack of pleasantness can therefore result in *oblivion* and even *displeasure*. We have observed that concrete tends to evoke sometimes opposing appraisals (e.g., *ugly* but *beautiful*).

The documentary research and mediatic review allowed us to tap into the public's opinion showing that design professionals are most likely to experience *aesthetic pleasure* when it comes to concrete artifacts. In fact, it is the architects, designers, or urban planners who prescribe the material in projects are most likely to *positively appraise* concrete the most (e.g., *beautiful*, *impressive, practical,* etc.).

However, our study has shown that although concrete seems to be appreciated by some, other users seem to experience displeasure, associating some concrete artifacts (e.g., social housings, prisons, or governmental buildings made of precast concrete panels, etc.) with *unpleasant appraisals* (e.g., *ugly*, *oppressing*, *depressing,* etc.).

The timeline evolution revealed that the *aesthetic potential* of concrete began to emerge when some started to interpret it as a plastic synthetic material - rather than a rigid natural material (e.g., blocks of stone, timber joints, etc.) (Simonnet, 2005; Forty, 2013). By expecting concrete to behave similarly to other synthetic materials such as polymers, concrete was doomed to fail. In fact, based on the observations of Simonnet (2005) and Forty (2013), the prospects of concrete emerged with the acceptance of its synthetic yet imperfect characteristics. When compared to natural materials, the value of synthetic materials lies in their *seamless uniformity* (Forty, 2013). However, concrete “singularity fails to deliver” this perfect consistency (Forty, 2013, P.51).

Concrete is thus an *imperfect* synthetic material, its *beauty* coming from that level of *unpredictability* and *uniqueness* which rather characterises natural materials.

5.1.2. Concrete’s meanings and associations

As explained before, the various meanings associated with concrete come through the interplay of our cognitive processes (e.g., interpretation, memory, etc.) by which we assess the artifacts and then assign them pragmatic, semantical, or syntactical dimensions.

Concrete’s connotative and denotative signs

Concrete can be associated with different meanings which can be linked to *connotative* signs (also referred to as *natural* or *analogical*) or *denotative* signs (also referred to as *artificial* or *digital*). For example, the material may hold obvious and elementary meanings such as ‘concrete is *heavy*’. Through denotation, this general assumption is based on common sense and previous experiences, as the material’s heavy weight is a known fact shared within multiple cultures. However, as we have previously specified, no sign is purely denotative as most of what we know and think is influenced by various contextual factors. In that sense, meanings such as ‘concrete is *cold*’ can be linked to both denotation (e.g., it is *cold to the touch* due to its thermal properties) as well as connotation (e.g., it represents Brutalism in its monolithic and *unwelcoming massiveness*, and is therefore *emotionally distant, uninviting, cold*). Likewise, ‘concrete is *depressing*’ can be denoted from its grey color all while linking this connotation to war (e.g., bunkers and bomb shelters), and the absence of nature (e.g., dense megacities such as Hong Kong), and so on.

Perhaps concrete, as a new material, was perceived as ‘less authentic’ due to its digital/artificial connotation. When the material first emerged, it was compared to more familiar mediums such as stone or wood (which are generally associated with more analogue/natural signs). Due to our romantic tendency to be more attached to analogue signs, emerging materials such as concrete or polymers are rather regarded with apprehension. Concrete can thus be associated with more artificial signs and thus automatically labeled as ‘*less good’* or ‘*inferior*’ in comparison to natural materials such as marble or stone.

Universal and learned meanings

Concrete has a rich history due to the timing of its re-discovery and exploitation, making it charged with multiple meanings. Some of these meanings can be shared by many communities and cultures (universal meanings), while others are more subjective to the specific individual (learned meanings).

Therefore, concrete can hold some universally recognizable meanings which are shared by different cultures or subcultures. Similarly to the examples given before, these universal meanings can be based on denotative signs, leading to agreed-upon conventions such as ‘concrete is *resistant*’.

In addition, concrete can also have learned meanings which are specific to one individual, subculture, or generation: for example, World War II veterans are more likely to think that ‘concrete is *protecting*’, linking it to shelters and bunkers. Whilst residents of Hong Kong in 2006 may think that ‘concrete is *suffocating*’, linking it with massive urbanization and pollution, and so on.

Intrinsic and extrinsic properties

When mentioning universal and learned meanings, it is interesting to reflect upon the material's characteristics and properties, and to find interrelations between the two.

In that sense, concrete as a material carries intrinsic properties which are inherent to its physical aspects. These are universally shared across many cultures and subcultures and tend to remain the same across time: for example, most of us would agree that traditional concrete's mechanical properties make reinforced applications *resistant*, its chemical properties make it *mouldable*, and its molecular properties make it a *good thermal conductor*.

Concrete can also have extrinsic properties which are context-dependent and can be linked to learned meanings. These types of properties can influence the user's perception, particularly when it comes to new technologies opening the doors for unexpected applications. For example, polished concrete can make it *reflective*, 3D printing can make it look *soft* and *flexible*, and added pigments can make it appear *warm* or *cozy*, and so on. In that same sense, concrete used to build bunkers associates it with *robustness* and makes it *impenetrable,* whereas new applications in home accessories such as service plates can make concrete seem *delicate* or even *fragile*.

Concrete versus nature

Our research shows that concrete is somewhat of a controversial material from a philosophical and ontological perspective, considering that it is often seen as "cutting people off from nature", or even "obliterating nature" (Forty, 2013, P.43). Forty (2013) emphasizes concrete's complex relationship with nature, amongst other aspects, in his book *Concrete and Culture: A Material History*, which served as a major source of insight for our research.

> "It [concrete] has the capacity to resist nature (gravity, the sea, weather) and so gives us power over nature to a greater degree than most other materials" (Forty, 2013, P.43)

At this point in our reasoning, ‘nature’, which has proven to be a concept that is extremely difficult to characterize, can be perceived in its traditional view dating back to the eighteenth century:

> “[...] nature is that from which man is absent, the place on earth before man arrived, and from which he emerged. Nature, it is supposed, has a power of its own, a power that man lacks and on account of which man is dependent upon nature, forced to draw upon its resources.” (Forty, 2013, P.68)

Here, nature is seen as a mysterious entity that can either be submissive (to be exploited by mankind) or admired (to be venerated, and even feared by people) (Hadot, 2006). Forty (2013) specifies that in this conception of nature, the city, being a man-made construct, thus comes as firstly separated from nature, and secondly in opposition with it.

However, in the late 1980s, the views about concrete began to shift: with earth’s natural resources and ecosystems deteriorating, the ontological origins of the materials became trivial, and its ecological impact became of much greater importance (Forty, 2013). In addition, as Gandy (2002) puts it:

> “While it is certainly true that one kind of nature has been displaced, another has also been created. Let us, following others who have written about this phenomenon, call this new nature ‘urban nature’ - here, as so often, created through the agency of concrete.” (Gandy, 2002, cited in Forty, 2013, P.61)

In fact, Forty argues that “if concrete offends, it is not so much for being ‘unnatural’, but rather because it threatens the convention of the division between nature and the non-natural.” (Forty, 2013, P.59).

5.1.3. The emotional response to concrete

Our emotions towards concrete either pull us toward it or repulse us. They are the feelings or impressions we experience resulting from our interaction with the artifact. Through the process of appraisal, we evaluate the artifact’s significance according to personal preferences (e.g., past experiences, cultural and spiritual beliefs, expectations, moods, etc.). This is what generates emotions such as *love* or *hate, attraction* or *repulsion*, *interest* or *boredom*.

For example, we can find ourselves touched or moved by a memorial made with concrete monoliths by experiencing emotions of *intrigue*, *fascination* or *grief*. Whilst others can be repulsed or traumatized by a deteriorating brutalist social housing project built with precast concrete, generating the feeling of being *oppressed* and *uncomfortable*.

5.1.4. The interaction between concrete's three levels of PAME

Based on the model of product emotions proposed by Desmet (2002), although the 3 types of experiences can be conceptually separated, they operate in unity while displaying a slight hierarchical relation: meanings and aesthetic experiences can elicit emotions.

In this section, we will use scenarios in which we will interpret these three levels of interactions based on personal experiences as an active end user, and passive observer.

For example, through my past experiences, I have associated concrete with post-war urbanization because I have seen the material dominate the urban landscape. I've seen concrete predominantly used in governmental buildings, social housings, prisons, bridges, highways, dams, and industrial buildings. The meanings I have transposed onto concrete are thus linked to images of megacities made up of precast concrete panels, creating ghettos and generating pollution: I have thus attributed to concrete semantical attributes such as *destructive*, *dominant, oppressing*. Meanwhile, as I am walking down the street in my rural neighborhood, I see multiple construction trucks dumping concrete into steel reinforcements while workers spread the material evenly with their tools. My pre-established meanings associated with concrete elicit emotions of *stress*, *apprehension* and even *fear.* I am *worried* that my rural neighborhood is transforming into an ill-conceived urban center: more dense, more hectic, more grey, and with less and less green spaces. Here, I am experiencing *aesthetic displeasure* in anticipation of what the structure will look like based on my assumptions. The aesthetic experience of lack of beauty and pleasure is making me want to *avoid* this area all together.

However, a few months later, I happened to be in Singapore walking down Upper Pickering Street. There, I fall upon WOHA architects' PARKROYAL hotel (figure 121), and I surprise myself by immediately finding it *beautiful*: the three shades of stacked concrete layers seem to be the perfect vessel for the abundance of plants and trees overflowing from the various levels. The undeniable *aesthetic pleasure* brought by the building's design elicits emotions of *desire* and *awe*. Based on my affective dispositions and my taste preferences, I find myself *attracted* to the building, the textures, the shapes, the colors, and the general ambiance they create. I am *drawn to* the artifact, and I want to go inside and prolong my experience: this is how product attachment begins to form. Now, I have created a new learned meaning which will potentially affect all my future appraisals of the material. I have witnessed how concrete can be *symbiotic with nature*, *organic*, *inviting*. This is how aesthetic experiences can help generate new meanings, and then elicit unexpected emotional responses.

Meanings can also be assigned through anticipated usage: as I am walking down the streets on a hot summer day, I see what I recognize as a seating artifact (e.g., a wide-enough horizontal surface supported by feet standing at a 15-20 inches height affords sitting) under the shade of a tree. Upon initial inspection of the product's indexical signs, I conclude that it is a concrete bench based on its grey color and surface imperfections (e.g., bubbles and stains), as well as its monolithic shape (e.g., bloc). Then, I anticipate myself sitting on the concrete bench. I have expectations or apprehensions: last summer, I remember sitting on a concrete bench while wearing shorts; although *rigid* and *rough*, the cooling temperature of the material was *refreshing* and *soothing*. Here, concrete is associated with being *hard* or *uncomfortable* on one end, all while being *cool* (e.g., here meant in literal physical temperature terms) or *refreshing* on the other. The first association might have generated feelings of *reluctancy* or *hesitation* to sit, while the other might evoke emotions of *anticipation* by promising *relief*.

While the pleasurable experience felt through the cooling effect of the concrete against the skin is aesthetic - in the same sense that the associations with *refreshment* and *comfort* are meanings - the resulting feelings of *satisfaction* or *content* are emotional.

5.2. Concrete's quality perception: a dualism

As previously mentioned, concrete can be perceived in different - sometimes contradicting - ways. We found that the material's perceptual qualities generally manifested in a dualism: its techno-economic advantages are put in opposition with its aesthetic ageing as well as ecological footprint.

5.2.1. Aesthetic perception

Concrete naturally exhibits superficial signs of wear and tear on its surfaces such as stains, crumbles, and random imperfections due to the recipe or manufacturing process. Our empirical observations have demonstrated how common these surface imperfections are. Most of the time, these signs are inevitable and are harmless in terms of structural performance.

Nonetheless, we have also found that concrete is judged harshly by some of its actors and can be labeled as *ugly, cheap, unpredictable,* and *impractical* due to some of physical characteristics. In fact, the material's superficial wear can be criticized based on the same criteria by which we tend to judge human aging.

Over the past centuries, scholars have observed that society's traditional attitude towards ageing assumes that artefacts are similar to humans: the older they get, the more weathering signs can be found on their surface (Karana et al., 2013; Forty, 2013; Ashby &Johnson, 2014; Chapman, 2015). In that instance, concrete's deteriorating surface is compared to ageing human skin.

However, we like to agree with those scholars, arguing that most materials - and concrete particularly - do not conform to the human pattern of ageing: its surface does not always reflect its internal physical condition (e.g., cracks compared to wrinkles, stains compared to age spots, etc.). In fact, concrete surfaces are notorious for developing unpredictable stains, cracks, and crumbles as the material cures. This is part of its natural behavior and is not a sign of its technical deterioration. For this reason, many concrete masons and entrepreneurs have accepted these imperfections as inevitable parts of the material's finish. Due to its intrinsic heterogeneity, concrete is unavoidably prone to form superficial cracks on its surface (Silva et al., 2015).

> "No matter what you do, concrete will crack" (Concrete Decor, Stephenson, 2018)

According to the American Concrete Institution Committee, the cracks can be caused by a variety of causes including shrinkage, thermal stress, weathering, externally applied loads, or corrosion of reinforcement, to name only a few. Although most superficial cracks are inoffensive, a more serious crack can lead to the penetration of aggressive and harmful compounds such as chloride ions (Cl-) and CO2 (Silva et al., 2015). These types of compounds can corrode the reinforcement inside the concrete, which eventually may cause structural damage (Silva et al., 2015). Thus, reinforced concrete usually deteriorates from within as the steel corrodes. However, this reaction is mostly invisible from the outside, and most of the superficial stains and cracks are neither a symptom nor an indication of the physical deterioration of the structure. Spalling and pieces falling off the surface are the only legitimate clue to its deteriorating physical performances (Forty, 2013). Therefore, the internal decay of concrete does not conform to the superficial ageing of human skin - or other materials (Forty, 2013). Whilst wrinkled skin for example is a clue of a person's advanced age, and to be put in blunt terms, is associated with the imminent end of life, cracks, stains, and bubbles on concrete's 'skin' are natural characteristics of the material.

> "What discomfort the erratic ageing of concrete draws attention to is […] our over-attachment to the appearance of human skin as the aesthetic criteria by which we judge materials." (Forty, 2013, P.59)

In addition, if we were to compare worn-out concrete surfaces with aged human skin, we should take into consideration how the respect of our elders is a universal doctrine. Given how older generations are treated with respect in most cultures, humans are seen to naturally want to engage in evolving and durable relationships (Chapman, 2015). People naturally empathise with older generations, offering to help with physical task, developing technologies and services to prolong their life and make them comfortable, and admiring their wisdom.

Despite our best efforts to fight ageing brought on by time, we still seem to accept it as an inevitable part of life. This particular perception of human ageing could serve as a guideline for how we judge older yet functional artifacts.

We also asked ourselves why ageing concrete is seen to be *deteriorating* and *weathering* whereas other materials such as wood, copper, or leather are seen to *mature* and *gain value* as patina and signs of wear and tear appear on their surfaces.

5.2.2. Ecological impact

The research revealed that concrete's life cycle steps can be problematic, especially when it comes to the ecological impact brought by the production of traditional MC. As mentioned, Portland cement is one of the most polluting materials on the planet, and MC recipes require colossal quantities of water, sand, and gravel, in a time where these resources are facing a global shortage crisis. In addition, the production process of concrete, from sourcing (e.g., raw material mining, transport, etc.), to manufacturing (e.g., production of ingredients, mixing, casting, etc.), to maintenance work (e.g., routine cleaning, emergency repairs due to premature deterioration, or vandalism in the form of graffiti tags, etc.), has proven to be incredibly energy consuming and labor intensive, which adds to its ecological impacts. These aspects give many actors reasons to question concrete's *viability* and contribute to its *bad reputation*.

Today more than ever, there is a need for more sustainable materials with lower carbon emissions and reduced ecological footprints. Although the initiatives developing eco-responsible alternatives to concrete are of great importance and relevance today, they cannot compare (yet) to what traditional MC has to offer.

However, we have documented some technologies which have been developed to improve the material's ecological footprint (pages 80-81). Some propose the replacement of certain concrete ingredients with more environmentally friendly ones (e.g., cementitious substitutes of other industries' by-products, reuse of recycled aggregates, etc.). Whilst others are experimenting with new manufacturing and finishing techniques (e.g., 3D printing, flexible molds, pigmentation, etc.). These are seen to offer improved performances (e.g., better freeze-thaw cycle, less permeability, higher resistance to impact, lower heat absorption, self-healing properties, etc.) and unexpected aesthetic experiences (e.g., organic and fluid appearance, warmer color palettes, etc.) compared to traditional monolithic concrete artifacts.

From an environmental, technoeconomic, and sociopolitical standpoint, there is a global need for more sustainable lifestyles and practices. Implementing such sustainability-driven strategies will require considerable efforts from all stakeholders (Meyer, 2005; Ackerman & Gallagher, 2002). Researchers from various fields, product developers, design professionals, the construction industry as well as governmental institutions need to be involved in order to encourage, incentivize, implement, and regulate such changes.

As was pointed out, our economy-driven society predominantly aims for profitability, which is rarely in line with sociocultural and environmental needs, or some sociopolitical ambitions of some governments and institutions. Unfortunately, change always encounters resistance: the public may be wary and doubtful of new unexpected yet technically sound solutions (e.g., recycling or reusing by-products in concrete mixes) despite all scientific and technical evidence to the contrary (Detzner, 1995).

> "Bold initiatives are required that are not without risk, yet strict adherence to principles such as "we have always done it this way" is certainly counterproductive, because the world around us will change anyway" (Meyer, 2005, P.3)

Others may even question the purpose of putting in the efforts to develop more durable and eco-friendly artifacts considering that the users and stakeholders tend to lose interest in preserving and repairing ageing concrete artifacts. Fortunately, the evolving collective consciousness is pressuring actors to adopt more environmentally friendly and emotionally durable practices to help remedy the problems generated by unsustainable lifestyles, premature obsolescence, and ultimately, climate change.

The research has revealed that design can play an important role in changing perceptions through convincing and innovative design applications and approaches. These lead to concrete technologies who require lesser quantities of natural resources (e.g., water, sand, energy, etc.)

and utilize recycled and repurposed materials that would have otherwise ended up in landfills. Design can thus generate value and meanings which encourage the users and stakeholders to maintain used concrete artifacts, and thus prolong their life expectancy.

5.3. Industrial design and material experiences

Our study has observed a significant shift when it comes to the general appreciation of ageing artifacts - particularly ones made of concrete. The literature review revealed a change in perception when it comes to material ageing notably amongst researchers, design professionals, investors, and end users (pages 119-127).

We were able to document this paradigm shift as concrete can be increasingly found in prestigious applications (e.g., artifacts of spirituality, of remembrance, interior decors, home accessories and furnishes, etc.) (pages 106-113). These unexpected contexts of use, which were rarely considered acceptable before, help elevate the material's perception of value, bestowing concrete with new meanings which increase attachment.

5.3.1. Knowledge in material user experience

As previously described, materials can convey powerful meanings driven by semantic (connotative) and pragmatic (denotative) interpretations. These relate to previous experiences, sociocultural and historical events generating semantic value, as well as technological progress, thus affecting the appreciation of concrete artifacts' physical attributes.

However, the research shows that a socially and environmentally conscious design process can intentionally trigger a shift in materials' social code to make more "compelling, memorable, and innovative designs" (Brownell in Karana et al., 2013, P.61). When designers gain a better understanding of the underlying mechanics that influence user experience, they can better employ their material knowledge to create more emotionally durable subject-object interactions.

5.3.2. Affecting quality perception and prolonging attachment through design

The gathered testimonials thus show that ideologies are detaching from the traditional views that design simply focuses on aesthetics, functionality, and usability. These changing ideologies prove that design has the ability to subtly embody emotive and sensual qualities into what they produce, thus allowing users to become more attached to perfectly functional yet slightly worn-out artifacts.

This can be attributed to those unique qualities certain ageing artifact gained through the passage of time (e.g., rusted copper, creased leather, etc.). The appreciation of the 'old and used' as opposed to the 'new and pristine' can be also seen as a trend which can be linked to the evolving collective consciousness in the context of global warming and climate change.

Overall, we have observed a change in consumer habits (e.g., favoring local manufacturing, faire trade, durable and long-term strategies, etc.), political discourses (e.g., inciting industries to adopt sustainable practices, financing research into alternative eco-friendly technologies, etc.), and design approaches (e.g., valorizing eco-concretes such as UHPGC page 81, or alternatives to concrete such as K-Briq page 84, etc.).

The research shows that users are increasingly compelled to *maintain, fix, and preserve* ageing artifacts, as opposed to *hastily discarding* and filling our overflowing landfills with them. Through the appreciation of *mature* artifacts (e.g., beauty in patina) and the utilization of repair techniques that highlight breaks and imperfections (e.g., Kintsugi), people are seen to accept and even embrace natural signs of use (pages 129-135).

5.4. Factors influencing the quality perception of artifacts

The research allowed us to identify ideologies and design approaches which can influence the quality perception of artifacts, particularly when it comes to ageing materials. We have selected them based on their relevance to our subject of concern and provided a brief description of each aspect according to the design approach it originates from, complimented what was described in our previous chapters.

This list was created with our research objectives in mind, helping us isolate certain design dimensions that could serve as guidelines for more sustainable and meaningful designs. The proposed aspects are in no way restrictive and are shown in a generic manner in the following sections.

5.4.1. Emotionally Durable Design material attributes

Some scholars point out that products and materials which are conceived with emotional durability in mind have proven to better withstand the passage of time, particularly in our technocentric consumerist society (Chapman, 2009; 2015; Karana et al., 2013). Certain attributes can thus help increase the emotional durability of artifacts, generating meaning and value, and thus reinforcing the subject-object relationship. They can be applied to the material itself as well as the artifact it composes. These include **curiosity and surprise, alterity, honesty and integrity,** and **attachment,** to name a few.

Curiosity and surprise

A preliminary example would be materials and artifacts evoking emotions of curiosity and surprise. These types of attributes are meant to *lure* the user in by *attracting their attention*, and then help give the artifact a *strong personality*, an *unforgettable character* (Chapman, 2015; Rompay & Luden, 2015). Additionally, they are built upon previous expectations created through the initial visual inspection of the material or its artifact. In that sense, products that *stand out in contrast*, that *behave in an unexpected manner*, that *never cease to bewilder* their users, are products who are more likely to be appreciated and preserved for a longer time.

For example, Universitat Politècnica de Catalunya's biological concrete (pages 84) encouraging the formation of pigmented living organisms onto its surface can be seen to attract from afar as its aesthetic appearance is unexpected and intriguing.

Alterity

Alterity can be seen as an *eccentric quality* where an object seems to be "*autonomous* and *in possession of its own free will*" (Chapman, 2015, P.81). This can be created by "lightly and carefully engendering a degree of *disobedience*" into the product (Chapman, 2015, P.81). This type of *unpredictable and surprising behavior* can help create stronger and long-lasting object-subject relationships. Alterity thus becomes a sub-feature of surprise as the artifact is designed to slowly (or even suddenly and unexpectedly) *reveal a hidden feature*. Emotions such as *anticipation* and *excitement* are thus evoked, further consolidating the subject-object connection.

This can be observed with the unpredictable surface imperfections almost all concretes tend to develop. In addition, photoluminescent concretes (page 84) display attributes of surprise and alterity as their luminescence is slowly revealed at nightfall.

Honesty and integrity

When materials and their artifacts *behave in a progressively and dynamically changing way*, they can display attributes of honesty and integrity which can be valued by their users. Therefore, they are seen to "[...] *confidently flaunt the scars* of age without apology or justification" which allows them to "[...] adopt a notable degree of integrity that enables them to *grow old in a dignified manner*" (Chapman, 2015, P.133). The *respect* these types of artifact gain from their users can be also seen when they proudly display the signs of their manufacturing process, or even production imperfections that can be considered 'flaws' (Karana et al., 2013).

For example, new takes on traditional wooden formwork such as unfinished board-marked or bamboo-marked concrete (page 87-88) can display attributes of honesty and integrity by proudly flaunting the imprinted texture of a low-tech manufacturing process.

Attachment

The previously mentioned attributes are seen to help increase product attachment. An emotionally evocative bond between the user and the artifact is thus strategically woven through its design and creates more stable and resilient subject-object relationships that can better withstand the test of time (Chapman, 2015).

This can be observed when actors fight to preserve an artifact due to its historical, emotional, or spiritual value, thus fueling preservation intentions as was described in the case of Kurokawa's Nakagin Capsule tower (pages 143-146).

5.4.2. Methods transforming dimensions of material knowledge to elevate user consciousness

The research revealed how extended design knowledge with regard to human perception and meaning-making can be implemented effectively in the design process to help form meaningful user experiences (Pierce, 1966; Barthes, 1972; Krippendorff & Butter, 1984; Ilstedt Hjelm, 2002, 2002; Brownell, 2013; Karana et al., 2013). These can be found within the field of design semiotics which considers that products have complex communicational dimensions which are understood through the interplay of subtle codes, signs, symbols, and icons, thus affording denotative functions and connotative meanings. According to those scholars, the main factors transforming dimensions of our material knowledge and by consequence, our perceptions, include **sensory manipulation, quasi-mimesis, transliteration, repurposing,** and **aggregation**.

Sensory manipulation

Sensory manipulation can be created through "the *manipulation of reality* by achieving *optical illusions* through materials" (Brownell, 2013, P.52). By distorting reality, designers can integrate elements of *subtle yet noticeable surprise* into the product experience, thus evoking the user's sense through *deception* (Kengo Kuma cited in Blaine Brownell, 2013; Oki Sato cited in Brownell, 2013).

For example, Japanese design studio Nendo utilizes sensory manipulation in some of their products, pushing their users above their threshold to evoke emotions of surprise as can be seen in their Cut side tables for example (Cut - Nendo, 2020). Another example is translucent concretes technologies (pages 82-83) which are usually associated with dense opaqueness. In addition, 3D printing concrete (pages 92-97) offers a new aesthetic to the material through sensory manipulation. Concrete, which was once considered a rigid orthogonal medium, can now be perceived as more fluid and organic.

Quasi-mimesis

Quasi-mimesis borrows its material vocabulary from the *natural world* through the "*mimicry of natural substances* to transform material meaning through the *partial emulation of a substance in another*" (Brownell, 2013, P.54). It is another *form of cognitive impenetrability* that goes *beyond deceiving* the user by *sparking their interest* and thus subtly pushing them to *question the material nature of artifacts* (Brownell, 2013).

Industrial designer Naoto Fukasawa is known for his subtle use of quasi-mimesis to stimulate user's senses (Fukasawa & Morrison, 2007). A great example of this application is his Juice Skin packaging design (Juice Skin - Nato Fukasawa Design, 2021). Pigmented concretes (pages 97-98) with natural earthy tones for example can also reflect quasi-mimesis by borrowing their color vocabulary from earthy natural tones (e.g., warm-grey, brown, beige, forest green, terracotta, etc.). In addition, flexible formworks (pages 90-91) also borrow their aesthetic vocabulary from natural organic forms such as water, for example.

Transliteration

Similarly to how quasi-mimesis borrows its vocabulary from the natural world, transliteration "*co-opts material language from the world of industrial objects*" (Brownell, 2013, P.55). Transliteration thus refers to "an *unexpected design language* as a way to shift material meaning that extends to the realm of functional objects" (Brownell, 2013, P.55). Brownell (2013) further explains that this *explores the gradients* *between two distinct objects*. By studying the subtle gradations from a chair to a table for example, we can firstly establish the boundaries between the two (which can allow the *emergence of new applications*), and then better understand what distinct features define a chair versus a table (e.g., specific height, proportions, etc.).

The same can be applied by looking into the gradation between fluid and rigid materials for example. Light-transmitting concrete (pages 82-83) displays transliteration as the material technology explores different gradations from the transparent optical fibers to the opaque concrete. In that same sense, photocatalytic concrete mixes (page 82-83) explore transliteration as the gradation between sleek white polymers and rough grey concrete is challenged given the white color of the self-cleaning concrete.

Repurposing

In addition, repurposing can be seen as a strategy involving the *use of one material for unexpected functions* (Brownell, 2013). It can even extend to the *borrowing of one discipline's processes or techniques in another,* the ultimate purpose being the *creation of novel unanticipated applications* (Brownell, 2013). The emerging use of concrete in tableware is a great example of this.

For example, we find MIT CSHub's electricity conducting concrete (pages 82-83) where the material technology is borrowed from other electricity conducting mediums and applied to concrete, which displays the method of repurposing used to create a novel application. Flexible formworks (pages 90-91) also display this attribute as they utilize manufacturing techniques from other industries such as the fine arts (e.g., plaster molding, etc.). Lastly, a simple yet great example is the increasingly popular use of concrete in home accessories such as office furnishings and accessories (pages 108-110). By venturing away from traditional building and construction applications, concrete is given a new identity which displays its versatility and allows users to see it under a new light.

Aggregation

Lastly, aggregation is a way to "*shift material meaning* in terms of *quantity, scale, and character*" (Brownell, 2013, P.58). It results in a *shift of focus* from the object perceived as a *discrete single unit*, to the *complex immersive aspects* brought by a *large surface or space* (Brownell, 2013). In that sense, a few bricks create a wall, a few walls create a building, and a few buildings create a neighborhood, etc.

In that same sense, hundreds of stacked concrete groins (also known as *groynes*) create a coast, superposed MMUs create space separators, and aligned concrete tiles create floors, etc.

5.4.3. Aesthetics of sustainability factors expressing material naturalness

We have seen that the AOS can be expressed through products which embody and reflect positive sustainability credentials (page 75), and are therefore found aesthetically attractive (Saito, 2007; Karana & Hekkert, 2010; Karana et al., 2013; Karana et al., 2015).

One way of reflecting those environmental values is through artifacts displaying **signs of naturalness**. This also means that what different users perceive as 'natural' is deeply affected by the material's form and type, as well as the context in which it is used, to name a few considerations. However, a study led by materials expert Elvin Karana (2012) suggested some aspects that help appraise a material as 'natural':

Amongst the factors expressing a material's naturalness is its **color and pattern**. If a material is placed *in the midst of nature*, it will *contrast or blend in* based on its color (e.g., earthy tones of brown and green vs fluorescent orange) or its patterns (e.g., organic random patterns vs geometric symmetrical patterns). Furthermore, the **signs of wear** associated with *prolonged use or exposure* through time are usually associated with more natural materials (e.g., worn-out stones due to water abrasion, etc.). An additional sign is the **presence of imperfect surface qualities** such as *uneven surfaces, irregularities, lack of uniformity,* etc. It is needless to repeat that most concrete recipes are characterized by this imperfection. And lastly, **signs of life** such *scratches, scrapes, discolorations*, etc., can *result from the different uses* the artifact is subjected to, and are seen to make it *unique* and *one-of-a-kind*. This can be observed when different climates have distinct effects on concrete surfaces (e.g., costal climates lead to the creation of fungi onto the surface while cold northern climates lead to efflorescence, etc.).

Despite its grey color, concrete displays natural patterns due to its unpredictable surface behavior. As was described previously (pages 140-142), most concrete artifacts easily bear signs of use (e.g., scratches, chipped edges, etc.), misuse (e.g., vandalism, graffiti tags, etc.) and exposure (stains, cracks, crumbles, discolorations, etc.). For example, Universitat Politècnica de Catalunya's biological concrete (pages 82-83) can display signs of naturalness through the organic colors and irregular patterns created by the microalgae, fungi, lichens, and mosses, making each application different and unique. In addition, board-marked concretes display signs of uniqueness and imperfect surface qualities: as the formwork is left imprinted onto the concrete's surface, the material's flaws and imperfections are also present, displaying signs of uniqueness and imperfect surface qualities, which are associated with material naturalness.

5.4.4. Zen aesthetics' Wabi-Sabi design principles

The literature review also showed that the philosophical and ritualistic tradition of mindfulness known as Zen aesthetics provides ideas which contribute to improving well-being and quality of life (Hisamatsu, 1971; Purser, 2013; Lomas et al., 2017). We have mentioned the aspects embodying Fukinsei (the beauty in asymmetry and inherent irregularity, the perfection of imperfection) as well as Koko (the beauty in aged or seasoned elements) (pages 130-133). Here, we elaborate further on the acceptance of transience and the quest for the unique and unconventional known as Wabi Sabi philosophy (Juniper, 2003; Koren, 2008; Rognoli & Karana, 2013), highlighting some of its relevant features:

The **organic** aspect of Wabi Sabi ideology entails that "the tides of time should be able to *imprint the passing of the years*" on the artifact (Juniper, 2003; P,106). Therefore, the *physical decay adds to the visual appeal* and can be observed through *uniform dull surfaces* (absence of shine or luster) showing the passage of time in an "*expressive* and *attractive*" way (Juniper, 2003). A natural concrete finish is inherently dull and lacks shine, therefore can reflect organic aspects based on this description.

Wabi Sabi principles suggest that design should *refrain from adding embellishments or ornamentation* by *letting nature do all the work*. Although these aspects can be considered as *neglect* and lack of maintenance in other cultures, **freedom of form** encourages nature to add the "*stamp of individuality*" onto the artifacts. This can be achieved through *irregularity or asymmetry*, *allowing the form factor to come from the materials* used, *avoiding symbolism and artistry*, and letting the artifact *evolve naturally without maintenance or control* (Juniper, 2003). Concrete artifacts who have been intentionally neglected, allowing nature (in the form of flora or fauna) to grow freely onto its surfaces, can reflect those intentions.

Although most modern designs utilize sleek and smooth material finishes, Wabi Sabi principles encourage the **use of the natural texture of the material and its derived forms** (Juniper, 2003). In that sense, objects that are *supposed to conform to unattainable immaculate perfection* ultimately *fail* as flaws are an "unavoidable part of the randomly evolving environment we live in" (Juniper, 2033, P.110). Therefore, *arbitrary, and complex natural textures* are welcomed and can be manifested through *roughness or unevenness*, as well as *variation* in color and form (Juniper, 2003). Indeed, concrete's notorious for its surface unpredictable texture and displays a wide variety of natural imperfections such as air bubbles, stains, and cracks.

Similarly to the natural textural aspect, Wabi Sabi principles encourage the **use of the material's natural color**, or *natural dyes* (Juniper 2003). This can be achieved through *muted, murky, matte, and subdued colors* from natural sources, all while presenting the artifact *under natural lighting* (Juniper, 2003). In that sense, the 'natural grey' of concrete wouldn't be perceived as monotone or depressing, but rather honest and natural, helping the material become recognizable and appreciated.

One of the most spiritual aspects of Wabi Sabi taps into the *freedom of early childhood and simplicity*, where spontaneous emotions ruled over rationality and learned ideas (Juniper, 2003). In this Buddhist view on the modern world, there is **no duality between learned concepts such as beauty and ugliness**. Therefore, deliberate definitions and rigid classifications are avoided through disregarding the more traditional views of beauty, and finding aesthetic pleasure in the smallest insignificant details, going beyond conventional ideas (Juniper, 2003). Concrete's imperfections (e.g., stains, bubbles, etc.) and natural characteristics (e.g., grey color) can be thus considered beautiful, adding to its humble aesthetic appeal.

Lastly, there are many additional design principles in Wabi Sabi philosophy which complement the ones described in this section. These revolve around the notions of simplicity, space, balance, and sobriety, amongst others.

The examples demonstrating how Wabi-Sabi's design principles apply to concrete artifacts are fairly similar to the ones displaying signs of naturalness. For example, flexible formworks (pages 90-91) challenge our definition of beauty relating to precast concrete by proving, through the sensory manipulation of the medium, that it can display freedom of form through achieving fluid and organic shapes.

5.4.5. Durability as seen from a resilience thinking standpoint

Lastly, what interests our research here is the notion of resistance in terms of *flexibility*: the system recovers by *absorbing and readjusting* as opposed to a rigid position of endurance and confrontation. Rather than putting up a fight to withstand inevitable changes and remain intact (e.g., weathering with time and exposure, lifestyle changes, etc.), artifacts should have an inherent and intentionally designed *ability* to take in the change and evolve on their own. Rather than having an attitude of *robustness to change*, artifacts should be about *resilience for transformation* (Folke et al., 2010).

When it comes to the need to change our consumption lifestyles, the **adaptability** feature of an artifact comes into play (Ashby & Johnson, 2014). When a product no longer suits the user, they have the option to buy a new one (and discard the old) or adapt the existing one. The design challenge thus becomes "to create products that can be *adapted and personalized* so that they *acquire [...] a character of their own*" (Ashby & Johnson, 2014, P.78). The adaptability of an artifact can also manifest in how they *adjust to new ideologies, methods, or techniques*. In that sense, new eco-responsible recipes utilizing by-products of other industries or recycled materials have allowed for concrete to adapt to the need for sustainability and environmental consciousness.

For examples, concrete recipes utilizing recycled or reused materials (pages 80-81), as well as those substituting Portland cement with by-products of other industries can display attributes of honesty and integrity in addition to adaptability. While 3D printing concrete (pages 92-97) can mean that the industry has readjusted and adapted to novel manufacturing techniques offering new possibilities.

Along those same lines, we investigate the attribute of **resilience for transformation**, which is seen as an aptitude of being the most responsive to change (Karana et al., 2013; Chapman, 2015). In that sense, resilience becomes an evolutive capacity to absorb a disturbance and accept it as opposed to defensively resisting and blocking it (Chapman, 2015). The damage that is inflicted is thus used to learn, to evolve, and to transform, becoming better overall in facing other sudden or drastic changes. This attribute is of high importance, particularly when it comes to the ever-evolving densifying urban world amid environmental or social crises. New recipes such as self-cleaning concrete thus become resilient in the face of air pollution, absorbing the CO_2 and using it to self-clean its surfaces, not only reducing pollution but also eliminating the need for maintenance and cleaning.

Self-healing concrete recipes (page 82) can display aspects of resilience for example, by healing themselves when faced with damages (e.g., microcracks).

Many of the new concrete recipes mentioned in the previous chapter can be further analyzed based on the design criteria and considerations presented above. We have thus showed how design can influence quality perceptions and prolong an artifact's life expectancy by composing *with* the material's natural behavior with time.

Chapter 6 – Conclusion

The research investigates concrete as an urban material from an industrial design point of view. The findings presented throughout the study aimed to answer questions on (1) the evolution of concrete technologies and applications, (2) the perceptual qualities of the material, and (3) the design aspects influencing the perception of ageing concrete artifacts.

As designers, we are interested in how concrete is perceived by its users. We look into how design can help influence those appraisals in order to better compose with the material from a sustainable perspective. In recent years, design has shifted its focus from technical considerations (e.g., ergonomics, usability, etc.) to sociocultural ones (e.g., user experience, emotional durability of product interactions, etc.). As such, it is concerned with future generations' the quality of life in their environment. Within this human centered approach, our study analyses *how* concrete is perceived by its users throughout its lifecycle. More specifically, we investigate *why* it is *embraced* by some users in a given context and *criticized* in others.

In order to familiarize ourselves with the research filed, an initial literature review helped reveal that, considering population growth and the resulting urban densification, the use of concrete as the most popular building material is *inevitable*. Although its first uses can be traced back to the 7th millennium B.C., its recipes and manufacturing techniques were revolutionized with the invention of Portland cement and reinforced concrete in the 19th century. The material went on to become a global commodity as its expanding range of performances generated new applications in various fields. Although concrete offers multiple techno economic advantages (e.g., structural performance, cost efficiency, etc.), some aspects give it a bad reputation. Concrete surfaces are seen to deteriorate poorly with time (e.g. apparition of stains, cracks, crumbles, etc.), and some of its lifecycle elements (e.g., the production of Portland cement, sand and water consumption, etc.) are contributing to the depletion of natural resources and global pollution. The research revealed that while some *appreciate* concrete's qualities, others *apprehend* it.

In order to better understand those appraisals, we firstly needed to look into the historical evolution of concrete technologies (1). We were thus able to create an overview of the material's main characteristics, ingredients, recipes, manufacturing, finishing techniques, and types of applications and uses. The review showed that concrete technologies have evolved greatly in the past decades and include innovations which promise to revolutionize the industry (e.g., 3D printing concrete). In addition, unexpected uses in fields other than the construction sector are emerging (e.g., concrete electrical sockets in industrial and interior design), and are offering advantages in terms of efficiency, aesthetics, and environmental footprint, to name only a few.

Then, to provide an overview of the perceptual qualities of concrete artifacts in the urban context (2), we applied a qualitative research methodology which allowed us to tap into the public's opinion through a mediatic documentary research. We used analytical tools such as categorizations and timelines to summarize, organize, and present our findings according to our research interests. We also used semantic mapping techniques to present concrete's attributes within a bipolar semantic space: we gathered different testimonies mentioning concrete's perceptual qualities, and we situated them according to two opposing attributes (e.g., *rigid* vs *amorphous*) to better understand their significance to their users.

Theoretical frameworks allowed us to clarify key concepts in our study and confront them to our research questions. A phenomenological perspective supported our human centered approach by focusing on the individual's subjective lived experience in a specific context. A feminist ethics point of view offered us an entry way into the importance of sustainability and emotional durability in human centered design. The theories of signs (semiotics) helped us understand that artifacts can carry complex meanings, and design semantics taught us how design can affect those associations. A product and materials experiences framework allowed us to analyse concrete artifacts interactions according to three levels: their aesthetic appraisal, the meanings associated to them, and the emotions derived from them. We thus understood that the perception of concrete artifacts is a complex context-sensitive process which can vary greatly based on each individual's experience and situational circumstances (e.g., post-war concrete social housings are seen as *oppressive* by war veterans).

In order to further support our findings, we resorted to empirical observations paired with two analyzed examples of concrete artifacts in the urban context. These revealed that concrete is an omnipresent urban material which naturally displays signs of wear and tear. These are not necessarily a symptom of its structural deterioration, but a normal and inevitable part of its curing, ageing, and use. Concrete urban artifacts are also subjected to accelerated deterioration due to exposure to the elements and misuses such as vandalism.

The literature review also revealed that modern society is characterized by over-consumption habits and an obsession with aesthetic perfection. In that sense, functional artifacts displaying natural signs of use are discarded and thrown into landfills instead of being fixed and preserved. Some materials and the objects they compose tend to lose value in the eyes of their users or owners when they age (e.g., plastics), while others are seen to gain in richness and meaning (e.g., leather). Based on the semantic review of concrete's perceptual qualities, it seems to comply with the former.

However, the triangulation between our literature review, our field observations, and the examples studied unveiled multiple revelations:

Concrete's perception of quality was facing a dualism. On one hand, the material offered multiple technoeconomic advantages that were appealing to many, whilst on the other it was seen to age ungracefully all while having a considerable environmental impact.

And yet, another key finding showed that society's unsustainable lifestyles are causing a shift in the collective social consciousness. This is leading to a paradigm change in ideologies which promotes sustainable behaviors. Society is calling for more responsible practices: instead of *discarding* artifacts which bear signs of use, users are *finding value in imperfections* and are learning to *fix* and *preserve*. Human centered design can contribute positively to this shift by composing with the material's natural ageing through its different uses.

Recent developments in concrete technologies and design trends show a new appreciation for concrete despite its controversial nature. Its recipes, manufacturing, and finishing techniques have been optimized and nuanced with an added appeal within a sustainable agenda. The material can be increasingly found in a wide variety of applications in different fields and is no longer reserved for urban infrastructural and utilitarian industrial uses. These emerging technologies and applications are promising to change the material's quality perception.

Therefore, the last part of the research showcases some design considerations (3) that can influence concrete's perceptual qualities to create more emotionally durable artifacts for the future. The ultimate purpose of these aspects is to serve as recommendations for design professionals composing with concrete. The goal is to empower and inspire them to intentionally weave value into the design of urban artifacts all while taking advantage of the material's natural behavior with the passage of time and across its uses (and misuses).

Our study's objective was not to quantitatively measure the quality perception of concrete, but rather to provide an overview of the material's evolution and appraisals based on a literature review and empirical observations.

However, it is important to note that, since aesthetic appreciations are also cultural ones, the analytical work addressing those appraisals is tainted by the author's cultural background and disciplinary perspective, amongst other subjective aspects.

In addition, thoroughly measuring perception would be possible through a more elaborate and long-term study. Potential avenues include applying quantitative methods to measure the perceptual qualities of concrete artifacts by analysis the appraisal of selected new technologies which promise to revolutionize the material's perception. This could be realized through a comparative semantic study which measures the quality perception of traditional concrete artifacts (e.g., precast jerseys) compared to new ones (e.g., 3D printed jerseys). Through a participatory study, it would be possible to measure the different appraisals of concrete based on Osgood's bipolar semantic scale (1957) for example, by selecting and comparing different actor profiles (e.g., millennial Western end user vs. baby boomer Western end user, or Western-trained architect vs. Eastern-trained architect, etc.). The samples of concrete artifacts presented could be conceived within an action research inquiry process (Buchannan, 2002). The samples can be developed within bachelors or masters design student projects, and their appraisals (of the designers themselves, as well as selected stakeholders and end users) can be critically reflected upon through action research frameworks and methodologies.

To conclude, the world of materials is one that is undeniably rich, fascinating, and infinitely inspiring.

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Annexes

Table 1 – the use of recycled materials and technologies in new concrete mixes – T. Harb, 2021

Types of recycled technology	**Description and specifications**	**Main advantages and disadvantages**	**Featured projects or studies**
C&D debris	• The world's solid waste disposal problem has been a major issue in recent years considering the drastic environmental impacts involved (Meyer, 2005; Ganiron, 2015). • Concrete constitutes the largest single element in C&D debris resulting from the construction, renovation, testing, demolition, and disposal of pavements, roads, buildings, etc. (Meyer, 2005; Ganiron, 2015; ASTM, 2009). • C&D concrete can be separated from other materials on site and used as coarse aggregates in new concrete mixes. • Demolition site concrete is being recycled as opposed to being sent to landfills, resulting in multiple advantages on economical, practical, and ecological levels (ASTM, 2009, Ganiron, 2013; Meyer, 2005; Mehta, 2002).	• Saves on costs by eliminating disposal, transportation, and manipulation fees (Ganiron, 2015). • Is considered a local product and eliminates the need for the extraction of valuable natural resources (Meyer, 2005).	Many European countries, in particular Germany, as well as Canada and Japan, have been regulating and mandating recycling concrete - notably to be used as aggregate in new mixes (Ganiron, 2014).
Post-consumer Glass	• Post-consumer glass can be granulated into various grades and then used as coarse or fine aggregate, glass sand, glass powder, fine glass powder, or as an alternative for Portland cement (Tangit-Hamou et al., 2015; Leblanc, 2016; Tangit-Hamou et al., 2018). • The resulting concrete UHPGC can replace up to 30% of Portland cement with micronized waste-glass (Tangit-Hamou et al., 2015).	• Reusing waste glass in new concrete mixes has been proven to be both economically feasible and practical (Jin et al., 2000). • It has zero-water absorption which leads to excellent durability, chemical resistance, and adds an aesthetic appeal with exposed glass aggregates (Meyer, 2005) • It is a sustainable alternative, offering a wide range of mechanical, economical, durability, and ecological benefits (Malhotra, 2000; Tangit-Hamou et al., 2015; 2018): • e.g., reducing the quantities of waste in landfills; lowering the ecological footprint by minimizing the CO2 emissions produced with the manufacturing of Portland cement; offering a highly workable, durable, and rheological material; comparable performances to other UHPCs; lowers the cost of UHPC; comes in a lighter off-white natural color, reducing heat islands in dense urban areas.	Researchers at the Université de Sherbrooke in Canada have been experimenting with the use of granulated waste-glass as a Portland cement substitute with their UHPGC (Tangit-Hamou et al., 2015); two concrete footbridges were built on campus. Multiple student projects at the Design School of the University of Montreal in Canada, under the GRAD, have collaborated with the researchers and included the use of the ecological concrete in their projects: e.g., Peninsula floating concrete docks (Clermont & Harb, 2017) and Réseau urban tiles (Bergeron & LeSant, 2019), amongst others.
Dredged Materials	• Studies have proposed the use of dredged materials (which are excavated from water bodies and waterways) as filler for concrete mixes (Detzner, 1995; Meyer 2005).	• They can help improve some concrete properties, (e.g., freeze-thaw durability)	

		• They can be an ecological and technically sound solution (Detzner, 1995; Meyer, 2005). • They can help reuse an otherwise water-contaminating material • They can reduce costs in terms of production (use of a recycled material instead of new resources) as well as depositing in landfills (Meyer, 2005).	
Waste Water	• The worldwide production of concrete requires excessive amounts of water. • Wash water is used to thoroughly clean the inside of concrete recipients and contains caustic soda and potash and becomes an extremely hazardous waste substance (Chini and Mbwambo, 1996).	• Although relatively limited investigations have been conducted and documented, the results thus far show that the reuse of wash water holds multiple advantages. • The compressive and flexural strengths are comparable to clear water mixes (Androlini and Franzoni, 2001). • The capillary and porosity are reduced, resulting in a more durable material (Androlini and Franzoni, 2001).	With a more environmentally friendly agenda, recent studies (Chini and Mbwambo, 1996; Sandrolini and Franzoni, 2001; Tsimas et al., 2011) and resulting standards (e.g., prEn 1008 standard) are encouraging the recycling of waste wash water from ready-mixed concrete plants.
Sand Alternatives	• Sand is the most commonly used fine aggregate in the production of concrete mixes (Gavriletea, 2017; United Nations Environment Programme, 2014). • In response to today's sand crisis, the concrete industry and other stakeholders are investigating alternative replacements for natural fine aggregates, prioritizing particularly waste products such as RGS (Marzouk et al., 2007, Ismail and Al-Hashmi, 2008, Limbachiya, 2009, Ferraris et al., 2009). • Some studies show the replacement of up to 50% of natural sand with mixed RGS (Taha and Nounu, 2008), while others replaced up to 20% of sand with non-biodegradable plastic wastes - mainly PE and PS (Ismail and Al-Hashmi, 2008). • Sand can be also substituted with quarry dust or stone powder: a by-product of the stone crushing industry, the material is already used in the construction industry and has been recently investigate as a fine aggregate replacement in concrete mixes (Lohani et al., 2019; Mahzuz et al., 2011). • Other more experimental sand substitutions include the use of sugarcane bagasse ash (SBA), a hydraulic and pozzolanic reactive by-product of the sugar industry (Sales and Lima, 2010).	• Replacing sand with non-biodegradable plastic wastes is a potential solution for the plastic solid waste problems (Ismail and Al-Hashmi, 2008).	
Ceramic Waste	• Chinese studio Bentu Design investigated the waste produced by the ceramic industry, particularly in the town of Chaozhou, known as the "biggest ceramics production base in the world and creates around 70 per cent of the daily-use ceramic commodities used globally" (de Klee, Dezeen, 2018).	• This initiative was made in an effort to highlight the value in waste; to reduce the unnecessary use of new resources; to lower energy consumption; and to better incorporate material recycling into modern lifestyles and habits	Bentu proposed a line of concrete furniture with an exposed ceramic shards aggregate (Bentu Design, 2021; de Klee, Dezeen, 2018).

Table 2 – use of Portland Cement Substitutes in new concrete mixes – T. Harb, 2021

Types of substitute	Description and specifications	Main advantages and disadvantages	Featured projects or studies
Fly Ash	• Fly ash is a residue of coal combustion and has received some attention in recent years as theoretically able to replace up to 100% of Portland cement; although a chemical activator is needed for replacements over 80% so far (Meyer, 2005). • Originally a very toxic waste product resulting from burning coal, fly ash is now required to be captured with pollution control equipment (Assi et al., 2018; Noe, Core77, 2020). • Inspired by the use of the chemically similar volcanic ash in ancient Roman concrete, researchers have been attempting to use fly ash as a binding agent in concrete recipes (Assi et al., 2018; Noe, Core77, 2020).	• Offers increased durability and cost reduction (Meyer, 2005; Çolak, 2003). • Is unpredictable in terms of variable chemical composition and quality, amongst others (Meyer, 2005; Çolak, 2003).	Some designers have begun showcasing its advantages in applications: Emeco and design master's student Erica Stine's fly ash chair is a great example demonstrating the reuse of the otherwise toxic material in furniture applications. The project has attracted the attention of the media and won a 2020 Red Dot Design Award (Noe, Core77, 2020).
GGBFS	• A by-product of the steel industry known as GGBFS has been looked-into as a cement replacement. • Current optimal levels of replacement are between 70% and 80% (Taylor, 1997; Meyer, 2005).	• Offers multiple technical, mechanical and economic advantages (Taylor, 1997; Meyer, 2005). • Although the price of GGBFS is comparable to that of cement, it is not as widely available as fly ash, which makes it less practical in some ways (Meyer, 2005).	
Condensed Silica Fume	• Is a pozzolanic material which comes as by-product of the semiconductor or silicon industry (Meyer, 2005).	• It was proven to enhance strength and durability of performance concretes (Meyer, 2005). • its cost surpasses that of cement, and its extreme fineness makes it difficult to manipulate (Meyer, 2005).	
Natural Pozzolans	• They have been used in combination with lime since the ancient times in concrete mixes: they can range from volcanic to sedimentary origins (Taylor, 1997). • They can be described as a "volcanic tuff that consists of glassy particles of variable silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) content" (Çolak, 2003). • They are mostly used to constitute pozzolanic cements in various applications (Taylor, 1997).	• Some require additional energy-consuming heat treatments to become reactive (Taylor, 1997). • The water content required for workability has to be increased for concrete mixes including natural pozzolans (Çolak, 2003). • Offers strength development, amongst other advantages (Çolak, 2003).	

Table 3 – concrete additives – T. Harb, 2021

Type of concrete	Description and specifications	Main advantages and disadvantages	Featured projects or studies
Photocatalytic Concrete	• The addition of photocatalysts to building materials has been rapidly developing in multiple fields, particularly	• It helps decrease pollution by reducing either air pollution or	• It was initially developed by Italcementi Group, which was acquired by Heidelberg Cement Group in 2014. In 2003, they developed the patented

	environmental and civil engineering (Beeldens, 2020; Mujkanović et al., 2016). • Photocatalysts such as Titanium Dioxide (TiO2) have been added to traditional concrete mixes resulting in a self-cleaning composite which is also known as smog-eating concrete (Italcementi Group, 2016) • It uses UV light sources (that can be found in sunlight) to neutralize harmful pollutants such as Nitrogen and Sulfur Oxides (Mujkanović et al., 2016). • TiO2 can be either mixed into all varieties of concretes or added as a coating • Rainwater simply washes away the surfaces revealing a cleaner and whiter concrete (Mujkanović et al., 2016).	the pollution of the surface itself (Beeldens, 2020). • It minimizes maintenance costs in terms of cleaning pollution and dirt stains (Mujkanović et al., 2016).	material that they called Bianco TX Millennium for American architect Richard Meier who required a consistently white material for his Jubilee Church in Rome, which WON Church of the Year in 2000 (Miller, The New York Times, 2007; ArchDaily, 2009). • Other applications can be found in the Air France headquarters at the Roissy-Charles de Gaulle International Airport near Paris, or the Sarajevo Bridge near Barcelona known as the “smog-eating bridge” (BetterWorldSolutions, 2021; Mujkanović et al., 2016). • It can be found in Nemesi Architects’ Palazzo Italia, created for the Milan Expo in 2015. This particular building was even dubbed one of the world’s smartest buildings: it incorporated the air-purifying self-cleaning concrete, its cladding was also made up of 80% recycled materials, and it included photovoltaic glass that converted solar energy into electricity (Cruickshank, PlaceTech, 2018). • Photocatalytic concretes have been already used in multiple applications such as “concrete paver blocks, sound barriers and facade elements, precast architectural concrete panels, pavements, sidewalks, finish coat applications, roof tiles, cement-based tiles and cement-based restoration products” (Barbesta, 2009, P.49).
Photovoltaic Concrete	• Some projects and studies investigate the energy collection and production aspects of concrete surfaces since the energy consumption levels of commercial and residential buildings and infrastructures are projected to increase with the expansion of the urban world (Hosseini et al., 2013; Bilgen and Richard, 2002). This leaves large surfaces of function-less concrete facades are left to be utilized. • A new hybrid product combining concrete panels capturing solar energy was developed by materials company LafargeHolcim in collaboration with electronics manufacturer Heliatek (Aouf, Dezeen, 2018). • A photovoltaic semiconducting material is applied to the surface of concrete in this case, thus converting sunlight into electrical power (Bube, 1998).	• Benefits include increased generation of on-site power, less cooling requirements, supplying electrical power wen equipped with batteries to store energy (Hosseini et al., 2013).	• One pilot project of the photovoltaic concrete was tested at the LafargeHolcim Research Center in Lyon (Dezeen, 2018). • Another prototype was built by ETH Zurich’s researchers with an ultra-thin curved roof: the structure is self-supporting and was built using a net of steel cables tensioned using a modular scaffolding structure (ETHz, 2017). The net was designed based on an algorithm to support the polymer textile used as formwork and included multiple layers, the second one enclosing the roof which had the thin-film photovoltaic cells (ETHz, 2017). This type of project adequately combined an alternative formwork with digital fabrication. The pavilion also called for specifying the adequate concrete recipe “which had to be fluid enough to be sprayed and vibrated yet viscous enough to not flow off the fabric shuttering” (ETHz, 2017) and was topped off with the new photovoltaic energy generation technology. • Other studies continue to investigate the integration of photovoltaic (PV) panels into precast concrete ones, resulting in a new prefabricated facade application for high-rise buildings renamed Photovoltaic precast concrete (PVPC) (Li et al., 2019).
Light transmitting Concrete	• the concept of green transportation has been gaining in popularity in the road construction industry (Liu et al., 2019; Cadman & *Önder*, 2019; Li et al., 2021).	• LTC, combined with photovoltaic roads and wireless charging technologies, will offer a wide	• The optical fibers light-transmitting concrete technology was first invented and patented in 2001 by Hungarian architect Aron Losonczi under Litracon™

	• A light-transmitting concrete (LTC) was developed with the integration of different quantities of waste tempered glass aggregates combined with an epoxy resin binder (Li et al., 2021). • Other light-transmitting concrete technologies can be obtained with the use of optical fibers and can offer multiple advantages in terms of energy savings and lighting efficiency (Navabi et al., 2021). • In an effort to minimize the costs, some recipes replaced the optical fibers with plastic rods, although the transparency effect is visibly attenuated (Kim et al., 2017).	spectrum of practical as well as aesthetic advantages (López-Escalante et al., 2018; Li et al., 2021): e.g., increased visibility, decreased need for artificial lighting, signalization, etc.	• It has been featured in projects such as the exterior walls of the Capital Bank in Amman. • Another example is the Cella Septichora Visitors Centre's door in Hungary (Etherington, Dezeen, 2008; Navabi et al., 2021).
Photoluminescent Concrete	• Within the investigation of visibility, signalization, and safety in the road construction industry, the use of glowing materials has been studied by some (Suleymanova et al., 2020). • Photoluminescent materials absorb photons of UV radiations found in sunlight or artificial lighting, and in return radiate a dimmed down glow that can last up to 10 hours with the absence of light (Lumintech, 2021). • Amongst those materials is a 'glowing' concrete achieved through the integration of photoluminescent pigments (Suleymanova et al., 2020, P.1).	• This results in "products with a glow effect, high architectural, decorative and physio-mechanical characteristics that correspond to the operating conditions" (Suleymanova et al., 2020, P.1).	• We find technologies such as LuminTech® which proposes photoluminescent particles which can be used as aggregates in concrete applications (Lumintech, 2021). • Another example is Ambient Glow Technology (AGT)'s photoluminescent pigmented aggregates (Concrete Network, 2021).
Biological Concrete	• Concrete is naturally prone to develop stains which can be traced back to the development of biological growth, particularly microscopic algae (Dubosc et al., 2001; Wee and Lee, 1980; Grossin and Dupuy, 1978). • Some scholars believe that the development of stains on external concrete surfaces leads to the artifact's "loss of aesthetic beauty" (P.1, Dubosc et al., 2001; Higgins, 1982; Verhoef, 1986). These types of studies consider natural biological growth on concrete surfaces as an aesthetic problem needing to be remedied. They go on to demonstrate how rough and porous surfaces that are frequently exposed to high humidity tend to be the most affected by biological growth (Grossin and Dupuy, 1978; Whitely, 1973). They sometimes blame poorly designed features or maintenance faults (Borgne et al., 1994; Dubosc et al., 2001). • Researchers at the Structural Technology Group of the Universitat Politècnica de Catalunya (UPC) have been developing	• It offers multiple aesthetic, environmental, and thermal advantages, amongst others: • The concrete surface that evolves and changes throughout the seasons and the years: "the idea is to create a patina in the form of a biological covering or a "living" painting" (ScienceDaily, 2012). • The coating absorbs and reduces CO2 particles through the biological coating, improving the ecological performance of the artifact from a pollution-reduction perspective. • By capturing solar radiations, the system works as an insulating material as well as a thermal regulator (ArchDaily, 2013; ScienceDaily, 2012). • Although the technology has been patented, it remains in experimental phases (ArchDaily, 2013).	• UPC's proposed concept for the biological concrete façade for one of their campuses is an example of how this technology would be integrated into artifacts.

	and patenting what has been described as a “a type of biological concrete that supports the natural, accelerated growth of pigmented organisms'', specifically certain types of microalgae, fungi, lichens and mosses (ScienceDaily, 2012). • By influencing bio receptive parameters such as the pH levels, porosity, and roughness of the surfaces, the researchers at UPC have created a multilayered concrete panel in addition to the structural one: The first layer is waterproof, the second is the biological one allowing water to accumulate inside, and the third is a discontinuous waterproofing one, capturing the water inside (ScienceDaily, 2012; ArchDaily, 2013; Dezeen, 2013). • The multilayered system becomes an integral part of the artifact, as opposed to vertical gardens or vegetated facades which are add-ons (ArchDaily, 2013).		
Self Healing Concrete	• Recent studies have been investigating biological self-healing concrete as a means to extend the service life of concrete artifacts without human intervention (Srinivasa et al., 2012; Silva et al., 2015; Talaei Khozani and Majid, 2014). • “When the concrete is mixed with bacteria (bacillus subtilis), the bacteria go into a dormant state, a lot like seeds. All the bacteria need is exposure to the air to activate their functions. Any cracks that should occur provide the necessary exposure. When the cracks form, bacteria very close proximity to the crack, starts precipitating calcite crystals.” (P.393, Srinivasa et al., 2012) • The bacteria is nonpathogenic, can be found in the soil or produced artificially, and can be safely utilized to remedy concrete cracks (Srinivasa et al., 2012).	• It promises to reduce maintenance costs • It can protect the reinforcement from corroding by helping prevent the surface from deforming and exposing them (Srinivasa et al., 2012).	
Electricity-conducting concrete	• In an effort to make concrete more sustainable by expanding its functions beyond its structural advantages, researchers from the MIT Concrete Sustainability Hub (CSHub) in partnership with the French National Center for Scientific Research (CNRS) have recently explored electron conductivity (Logan, MIT News, 2021).	• It promises additional concrete functionalities such as self-heating, electromagnetic shielding, and energy storage (Soliman et al., 2020). • “The emergence of multifunctional cement-based materials in the construction industry has the potential to shift the paradigm from strength-only performance to new functionalities enabled by	

		electron conducting capabilities in one of the most material- and energy-intensive industry sectors worldwide" (Soliman et al., 2020, P.1)	
Nano Platelets Concrete from Root Vegetables	• Researchers at Lancaster University in collaboration with industrial sustainable materials company, Cellucomp, have found that nano platelets found in waste products of the food industry (e.g. roots vegetables, specifically carrots), could strengthen concrete mixtures (Aouf, Dezeen, 2018).	• The composites surpass current cement products in terms of mechanical and microstructure properties (Mohamed Saafi, lead researcher, cited in Aouf, Dezeen, 2018). • They call for smaller amounts of cement, reducing CO2 emissions and energy consumption (Mohamed Saafi, lead researcher, cited in Aouf, Dezeen, 2018). • It can be a more cost-efficient alternative to graphene or carbon nanotubes (which contains concrete's primary strength substance: calcium silicate hydrate) (Aouf, Dezeen, 2018).	

Table 4 – Alternatives to concrete – T. Harb, 2021

Concrete Alternatives	Description and specifications	Main advantages and disadvantages	Featured projects or studies
Bio-'concrete'	• A new material referred to as bio-concrete has been proposed by Central Saint Martins graduates Brigitte Kock and Irene Roca Moracia (Hahn, Dezeen, 2021). • Based on the Roman's volcanic ash concrete recipe, two invasive species (e.g. Japanese knotweed acting as the binder and shells from American signal crayfish acting as the aggregates), which are combined to water and gelatin to create tiles of different natural pigmentations and textures. • The bio-concrete project is considered to be in its very preliminary stages and will require time to optimize the recipe as well as overcome building regulations and rules (Hahn, Dezeen, 2021).	• The non-native species are labeled as hazardous waste in the UK, threatening biodiversity on a worldwide level by changing local water quality and leading to floods and other catastrophes (Hahn, Dezeen, 2021). The researchers thus aim to relocate them by creating a new industry. • The resulting material can be cast into any shape, offering both economical and ecological advantages (Irene Roca Moracia cited by Hahn in Dezeen, 2021)	
Sea Stone 'Concrete'	• Royal College of Art (RCA) materials lab Newtab-22 created a sustainable concrete-like material that utilizes seashell waste from the seafood and aquaculture industries (Crook, Dezeen, 2020). • Seashells contain high concentrations of limestone; therefore, when combined with non-toxic natural binders such as sugar and agar, the resultant is similar to cement (Crook, Dezeen, 2020).	• It offers multiple ecological advantages in addition to being able to be easily pigmented • The material is brittle and non-structural	• The new material has been utilized in non-structural small-scale products, notably decorative tiles, tabletops, plinths, and vases (Crook, Dezeen, 2022).
Dead Sea Salt building blocks	• As a sustainable approach to building by focusing on local material sourcing designer Erez Nevi Pana used 5 tons of salt from the Dead Sea in his building blocks Crystalline collection.	• The aim was to draw attention on the quantity of waste salt produced in the	

	• Thus temporal structures were created by utilizing by-products of potassium and bromine industries as well as existing salt-water waste: (Carlson, Dezeen, 2021; Erez Nevi Pana, 2021). • The product utilizes technologies such as compression-and-heating processes, CNC-milling, and adding an impervious layer for a protective surface (Carlson, Dezeen, 2021). • "In environments where the abundance of salt is present, there is no logic in importing sand from disappearing beaches, [...] I can imagine salt cities being built right there – white, glossy natural structures emerging." (Erez Nevi Pana cited in Carlson, Dezeen, 2021).	world as well as alternative building materials.	
Wastepaper Cellulose Fiber Construction Boards	• Spanish start-up Hontex has taken cellulose residue found in paper mills waste and transformed it into sustainable construction boards for interior partitioning or cladding (Hitti, Dezeen, 2020). • The carbon-neutral manufacturing process includes enzymatic treatments instead of non-recyclable resins or gluing additives as a binder, and non-toxic UV protection additives can be integrated (Hitti, Dezeen, 2020).	• The resulting material can be seen as a lightweight alternative to concrete or MDF construction panels.	• Spanish start-up Hontex's sustainable construction boards have been used in some projects around the world so far.
K-briq	• Heriot-Watt University engineering professor Gabriela Medero's K-Briq is a construction brick launched by startup Kenoteq made from 90% construction waste (Aouf, Dezeen, 2020; KENOTEQ, 2021). • It is the manufacturing company's wish to transition shortly into mass production, all while preserving the zero-waste and carbon-free initial intentions.	• The ecological bricks aesthetically and technically behave like regular clay ones • They offer better insulation properties • They can be produced in any color (Aouf, Dezeen, 2020). • Currently, they are being sourced, produced, and used locally in Europe, in an effort to reduce carbon emissions from transportation (Aouf, Dezeen, 2020).	

Table 5 – Concrete's semantic attributes based on the historical and mediatic review – T. Harb, 2021

Attribute A & complimentary terms	Citations	Attribute B & complimentary terms	Citations	Definitions and understandings of attributes
Sensuous beautiful, pleasant	[architects] "exploited concrete's sensuous and tactile properties, and its capacity to suggest that buildings were 'real', the outcome of an actual process of construction […]" (Forty, 2013, P.281)	**Dull ugly, unpleasant harsh**	"[…] some substances age less well that others. Concrete becomes more ugly every passing year, looking greasy if smooth, squalif if rough" (David Lowenthal cited in Forty, 2013, p.52)	Within our research, what is referred to as 'sensuous' is defined as "producing or characterized by gratification of the senses : having strong sensory appeal" while 'dull' is understood as what is "lacking brilliance or luster" or "uninteresting". Additionally, 'beautiful' refers to what has "exciting aesthetic pleasure" and "is generally pleasing"; and 'pleasant' describes what is "having or characterized by pleasing manners, behavior, or appearance". Whereas "ugly' refers to what is "offensive or unpleasant to any sense" and is "likely to cause inconvenience or
	"[…] we see architects preoccupied with the problem of how to make matter disappear so that other qualities would emerge - quite the opposite to the privileging of concrete's sensuous and tactile properties in the recent revival of concrete." (Forty, 2013, P.283)		"[…] one of the early icons of the heavy concrete style [Marchiondi Institute] has weathered very badly, and now that the exposed concrete is stained and streaked, to the visitor, it seems very harsh" (Reyner Banham commenting on the Marchiondi Institute, P.124, in Architectural Design, 1966)	
	"As a surface that enabled photography to exploit its own specific qualities, its ability to represent every tonal variation from total black to extreme white, concrete was second only to human skin" (Forty, 2013, P.271)		"grey boring mass" (Ronco, 2017) that bear "the usual stains and steaks" (Theo Crosby commenting on Brunswick Centre in London, cited in Forty, 2013, P.54)	
	"In a flexible mould, concrete is rediscovered as a wet, sensual, and responsive material." (West, 2016, P.4)		"It is not that concrete refuses to stay securely within either the one or the other category, flitting between them, but that it fails to conform to a classificatory system through which we habitually make sense of the world; this	
	"[…] concrete was considered to be the concern of skilled craftsmen, and capable of displaying an inherent			

	beauty" (Ernest Leslie Ransome, one of the first American architects using reinforced concrete, cited in Collins, 2004, P.62)		is without question one of the causes for the distaste with which it is often viewed within the developed world." (Forty, 2013, P.41)	discomfort" and 'unpleasant' refers to something that is "not pleasant: not amiable or agreeable". Furthermore, 'harsh' is used to describe what is "causing a disagreeable or painful sensory reaction" or "having a coarse uneven surface that is rough or unpleasant to the touch".
	"The material's [polished concrete] natural beauty that's expressed through varying aggregate reveals, the color of the cement binder and the clarity of the polished surface makes it a singularly unique flooring choice." (Morris, in Concrete Decor, june 2020)			
	"Two critics described the Garage rue de Ponthieu as the work where the original beauty of reinforced concrete first emerged" (Legault, 1997, referred to in Forty, 2013, P.27)			
	"[…] concrete is the stone that we make, much more beautiful and more noble than natural stone […]; it [concrete] is the rejuvenated stone" (Auguste Perret, French architect and reinforced concrete pioneer, as quoted in Forty, 2013; Zahar, 1959; and Culot et al., 2000)			
	"concrete is the stone that we make, much more beautiful and more noble than natural stone" (August Perret cited in Forty, 2013, P.45) Readers of the Dezeen article published in July 2020 commenting on MoDus Architects' undulating concrete tunne displayed positive remarks such as "the only problem will be people wanting to stop for selfies with the tunnel entrances" (by @Bubba10, Dezeen, 2020) or "extremely handsome" (by @Felix Amiss, Dezeen, 2020).			
	the Zeitz Museum of Contemporary Art Africa by designer Thomas Heatherwick which was described by commenters as "seriously remarkable" (by @Steve Leo, Dezeen, 2017)			
	Comments on architect Marco Merendi and industrial designer Diego Vencatoès Petra collection include impressions such as "I'm not a fan of concrete but in this case looks beautiful." (@Sylvia Sanchez, Dezeen, 2019); "Concrete is the best material." (@Aigoula48, Dezeen, 2019); and "Material innovation (even though concrete is getting old) at its best." (@Marc Sicard, Dezeen, 2019).			
	"From this point on, photography's main service to concrete was to enhance its aesthetic properties." (Marcel Magne, in Art et Décoration, July-August 1919, cited in Forty, 2013, P. 28)			
Luxurious prestigious, expensive	"[…] it was the mission of entrepreneurs like Françcois Coignet in France, or W.H. Lascelles and James Pulham in Britain, to redeem it [concrete] - and church building, the most prestigious branch of architecture, presented the best opportunities to lift the medium out of its base associations." (Adrian Forty, architectural historian, P. 169, in Forty, 2013)	**Inferior cheap**	"[...] the results [concrete constructions] are likely to be stigmatized as 'cheap'. Because, supposedly, anyone can do it, the work of making concrete carries little prestige; compared to things made out of materials whose workmanship relies upon crafts with long traditions and established patterns of training, concrete has for most of its history been looked down upon as inferior" (Adrian Forty, architectural historian, P. 225, in Forty, 2013)	In our context, 'luxurious' is understood as what is "characterized by opulence, sumptuousness, or rich abundance" or "of the finest and richest kind" while what is 'inferior' is seen as "of little or less importance, value, or merit" and "of poor quality". In that sense, 'prestigious' refers to what is ": standing or estimation in the eyes of people" and 'expensive' is what commands "a high price and especially one that is not based on intrinsic worth or is beyond a prospective buyer's means". Contrarily to 'cheap', which refers to what is of "inferior quality or worth" by being "contemptible because of lack of any fine, lofty, or
	"Until the last quarter of the century [19th century], the high cost of imported cement made the use of mass concrete an unjustifiable luxury for any type of building" (Adrian Forty, architectural historian, P. 56, in Forty, 2013)		"[...] when first developed in the early nineteenth century concrete was regarded as a low-grade substance suitable for foundations and retaining walls [...]" (Adrian Forty, architectural historian, P. 169, in Forty, 2013)	
			"Many cheaply built churches, it was said, would serve the purposes of religion better than a few magnificent ones. In this context, cheapness became a virtue." (Adrian Forty, architectural historian, P. 185, in Forty, 2013 referring to Winiger, 1957)	
			"[...] le béton, massif, inélastique, inerte, artisanal, incalculable, pas cher, dans un contexte économique restreint et fluctuant [...]" (P.2 in Guillerme, 2007, referring to Simonnet, 2005)	

			"During the whole of this early period [1870s], the principal concern of those who advocated concrete was, as has already been pointed out, that of cheapness" (Adrian Forty, architectural historian, P. 53, in Forty, 2013 "[…] there are the usual stains and streaks, the usual lack of drip mouldings which might throw the water clear of the vulnerable splayed surfaces, but again that is almost an essential element of the new architecture: concrete's deficiencies with regards to the effects of time seemed unavoidable" (Theo Crosby commenting on Brunswick Centre in London cited in Forty, 2013, p.54) "Reinforced concrete is one of the 'new technologies of poverty' - in overall quantity consumed, its use by self-builders in poor countries probably exceeds all other applications" (Forty, 2013, P.40)	redeeming qualities".
Durable **resistant, reliable**	"it [concrete] empowers people with no more than a rudimentary knowledge of construction to produce durable and salubrious structures on a scale that would otherwise be beyond their means." (Forty, 2013, P.225) "Concrete is a base material. Its dense mass lends to the resistance of forces, whether natural or man-made." (Forty, 2013, P.169) '[…]a medium of defense.' (Charles Reilly, English architect, P.178, in Forty, 2013) "As an essentially passive medium, capable of absorbing enormous forces, concrete's defensive properties were recognized early on, and among its other early applications were sea defences and harbour works" p.170 "il [béton] devient fiable parce qu'on peut calculer ses états limites, il résiste à l'incendie, aux bombes" (Guillerme, 2007, P.3)	**Ephemeral** **weak, non-durable**	"A real problem with the concrete of the 60s was that it has not resisted humidity and frost in the long run as durable as we believed" (Pekka Pitkanen, Finnish architect, P.53 in Forty, 2013, referring to Dodson, 2006)	What is 'durable' is understood as something that is "able to exist for a long time without significant deterioration in quality or value"; whereas what is 'ephemeral' lasts for "a very short time". Complimentary adjectives 'resistant' refers to the "power or capacity" to "withstand the force or effect of" and 'reliable' is understood as what is "dependable" by "giving the same result on successive trials". Contrarily, 'non durable' is what is "able to exist for only a short time before deteriorating" and 'weak' is understood as what is "lacking strength" while not being able to "resist external force or withstand attack" or " sustain or exert much weight, pressure, or strain".
Warm **inviting**	"The aging of the concrete is a natural and aesthetically pleasing characteristic that influences its appearance in a graceful manner" (IVANKA, 2021) "despite its texture and colors which would make a space feel cold and not exactly cozy, concrete can be used in numerous ways and, in the right combination, a home can have concrete features and still be warm and inviting" (Ganea,Home Edit, 2013)."despite its texture and colors which would make a space feel cold and not exactly cozy, concrete can be used in numerous ways and, in the right combination, a home can have concrete features and still be warm and inviting" (Ganea,Home Edit, 2013).	**Cold** **depressing, distant, boring, hostile**	"the natural grey of Portland cement is cold and depressing, and time and weather, […] make untreated concrete more and more dirty, dark and untidy […]" (the Royal Institute of British Architects, P.40, in Ministry of Works, 1946) " [concrete] generally only has one colour, it is not polychrome - a feature that has often caused concrete to be seen as dreary and depressing." (p.260, in Forty, 2013) " [concrete is] considered as a grey boring mass it is a kind of unknown, seen as distant and rejected as a noble material." (Ronco, Concrete Perception, 2017) "I do not dream when in Paris, in this geometric cube, in this cement cell, in this iron-shuttered bedroom so hostile to nocturnal matter" (Gaston Bachelard, french philosopher, in La Terre et les rêveries du repos, P.96, 1948, cited in Forty, 2013, p.197) "[…] concrete the material of oblivion, avoided by artists hostile to mnemonic representation, but chosen by those seeking to represent memory - might at least tell us something about the semantics of concrete, if not also about the modern representation of memory" (Forty, 2013, P.198) "[concrete] generally only has one colour, it is not polychrome - a feature that has often caused concrete to be seen as dreary and depressing." (Forty, 2013, p.260) "The role of concrete is more commonly to supply effects of density and mass than to prove how 'advanced' architecture is" (Forty, 2013, p.290)	Something that is 'warm' can be literally seen as "serving to maintain or preserve heat especially to a satisfactory degree", while metaphorically being "marked by or readily showing affection, gratitude, cordiality, or sympathy", in addition to "having the color or tone of something that imparts heat" and "comfortably established". In that same sense, 'inviting' refers to something that is "attractive" and "tempting". Whilst 'cold' refers to something literally "having or being a temperature that is uncomfortably low for humans" and the more psychological "marked by a lack of the warmth of normal human emotion, friendliness, or compassion". In addition, 'depressing' refers to what leads to a state of "feeling sad"; 'distant' is underwood as being "reserved or aloof in personal relationship"; 'boring' is what causes "weariness and

			"[...] presumably, bare concrete would have been considered disrespectful to the memory of the dead" (Forty, 2013, P.199)	restlessness through lack of interest"; and 'hostile' is seen as what is "not hospitable", something that has "an intimidating, antagonistic, or offensive nature".
Predictable **precise, exact**	"Concrete was understood as an exact material, which resulted in precise structures. Every work appeared as an optimum solution, a determinate structural outcome, arrived at by mathematical calculation." (Forty, 2013, P.288) When questioned about the stain resistant as opposed to the self-cleaning aspect ogf the Petra sinks, Vencato replied that "the material is dirt resistant. It's the result of a 6 years long research: it means hundreds of tests and, in the end, in a deep technical certification. That's why Agape chose it for the bathroom world, and didn't choose other types of concrete, surely less expensive. For sure it's not "self cleaning", but neither [are] ceramic or solid surface materials: you have to clean it ;)" (@Diego Vencato, Dezeen, 2019).	**Unpredict-able** **imperfect, high-maintenance**	"We can see the concrete of the wall as not simply the result of an instant, a frozen moment, but also as something that is made slowly, revealing itself as an unpredictable and long drawn-out process. The architects write about it, "most walls are detailed to shrug off the effects of time, but this is a wall that has been designed to allow to pass through it, and thereby to modify it; an evolutionary architecture" (Jeremy Till & Sarah Wigglesworth, 2001, P.26, cited in Forty, 2013, P.257) "[...] entre le fer, matériau élastique, fibreux, continu, calculable, savant, industriel, coûteux, et le béton, massif, inélastique, inerte, artisanal, incalculable, pas cher, dans un contexte économique restreint et fluctuant, la concurrence puis l'association pour étendre la résistance des matériaux et élever les architectures jusqu'aux cieux." (P.2, Guillerme, 2007 on Simonnet, 2005) "Objects will differ slightly in terms of colour, texture and porosity. Concrete products change slightly over time, potentially becoming darker on contact with air and humidity." (AtelierB disclaimer, 2021) "if concrete was perfect, it would be less good [...] it is hard to achieve concrete without imperfection" (Paul Andreu, in Marrey & Hammoutene, 1999, P.209, cited in Forty, 2013, P.52) "[...] concrete is a high maintenance material. It cracks and suffers serious wear and tear over the decades of its expected term of service." (Srinivasa et al., 2012, P.392) "The unpredictable behaviour of concrete over time is one of the main causes for its being perceived as 'unnatural' - and indeed for its bad name generally " (Forty,2013, p.52)	On the one hand, being 'predictable' is when something behaves "in a way that is expected" while being "able to be known, seen, or declared in advance". Similarly, 'precise' refers to what is "strictly conforming to a pattern, standard, or convention", and 'exact' is exhibited in "strict, particular, and complete accordance with fact or a standard". On the other hand, 'unpredictable' describes something that tends to behave "in ways that cannot be predicted" nor "known or declared in advance". In that same context, complimentary adjectives such as 'imperfect' can refer to something that can be 'defective', and 'high-maintenance' implies that something will require "a large amount of care or maintenance".
Natural **alive, evolving**	"In such a flexible system, the materials in play can no longer be considered inert or passive. Instead they are alive to action as they engage in a kind of formal self-invention in real time. This aliveness is a direct result of the system's mechanical flexibility, which challenges the designer/builder to think of matter as a participant in determining form." (West, 2016, P.5) "So we are faced with a process that while non-natural in its incapacity to exist apart from the uses to which it is put, is on the other hand much more like a natural material in its failure to be perfect" (Paul Andreu, in Marrey & Hammoutene, 1999, P.209, cited in Forty, 2013, P.52) "Architects and designers are well versed in concrete's ability to contribute to the cool, natural look that is in such demand. What is not as well known is the growing popularity of concrete furniture pieces some of North America's most creative craftsmen are creating." (Peterson, Concrete Decor, 2002) "When formed in a flexible mould, concrete begins life as a wet and flexible system, behaving precisely as a natural, biological structure might." (Marl, 2016, P.4)	**Artifical** **synthetic**	"The biologist Steven Vogel observes that there are fundamental differences between natural and human-made forms: "Living structures are generally small, wet, and flexible, while human-made structures are generally large, dry and brittle" (Vogel 1981)." (West, 2016, P.4) Comments on Jerome Byron's curved stool included : "What an environmentally destructive abomination! I know, let's pick two materials that either damage the earth or release a load of carbon, then combine them to create a monstrous hybrid that can't be reused or separated. This is not the sort of work that should be promoted and celebrated. I'm appalled." (@Cat Brown, Dezeen, 2020) "[...] a synthetic material similarly lacking in a 'raw' state, it 'is wholly swallowed up in the fact of being used"; there is no pleasure to be had from the material as such, for it only exists to satisfy a previously defined use [...] Yet concrete does not fully conform to the expectations of synthetic materials in that it lack their perfectibility" (Roland Barthes, *Plastic* in *Mythologies* 1957, cited in Forty, 2013, P.51) "Is it stone? [...] Is it plaster? [...] Is it brick or tile? [...] Is it cast iron? Yes and no. Poor concrete! Still looking for its own at the hands of Man" (Frank Lloyd Wright, architect, P.301, In Lloyd Wright, 1992)	Although 'natural' as a term has a wide range of contextual definitions, we understand it here as the characteristic of "having or constituting a classification based on features existing in nature" as in "existing in or produced by nature : not artificial". In that same sense, 'alive' can be also used to describe what is "marked by much life, animation, or activity" or even "alertness, energy, or briskness". In addition, 'evolving' refers to what undergoes "evolutionary change" or any type of change in that matter. In opposition, 'artificial' refers to something that is "caused or produced by a human and especially social or political agency" or "humanly contrived". Furthermore, 'synthetic', is used to simply describe "something resulting from synthesis rather than occurring naturally".

			“While it is certainly true that one kind of nature has been displaced, another has also been created. Let us […] call this new nature ‘urban nature’ - here, […] created through the agency of concrete.” Matthew Gandy, cultural, urban, and environmental geographer, P.61, in Forty, 2013 mentioning Gandy, 2002)	
			‘If concrete offends, it is not so much for being ‘unnatural’, but rather because it threatens the convention of the division between nature and the non-natural.” (Forty, 2013, P.59)	
			“Concrete, a non-natural, industrially derived product, does not conform to the expectations that we have of synthetic products. " (Paul Andreu, in Marrey & Hammoutene, 1999, P.209, cited in Forty, 2013, P.52)	
			“[…], an artificial product, plundered from nature, it resists nature and produces environments from which nature is excluded, that are ‘denatured’.” (Forty, 2013, P.68)	
Amorphous-us **plastic, flexible**	“Concrete has next to no opinion about its shape; a wet, heavy, gloppy material, it will take any shape you give it, so long as you can hold it still for a few hours (Schjeldahl 1992). Its plasticity suggests that it might take an extraordinary variety of forms – so how did such an amorphous material end up as so many rectangular solids and cylinders?” (P.4, West, 2016)	**Rigid** **orthogonal, monolithic**	“Nearly all industrial building materials are produced through some form of simple mill – saw mill, rolling mill, extrusion, etc. These are all single-axis mills, whether powered by wind, water, animal, or engine.1 Whatever passes through such a mill will have a uniform section along its length. This is the instrumental origin of all the straight, flat sticks and sheets that constitute our building materials. Obvious exceptions include things that are carved or cast. But if you are casting into a mould made of sheets and sticks, then the casting will likely be both flat, straight and built with 90-degree joints” (West, 2016, P.4)	Being ‘amorphous’ can characterise something that has “no definite form”, that is “shapeless”. In addition, ‘plastic’ is seen as what is capable of “being molded or modeled” or “adapting to varying conditions” by being “pliable”. In that same sense, ‘flexible’ characterizes something that has a “ready capability to adapt to new, different, or changing requirements”. Whereas being ‘rigid’ can refer to something that is “deficient in or devoid of flexibility” while “appearing stiff and unyielding”. In addition, ‘orthogonal’ here refers to what has “a linear transformation”. Finally, ‘monolithic’ is understood as what is “cast as a single piece” while “constituting a massive undifferentiated and often rigid whole” while “exhibiting or characterized by often rigidly fixed uniformity”.
	"concrete can be designed in options, straight, curved, or freeform; a variety of edge treatments are possible; surface treatments such as textures and inlays can be used; and the concrete can be tailored to compliment glass, metal, or wood. " (Peterson in Concrete Decor, 2002)		“[…] entre le fer, matériau élastique, fibreux, continu, calculable, savant, industriel, coûteux, et le béton, massif, inélastique, inerte, artisanal, incalculable, pas cher, dans un contexte économique restreint et fluctuant, la concurrence puis l’association pour étendre la résistance des matériaux et élever les architectures jusqu’aux cieux.” (P.2, Guillerme, 2007 on Simonnet, 2005)	
	"A primary reason for its popularity as a building material stems from the fact that it goes naturally from a fluid to a solid state – being able to flow and fill a mold, and upon hardening sustain a load. This gives great flexibility in terms of material handling and placement, something that has yet to be fully exploited in the world of digital fabrication.” (Wangler et al., 2016, P.67)		“Nearly all our traditional tools, from the table saw, to the drafting machine, to the crosshairs of the cursor in your computer, are saturated with this self-same orthography.2 This is a powerfully coherent material culture indeed, and when reinforced concrete architecture made its appearance (let’s say, from the late 19th century), it is little wonder that the shape of its moulds fell right in line. Although the potential for concrete to take other kinds of forms is latent, and many have dreamed of and sought such liberation, the cultural current of the right angle remains very strong indeed” (West, 2016, P.4)	
	“Concrete’s activity in this new relationship [flexible molds] constitutes an empowerment of plasticity itself in construction and design. The arrival of flexibility and plasticity into construction alters form in a fundamental way.” (West, 2016, P.4)			
	“[...] the plasticity of concrete reappears to us as something extraordinary in a construction material” (West, 2016, P.4)			
Versatile **practical**	“The economy, efficiency, durability, moldability and rigidity of reinforced concrete make it an attractive material for a wide range of structural applications” (P.381, Mahzuz et al., 2010 quoting Ferguson et al., 1988).	**Limiting** **impractical**	However, on the subject of 3D printing with concrete and the speed it takes, some readers pointed out that “a week is too long [referring to the 3d Housing 05 project], considering the China ones [referring to the Winsun New Materials houses] take a day” (by @spadestick, 2019) whilst others proposed an alternative point of view with “3D printing is the first step in affordable housing. You will just get the walls. You still need to add windows, doors, utilities, insulation, etc. We need a new building technology – Manufactured Modular Construction” (by @Gilbert Meyer, 2019)	‘Versatile’ characterises something that embraces “a variety of subjects, fields, or skills” in addition to “turning with ease from one thing to another” and has “many uses or applications”. Similarly, ‘ practical’ can refer to what is “capable of being put to use or account” by being “useful”. Whereas “limiting’ is understood

	“In reinforced concrete’s first century its versatility as a structural medium has been used to make all sorts of things, while its pliability as a cultural medium has allowed it to serve many purposes, some of them entirely at odds with one another.” (Forty, 2013, P.296)		"George Edmund Street’s concern (1878) was that concrete would restrict the expressive possibilities of architecture" (Forty, 2013, P.243)	as something that is “restrictive”; and ‘impractical’ refers to what is “not wise to put into or keep in practice or effect”.
	The 24-hours 2D printed concrete houses project received encouraging comments such as “this can be a game changer in so many markets. Fantastic potential” (by @Jelle van Buuren, DesignBoom, 2014)		"In the second half of the 19th century, whereas many enthusiastically embraced concrete, others grew wary of it and feared it “primarily on the account of its aesthetic limitations” (Forty, 2013, P.243)	
	“[...] reinforced concrete is more than a material, it is a totally new construction process which permits the realization of all kinds of forms, the solution of all constructional problems. It can appear under all kinds of costume.” (Edouard Arnaud in Hennebique’s le Béton Armé, 1901 quoted by Forty, 2013, P.83)			
	“[concrete is] capable of unlimited development [...]” (Progressive Architecture American Journal, 1966 quoted in Forty, 2013, P.87)			
Dominant **present, conspicuous, ubiquitous**	“ [...] attempts to make concrete behave as if it were a colourless, recessive, non-substance invariably turned out to have the opposite result” (on Peter Eisenman’s House I and II, 1967-1969, in Forty, 2013, P.285)	**Inconspicuous** **trivial, unnoticeable, recessive**	“concrete is a material without any absolute value as such”(Pekka Pitkanen in Helsinki, 2003, cited in Forty, 2013, P.78)	Something that is ‘dominant’ can be seen as “commanding, controlling, or prevailing over all others”. In that same sense, by being ‘present’, something can be “actually involved, at hand, or being considered”; and by being ‘omnipresent’, one can be “present in all places at all times”. Similarly, ‘ubiquitous’ is what is “constantly encountered” by being “widespread”. Whereas ‘inconspicuous’ refers to what is “not readily noticeable”, while ‘trivial’ refers to what is “of little worth or importance”. Furthermore, ‘unnoticeable’ can refer to what is “not worthy or likely to be noticed”, while ‘recessive’ can mean something that has a tendency to “move back or away”.
	“If this is what the architects who specified concrete hoped for, they were doomed to failure, for concrete has been one of the most meaning-attracting substances there is: meanings stick to it like flies to flypapers. Its very ‘neutrality’ makes it an Aladdin’s cave of signification.” (Forty, 2013, P.286)		“Pitkanen talks of fair-faced concrete as ‘insignificant’ as ‘hardly anything’” (Pekka Pitkanen in Helsinki, 2003, cited in Forty, 2013, P.281)	
	“In stratagems of the ‘neutral’ and the ‘unmarked’, concrete is no longer available as a medium. At least in the West, as long as concrete remains bound to modernity, with all the tensions that carries in its train, concrete cannot easily revert to invisibility. In the most successful instances of its recent use, it is given a presence, one that is full knowing about, and engages with, ambivalence, towards modernization” (Barthes translated by Rosalind, Kraus and Hollier, 2005, p.51, cited in Forty, 2013, P.286)		“Somewhat ambiguous - and the architect’s [Pekka Pitkanen] comments draw attention to this - the concrete both recedes, making a background against which other things stand out, but also entirely dominates the building [The chapel of the Holy Cross at Turku Cemetery]” (Forty, 2013, P.281)	
	“Its [Moshe Safdie’s Habitat 67] being of concrete, though now its most insistent feature was, in a sense, of no importance at all.” (Forty, 2013, P.283)			
	“If concrete was meant to be invisible, it is unmissable” (Forty, 2013, P.281)			
	concrete is everywhere, and makes everywhere the same - or does it?” (Jacques Tati’s 1967 film Playtime quoted in Forty, 2013, P.101)"			
	“Somewhat ambiguous - and the architect’s [Pekka Pitkanen] comments draw attention to this - the concrete both recedes, making a background against which other things stand out, but also entirely dominates the building [The chapel of the Holy Cross at Turku Cemetery]” (Forty, 2013, P.281)			