INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

PERFECTION VS IMPERFECTION - EVOLVING PERCEPTUAL QUALITIES OF CONCRETE

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ABSTRACT
This paper talks about material aging and quality perception of concrete artifacts and discusses how both can affect the user experience. It explains how innovative concrete recipes and manufacturing techniques gave rise to alternate uses while referring to critical milestones that triggered change throughout the material's history. The authors observe changing attitudes towards perfection and imperfection and discuss sustainable and emotionally-durable trends that embrace material ageing. The research reveals significant progress in concrete technologies. It will remain the most prescribed building material for the expansion of the urban world. Learning to better compose with material ageing is therefore necessary and of high relevance to design education and all disciplines concerned.

Keywords: Industrial design, sustainable design, quality perception, product and material experiences, concrete artifacts

1 INTRODUCTION
In a world where city centres continue to expand, concrete is under great scrutiny. Over the years, it has considerably shaped the urban landscape and affected urban users' quality of life. The environmental, sociocultural, and economic effects of urban densification are of great concern and have caught attention of various disciplines which recognise the urgent need to address these issues [1], [2], [3].
Engineers, architects and industrial designers are thus searching for more durable solutions all while favouring eco-friendly materials and diminishing wasteful practices. Trending activities include life cycle analysis, recycling of materials, and reduction of waste.
We were interested in looking into possibilities to prolong the use of a product and making material aging acceptable. Our research was more specifically investigating the appraisal and user experiences of concrete artifacts [4], [5] to better understand the complex cultural and social phenomena that affect quality perception of concrete. Since perceptions are idiosyncratic and highly context dependent, it was necessary to immerse ourselves in the subject by both observing and actively participating in the experience of the material in its contexts [4] by studying the material's appraisal through a naturalistic approach [5], [6], [7].
Literature reviews helped us amass data from historical and technical documents, scientific studies, and mediatic sources providing us with insights into concrete's development throughout history and identify the milestones that triggered change. Empirical observations and photographic content helped us document physical and contextual characteristics of concrete artifacts and extract varying perceptual qualities [9]. The gathered data was subsequently mapped out, categorised and interpreted using the material's experience frameworks [13] [14]. In addition, gathered statements and testimonies revealed people's varying perception of the material. The following sections explain the key findings and how they influence the perception of concrete.

2 WHAT CAN BE LEARNED FROM THE EVOLUTION OF CONCRETE
History teaches us how technological progress and socioeconomic needs have shaped societies. Our historic overview of concrete's evolution revealed to us which critical milestones have affected the industry.
The research showed that a wide variety of concrete-like materials and mixes can be traced back to ancient Neolithic, Greco-Romanic, and Middle Eastern civilisations [15]. The categorisation of concrete, as seen below, shows that concrete-like materials can be either naturally found or manufactured from various compounds (Figure 1).

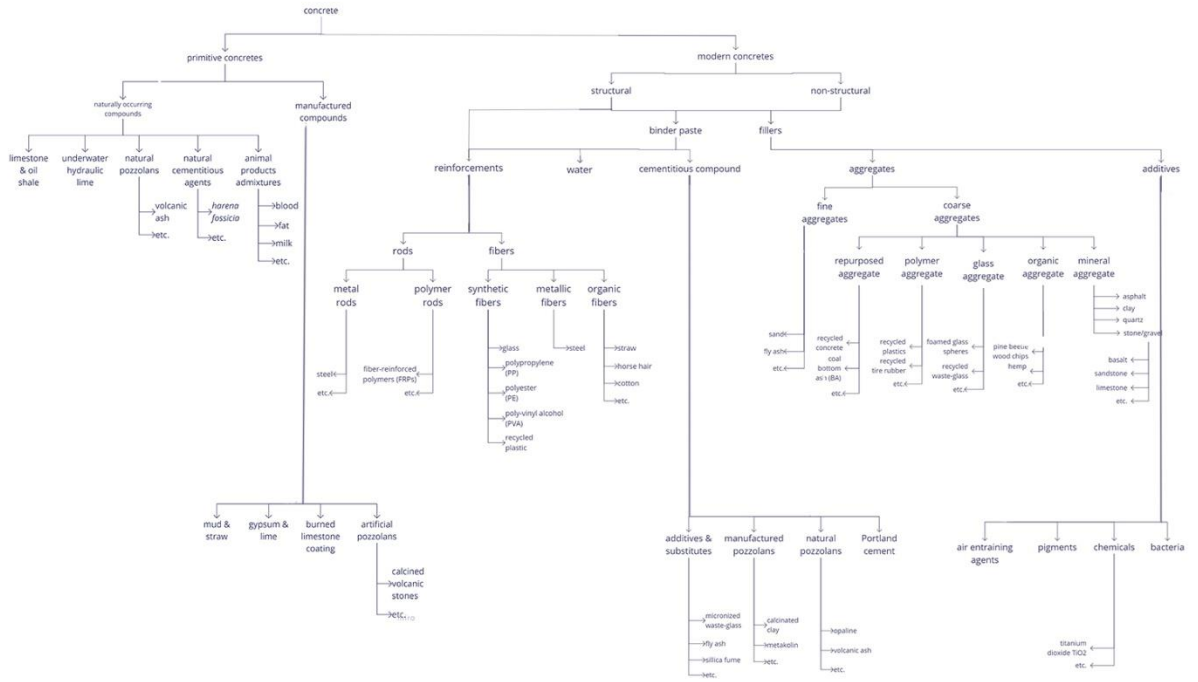

Figure 1. Primitive and Modern Concretes, T. Harb (2022)

2.1 Changing recipes

Although, recipes have been significantly improved, steel reinforced concrete and Portland cement remain to date two of the most relevant discoveries which have revolutionised the industry [15], [16], [17]. However, in the late 20th century, the material's environmental impact had become cause for great concern [18], notably due to the astonishing quantities of natural resources required to manufacture it and the effects it has on our ecosystem [19]. Driven by the sustainability movement, researchers continue to develop new mixes in order to improve concrete's physical properties, including its ecological footprint, durability, and aesthetics.

New mixes, such as the Ultra-High-Performance Concretes (UHPC), offer better compressive strength, ductility, tensile strength, heat-deflection, auto-repair capabilities, and freeze-thaw cycle resistance [21]. Other eco-friendly recipes also enhance the ecological performance of traditional MCs by incorporating recycled materials as fillers [19].

Current studies are looking into optimising the natural resources by reusing wastewater, replacing ingredients with non-biodegradable waste materials [20], or by using by-products of other industries (e.g., fly ash) [21]. Other experts explore other additives to improve concrete's performances and quality such as self-cleaning 'smog eating' concrete with photocatalytic additives [22], photoluminescent concrete absorbing UV radiation [23], and even bio-concretes which facilitate the growth of microalgae, moss, fungi, and lichens on its surface [24], to only name a few.

2.2 Changing manufacturing techniques

Furthermore, the introduction of on-site recycling and modern production techniques has considerably changed the construction industry in terms of efficiency, cost saving, and speed.

Traditionally casted in wooden formworks leading to *rigid* and *robust geometrical* shapes, alternative manufacturing techniques began using flexible formworks that produce *softer* volumes and more *delicate* finishes, as seen below (Figure 2) [25]. The introduction of 3D printing or CNC-milled moulds using fluid-dynamics algorithms, are pushing the limits even further [26], [27] (Figure 3). The need for formwork has been eliminated, all while optimising the production process, reducing waste, and increasing the precision of complex artifacts in which material is strategically placed when structural support is required [26].


Figure 2. (left) Concrete Pavilion by ZHA & ETH Zurich – image by Philippe Block via ZHA from ArchDaily.com (2018)
Figure 3. (right) Concrete Choreograph by ETH Zurich – image from Dezeen.com (2019)

2.3 Changing applications

The emergence of high-performance recipes as well as alternative manufacturing techniques is providing designers, architects, and engineers with unprecedented opportunities. They allow them to create once unthinkable shapes and textures with concrete [9]. The material, once mainly featured in large-scale architectural and structural applications, is now also being used on a smaller scale to produce indoor furniture, lampshades, sinks, or tableware.

In recent years, architects and interior designers are exposing the qualities of *béton brut* in artifacts of remembrance or spirituality (memorials, mosques, temples, churches, etc.), and more recently in residential environments, thus highlighting a *rough, strong, industrial* look, which is often associated with "brutalism". These perceptual qualities of the material are also exploited in cinematography, photography, and sculptural artwork, drawing attention to concrete's *rhetoric*, *poetic,* and *symbolic* values [9].

2.4 Changing perceptions

Although concrete is usually highly appreciated for its pragmatic qualities (e.g., *availability, performance, cost, adaptability to wide spectrum of applications*, etc.), it remains a *controversial* material which some learned to love, and others reject [9].

Our research was trying to elucidate the causes of this apparent dualism by analysing mediatic and historical documents and by extracting experts and public appraisals and testimonies. The results were organised using bi-polar semantic scales [28] (*ugly* vs. *beautiful, durable vs. non-durable, cheap vs. rich)* and subsequently analysed according to Desmet & Hekkert's *product and material experience framework* [14] by assessing the described aesthetic pleasure (or displeasure) produced while interacting with the product, the associated meanings, and the resulting emotional responses.

The study [9] revealed that design professionals, insiders, and early-adopters consider concrete artifacts as *impressive, practical, durable, richly textured, (denotative meaning),* as well as *beautiful*, *modern*, *masculine*, *sexy (connotative meaning)* [29]. According to statements, the product and material experience of some concrete artifacts generate strong feelings of *fascination*, *attraction*, and *desire*.

On the other hand, others associate concrete with *social housings, prisons,* or *bunkers*, thus resulting in a certain degree of adversity towards the material. They tend to link the material with (connotation) *war*, *social housing*, and *concrete jungle* while denoting its physical qualities: *heavy*, *grey*, *cold, rough, etc*. Concrete thus comes off as *uninviting, cold, oppressing*, and *cheap* which generates feelings of *repulsion*, *hate,* or *boredom* [9].

To appreciate a product or a material, people draw from past experiences (positive or negative). They consciously or subconsciously make associations that are meaningful or memorable to them.

Therefore, some older generations, for example, tend to associate concrete with *wars, ghettos and crumbling infrastructures*, whereas the younger generations, which may rather associate concrete with *social housing* and *vandalism.* Their experiences and appraisals affect their attitude towards the material.

2.5 Quality perception of concrete

In general, experts see concrete as a *synthetic* material which behaves like any other *natural* one as it ages [15], [16], [17]. During the casting process, as the mix cures, it spontaneously exhibits superficial *"imperfections"* that manifest themselves in form of stains, air bubbles, crumbles, and cracks (see Figures 4, 5 & 6). However, these 'signs of life' [30] are *inevitable* and *harmless* as they do not diminish the structural performance of the material [15]. Others, however, perceive them as *unattractive imperfections*, similar to blemishes, scars, or stains on skin.

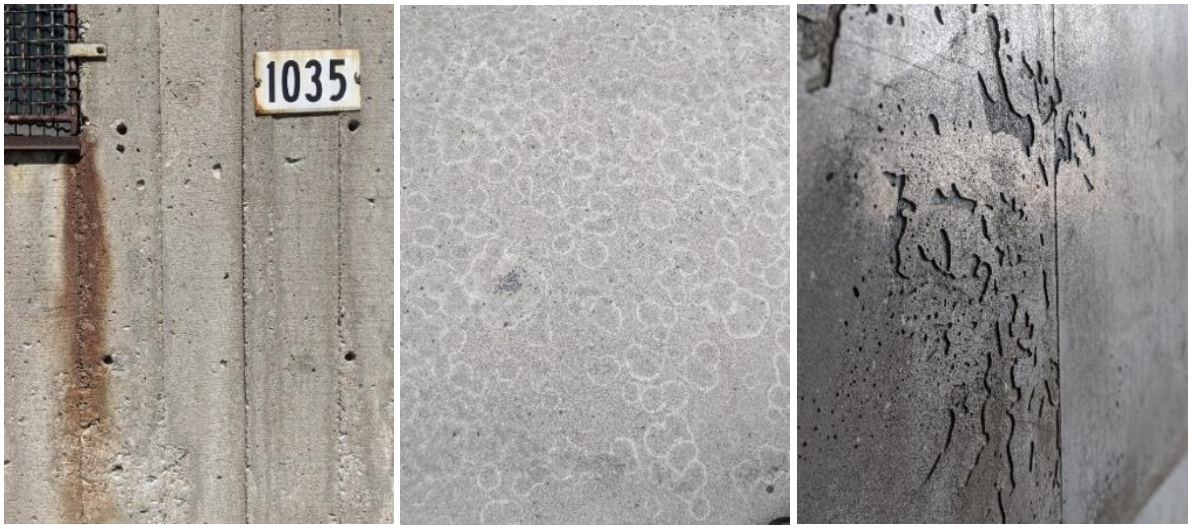

Figure 4 & 5. (left, middle) Concrete imperfections – image by T. Harb, Montreal, CA (2020)
Figure 6. (right) Concrete imperfections – image by T. Harb, Tokyo, Japan (2019)

Indeed, quality perception can be linked to modern trends in economy-driven consumer societies which easily discard *worn* artifacts rather than *preserving* or *repairing* them [30]. However, different cultures can have varied attitude towards imperfections and material ageing in general. In fact, some like to compare surface stains and scratches to wrinkles and scars on a human skin while others tend to accept these 'imperfections' as traces of life, which add a sense of *wisdom* to the artifact, making it more *valuable* and *worthy of preservation.* It mirrors the *respect* of a culture for their elders, or the appreciation of the patina on materials such as oxidised copper, old leather, seasoned wood, and other natural materials [31], [32].

Yet, while *naturally-behaving* materials and their imperfections are seen to acquire *pleasing sensorial characteristics* as they age [33], most *synthetic* materials – and concrete in particular – do not benefit from such considerations of their imperfection. This begs the question: What does it take to embrace *imperfection in* concrete and to find *beauty* in its *unpredictability* and *uniqueness*?

3 A CHANGING PARADIGM

The evolution of the material and the (re)discovery of old and new recipes contributes to a multitude of uses that are of contradicting values and meanings and which vary from one generation, culture, and society to the other [9]. Some are universally shared and pragmatic (*affordable, accessible, imperfect, etc.),* while others are far more subjective (*unique, meaningful, expressive, repulsive, intimidating, cold, etc.*) [20]. Our research shows, that these perceptions can change. Technological progress brought along new unexpected and useful features (e.g., self-repairing, CO2-absorbing, etc.) and surprising applications in new fields which affect the quality perception of concrete artifacts. The younger generations tend to embrace progress more easily by celebrating the re-discovery of the material [34].

Furthermore, modern societies are witnessing a shifting collective consciousness which call for more responsible lifestyles and sustainable practices [34]. Instead of discarding artifacts which bear signs of use, more and more users are finding value in imperfections and are learning to fix and preserve. Human centred design can contribute positively to this shift by composing with the material's natural ageing through its different uses. This paradigm shift is in part the result of our climate change awareness, a crisis that requires the world's attention.

However, aesthetic appreciations are also cultural ones. Society is learning to reject premature obsolescence by respecting, and sometimes embracing, a materials' natural behaviour as it ages. For

example, to remedy concrete defects, which may occur with the passage of time, multiple repair techniques are available (e.g., epoxy injections, overlay, stitching, routing & sealing, patching, etc.) which would prolong its use.
Yet, we may need to learn to accept such signs of material aging. Designers can play a role in this equation by considering from the beginning of the design process the different stages of the material aging across its lifecycle, knowing that some materials will degrade with time, while others mature and improve (e.g., by gaining a patina, etc.). The social values affixed to such material ageing are indeed contradictory [30] as signs of wear are seen to greatly influence the user experience thus sometimes adding value and charm through the discovery and appreciation of these manifestations (e.g., scratched old wooden surfaces), while other times rather devaluing the artifacts (e.g., stains on concrete floors)

4 RELEVANCE TO DESIGN EDUCATION

Some cultures began adopting a new material aesthetics which embraces imperfections and graceful aging and deterioration. With this rising interest in sustainability, concepts such as the aesthetic of sustainability have emerged, proving to be of high interest for design disciplines and can be seen as an effective way to influence the behaviours and actions within a society [33].
Design educators may need to do more to address questions of how to promote sustainable lifestyle, how to embrace material aging, and how to assess a material's lifecycle.
Despite its multiple advantages, concrete maintains a bad reputation. It is seen to deteriorate poorly, and mass urbanisation contributes to the depletion of our natural resources worldwide. Although, a significant progress has been made in the field, design curriculums do not always showcase it adequately and requires more attention.

5 CONCLUSIONS

To conclude, concrete can be perceived in contradicting ways as the material can hold opposing meanings: while some apprehend the material and associate it with *premature deterioration* and *environmental concerns*, others appreciate it and *admire* its *bold and unique qualities*.
The research has shown that technological progress and novel applications offer design opportunities that can also support sustainable design practices. It is our belief that design disciplines can play a significant part in helping promote a sustainable material culture and change user perception of typically neglected materials. In that sense, human-centred and sustainability-driven design teachings have the ability and responsibility to contribute positively to the shift in paradigm. Although we solely focused on the case of concrete, our observations are also relevant to other materials and artefacts.
The human centred design approach needs to better represent people's individuality and to promote emotional attachment, specifically relating to product and material experiences. Design education can thus put more emphasis on material behaviour over time and encourage designers to compose *with* – as opposed to *against* – materials' natural aging process by envisioning alternatives which extend life expectancy and embrace signs of use.

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