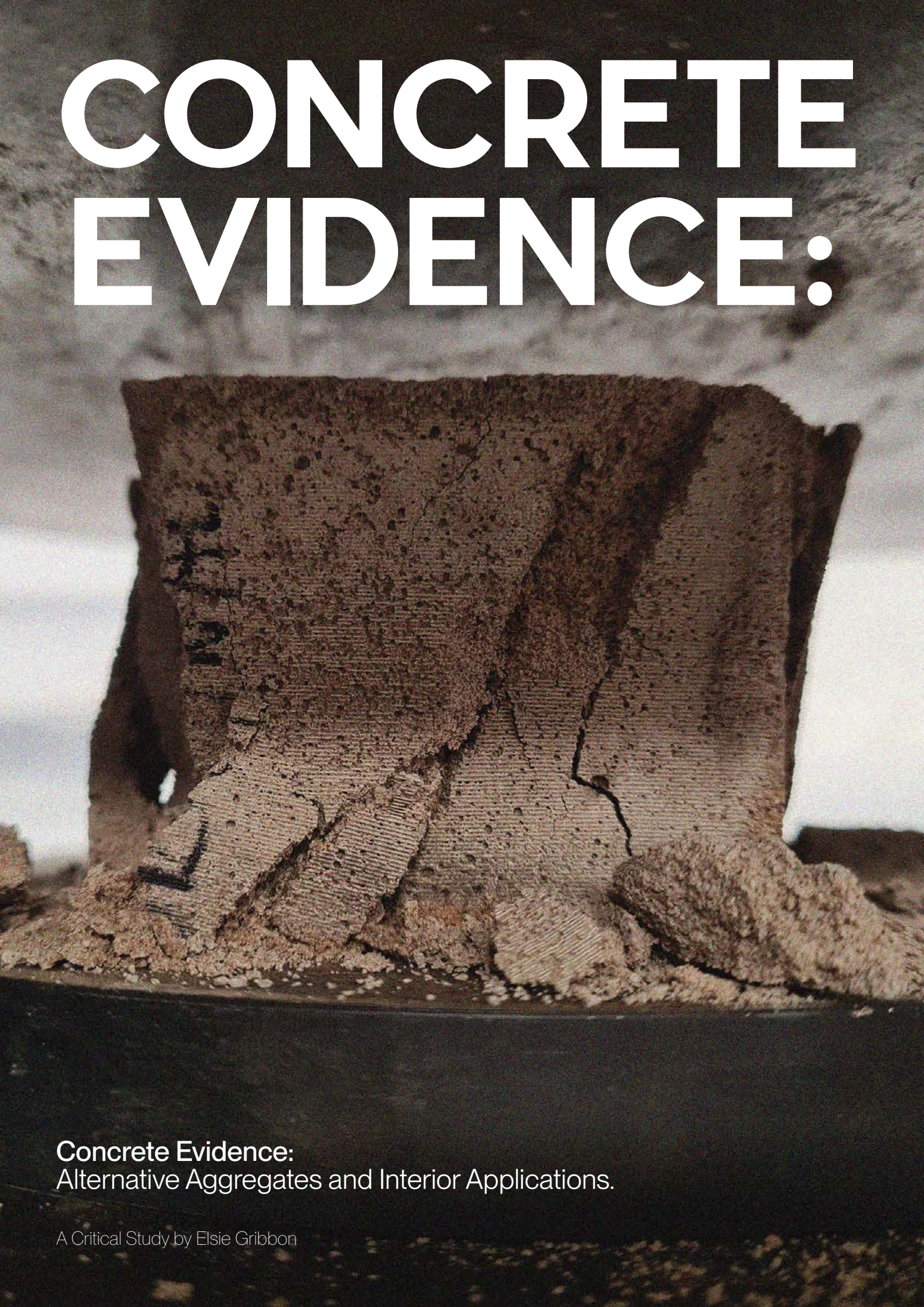
CONCRETE EVIDENCE:



Concrete Evidence:
Alternative Aggregates and Interior Applications.

A Critical Study by Elsie Gribbon

2. Mixing Mortars by Elsie Gribbon (2023).

ABSTRACT:

HOW CAN ALTERNATIVE AGGREGATES IN CONCRETE BE UTILISED BY DESIGNERS TO HELP ALLEVIATE THE ECOLOGICAL CRISIS AND DAMAGE TO COMMUNITIES CAUSED BY SAND MINING?

This study began as a critique on the amount of embodied carbon left to landfill in the environment. It was unexpected to discover through research that the Concrete Industry is dependent on mining a resource to depletion. Concrete may be made of natural materials, but the vast quantities and overuse of them make it unsustainable and have become symbolic of the examples set in Hardin's "The Tragedy of the Commons" (1968).

This critical study will begin with a literature review exploring the Designer's relationship to concrete and the initial research on embodied carbon, before outlining issues within the ecological sustainability of the raw materials needed for concrete production as well as the impact on communities of the affected areas. Case studies will be presented detailing the impact on a community in Gaborone, Botswana and from a wider ecological perspective on the impact of sand mining in India.

Research will be conducted into alternative aggregates that can potentially limit the damage currently being caused. This will be related to the importance of haptic design within Interiors by first-hand experimentation with some of the materials outlined in research as potential solutions. It will then be determined whether these materials have feasibility and real-life applications using a collaborative experiment with the Department of Engineering in testing their compressive strength to apply to Interior projects within finishes. For the purposes of this study "Interior finish means the exposed interior surface materials of walls, fixed or movable partitions, and ceilings ... surfacing materials such as panelling, tile, or other interior finish material and any surfacing materials" (Law Insider Definition, n.d.).

The potential limitations of using new products within the construction process will be discussed and a design guide produced for the process of applying sustainable and alternative material choices into Interior projects.

The conclusion of this critical analysis will be the definition of a method for Interior Designers interested in using material innovations in projects before they are used as structural components and outlining further areas for continued study.

This paper is a critique on the current method of specifying materials without consideration for the implications of the raw materials resourcing, written with the hope that it inspires designers to explore options for alternative materials within their own work.

CONTENTS

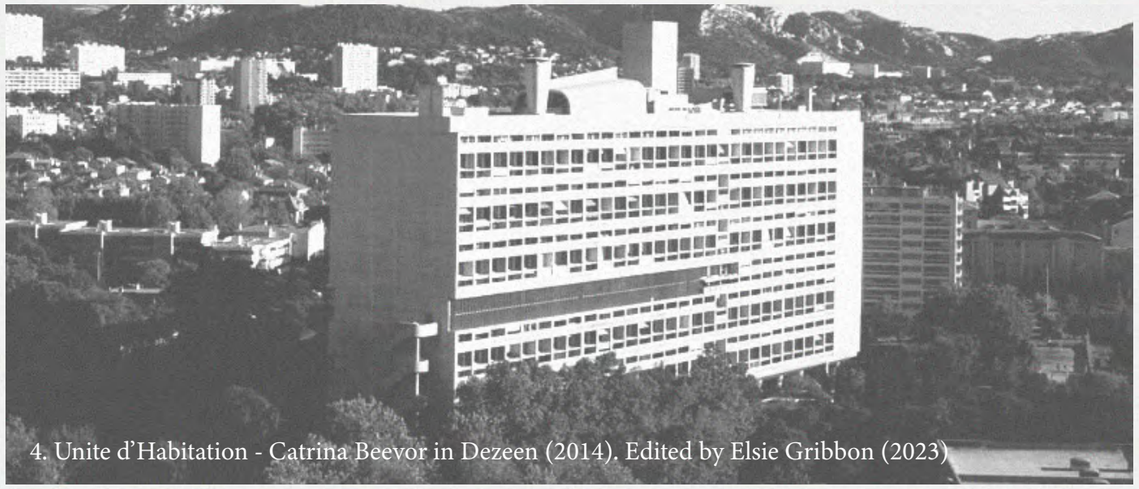
3. Dusty Cement. Valery Shanin(n.d)

A BRIEF HISTORY OF CONCRETE & DESIGN

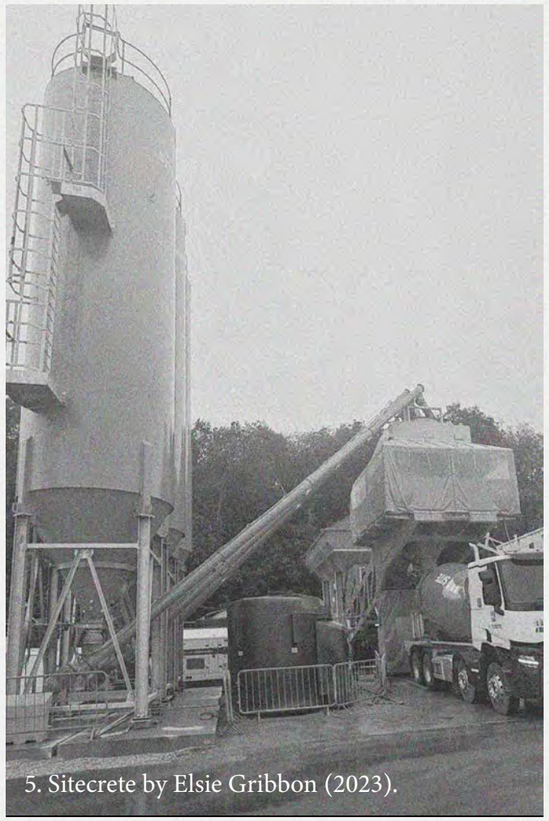
Concrete is, quite literally, the bedrock to modern society. It is the foundations that our lives are built on top of and our protector from the elements. To construct the designs we conceive, concrete is relied upon for the structural properties of the material, yet the designers relationship to concrete is far more complex; as the trends cycle it's use within our designs fluctuates. The most prominent example of this is the design industry's relationship to Brutalist design.

Where concrete and design are considered, the most ubiquitous design style is Brutalism. It's prominence as a design style rose after Reyner Banham's 1966 book The New Brutalism: Ethic or Aesthetic, as designers began to idolise Le Corbusier's Unité d'Habitation. Combining this with its emergence at a time where affordable and fast development was a priority, it became the not only the reason for it's popularity but it's downfall. "British Brutalism has been widely seen as the architectural style of the welfare state, a cheap way of building quickly, on a large scale" (Calder, 2016). Brutalism became almost symbolic with negative connotations of mega-corporations exacerbated by it's use in Sci-Fi films of the 1980's.

In spite of the trend cycles, concrete does the one thing it was created to do - it persists. I explored the city for examples of it's use and found that concrete is still featured prevalently in modern design, albeit more subtly, balancing the harshness of the material with combinations such as natural timbers and glass.



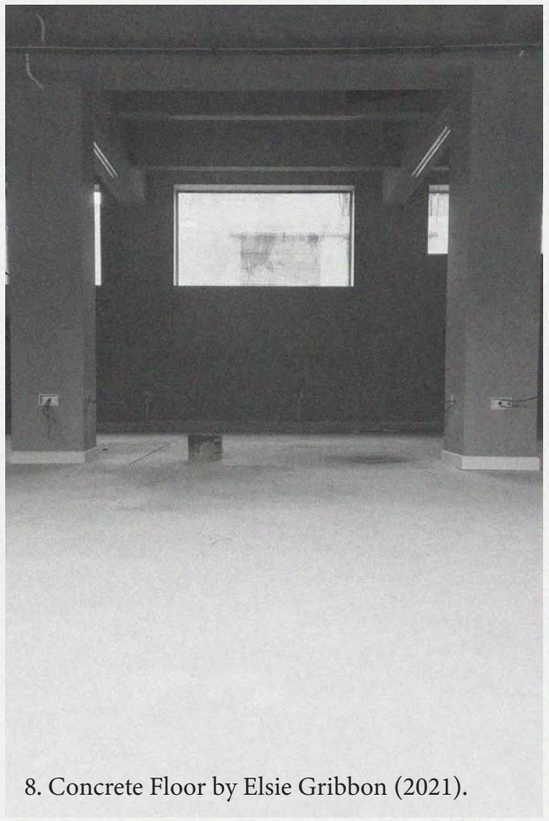
4. Unite d'Habitation - Catrina Beevor in Dezeen (2014). Edited by Elsie Gribbon (2023)



5. Sitecrete by Elsie Gribbon (2023).

6. Construction by Elsie Gribbon (2023).

7. Steamhouse by Elsie Gribbon (2022).



8. Concrete Floor by Elsie Gribbon (2021).

EMBODIED CARBON

“Embodied carbon refers to the emissions during the construction of a building rather than when it is in use – or the carbon footprint of a material” (RPS Group, n.d.). The stages within the life-cycle of concrete are as follows:

1. Raw material extraction
2. Transport to factory
3. Manufacture
4. Transport to site
5. Construction

According to ARUP (2023) 75% of carbon emissions happen in the first three stages, 15% are in the fourth and fifth, and 10% occur at the end of product life.

The carbon used end of life is due to the durability of concrete and difficulties in recycling, “the monolithic nature of [...] concrete makes it, by definition, impossible to disassemble” (Forty, 2012). This also leads to continuous extraction for new raw materials that exacerbates the environmental strain.

But for how long can a resource be mined continuously with finite natural resources?

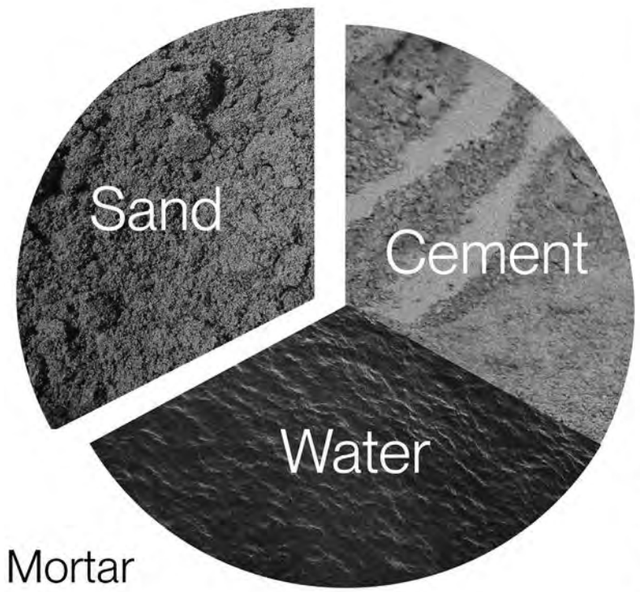
Until this point, research had focused on the Carbon Footprint of Concrete, but it became apparent that whilst the embodied carbon in the product is a problem, the sustainability of raw material extraction by capitalist mining practices is a far more pressing concern for environmental and community sustainability.

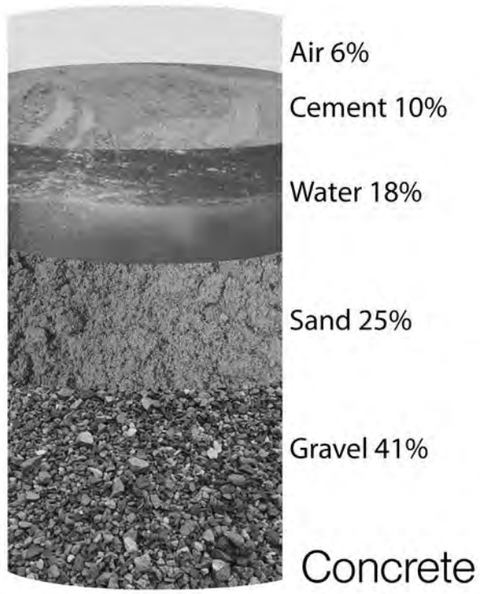
9. Embodied Carbon in Concrete. Illustration by Elsie Gribbon (2023).

THE TRUE COST OF
RAW MATERIALS

Concrete consists of a mixture of cement - popularly Portland cement, sand and a coarse aggregate. Mortar is the mix of cement and sand, often used in Interior finishes and to bind brickwork. After mixing these proportionately a chemical reaction is produced via the addition of water which allows the cement to harden and bond the particles together. It is used in the structural components of buildings and is incredibly strong and long lasting. Concrete masquerades as human ingenuity in the combination of raw materials; what could be unsustainable about the mixture of water with lime and sand?

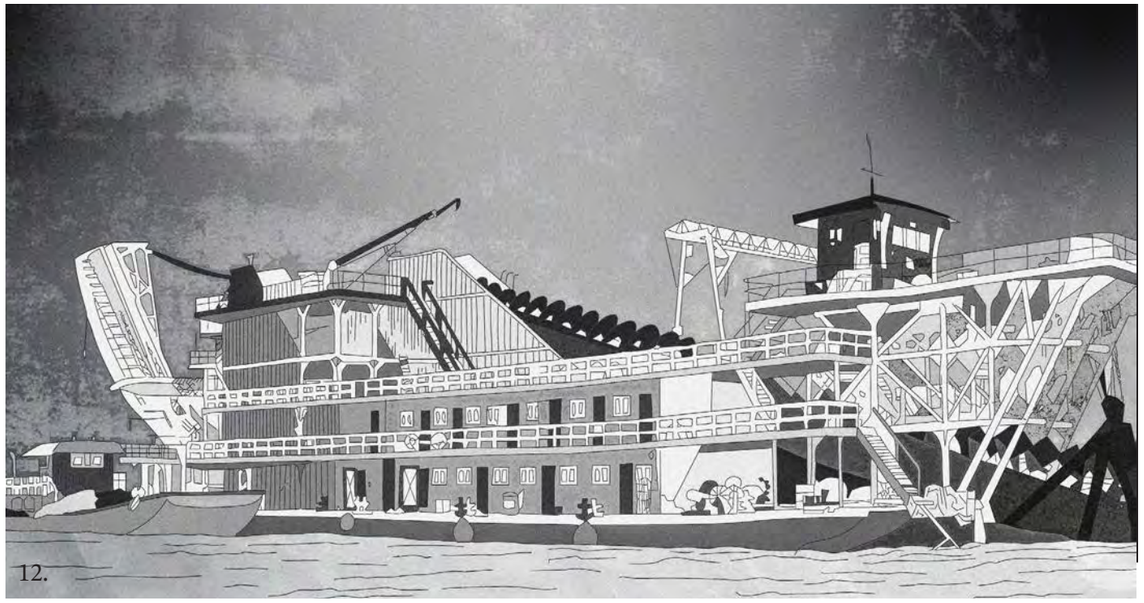
RATIO OF CEMENT MORTAR	
MASONRY CONSTRUCTION	
WORK	MIX RATIO (CEMENT : SAND)
Ordinary Mason Work with brick / stone as a structural unit.	1:3 - 1:6
Reinforced Brick work	1:2 - 1:3
Wet works	1:3
Load-bearing Structures	1:3 - 1:4
Architectural Work	1:6





10.Ratio Cement Mortar Mix Table Elsie Gribbon (2023). Based on Table by Nithin Kumar (2023)

11.Concrete Mix Diagrams by Elsie Gribbon (2023).



There is seemingly an endless supply of sand that could be sourced from vast deserts and beaches yet the price of raw materials indicates a shortage. “The sand that lies on the sea floor is this jagged edge textured sand with sharp edges, unlike its smooth desert counterpart. This plays a vital part in the construction sector as the desert sand does not bind” (Alfvin, 2019).

Further complicating this, the type of water source affects the quality of the sand produced for concrete - with salt-water damaging the structural integrity of the concrete and a costly process to remove it, meaning river sand is the most common choice within construction.

Through the dredging of this river sand the water quality can be severely impacted for communities that may lie downstream and changes the morphology and slope of the natural river. This shift in natural ecology has implications for the community surrounding it who depend on the ecosystem for building, agriculture & water consumption.

With commercial sand dredging using hydraulic dredgers that pump vast quantities of sediment through their system and displace finer material with the addition of water (Agarwal, 2021) there are fundamental changes to the ecology of the river system and, being a finite resource, render it unsustainable.

It can be observed that this use is in line with Hardin’s (1968) economics paper “The Tragedy Of The Commons” where the author poses that when faced with a vast shared resource it will be exploited by individuals, leading to the degradation of the resource and ultimately being of detriment to the wider society.

“After water, concrete is the most widely used substance on Earth. If the cement industry were a country, it would be the third largest carbon dioxide emitter in the world with up to 2.8bn tonnes” - (Watts, 2019)

12. Commercial Dredging. Illustration by Elsie Gribbon (2023).

WHO REALLY
PAYS THE PRICE

Madyise (2013) “Case Studies of Environmental Impacts of Sand Mining and Gravel Extraction for Urban Development in Gaborone” outlines the impact of river sand mining on communities using qualitative research. His methodology involved survey, interview and field observation.

The positive effects villagers commented on included the creation of employment for youth (although notably their age was not specified in paper) and that the villagers could buy river sand and gravel at cheap prices as they reside close to extraction sites.

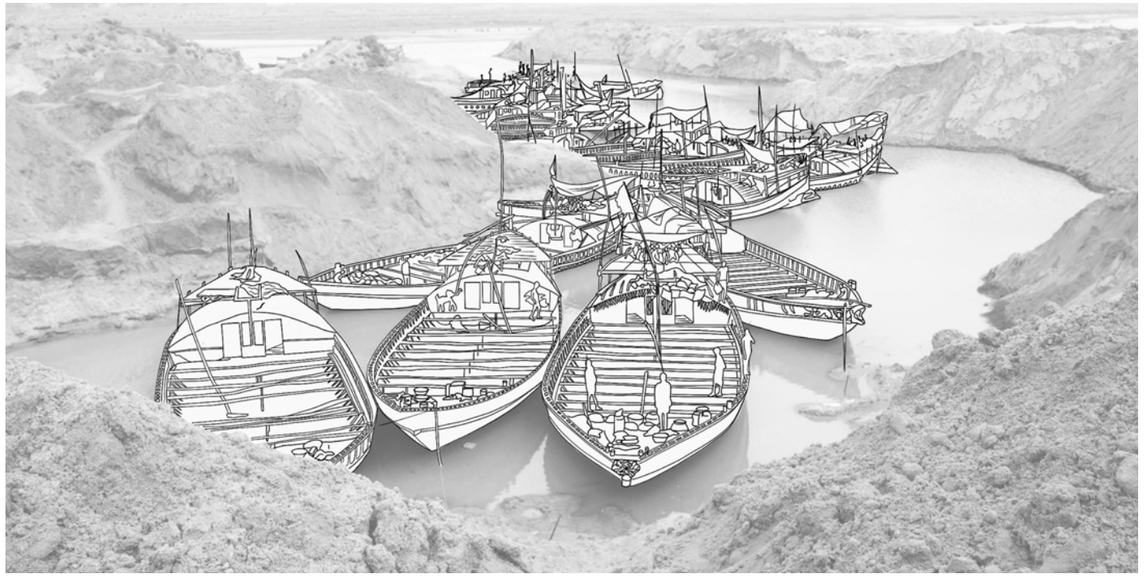
Key findings from these surveys show that 22.5% of participants had observed deepening of the riverbanks, 14.5% noticed an alteration in the landscape, 16.3% saw a loss of vegetation and 13.2% recognised land degradation in the area.

One continued theme throughout the survey responses was the negative outlook on illegal mining activity, with one participant commenting “Illegal miners are dangerous to farmers and villages as they bring sharp objects and spades to fight police and watch groups mostly at night”. 31% are “not happy and disturbed by sand and gravel mining activities which destroy their agricultural land, cause many accidents leading to the deaths of people in their community”.

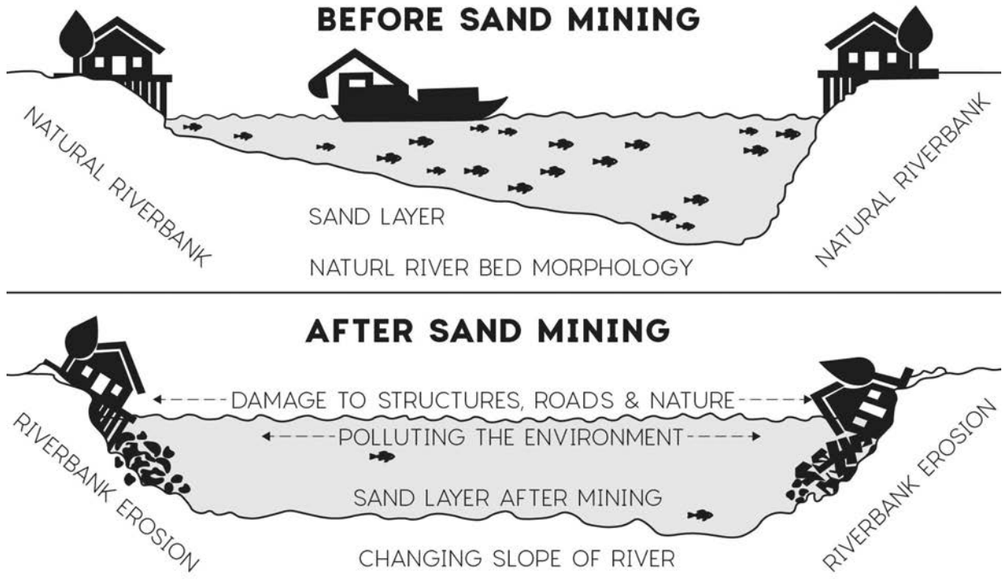
An article written on the topic of “Unregulated Sand Mining Threatens Indian Rivers” by Bagchi (2010) outlines ways in which weak governance and rampant corruption facilitates uncontrolled mining in India, impacting the ecosystem of the rivers that communities depend on for survival.

The Indian government exempted mining of sand or gravel from legislations on conservation of environment and mineral resources, leading to excavations of sand to be uncontrolled. This has reduced the water-holding capacity of rivers throughout the country as sand is removed from the water table. Combining this with climate change leads to avoidable water shortages. On the Bharathappuzha river in Kerala, the Journal India Together reported “Water tables have dropped dramatically, and a land once known for it’s plentiful rice harvests now faces scarcity of water... In the villages and towns around the river, groundwater levels have fallen drastically and wells are almost perennially dry.”

Thrivikramaji (2014) also discussed the impacts on rivers in Kerala, summarising that removal of river sand resulted in deeper channels causing disequilibrium between channels and floors of rivers. This brought about a slump resulting in destruction of coconut trees and crops over 20km of the Neyyar on both banks.

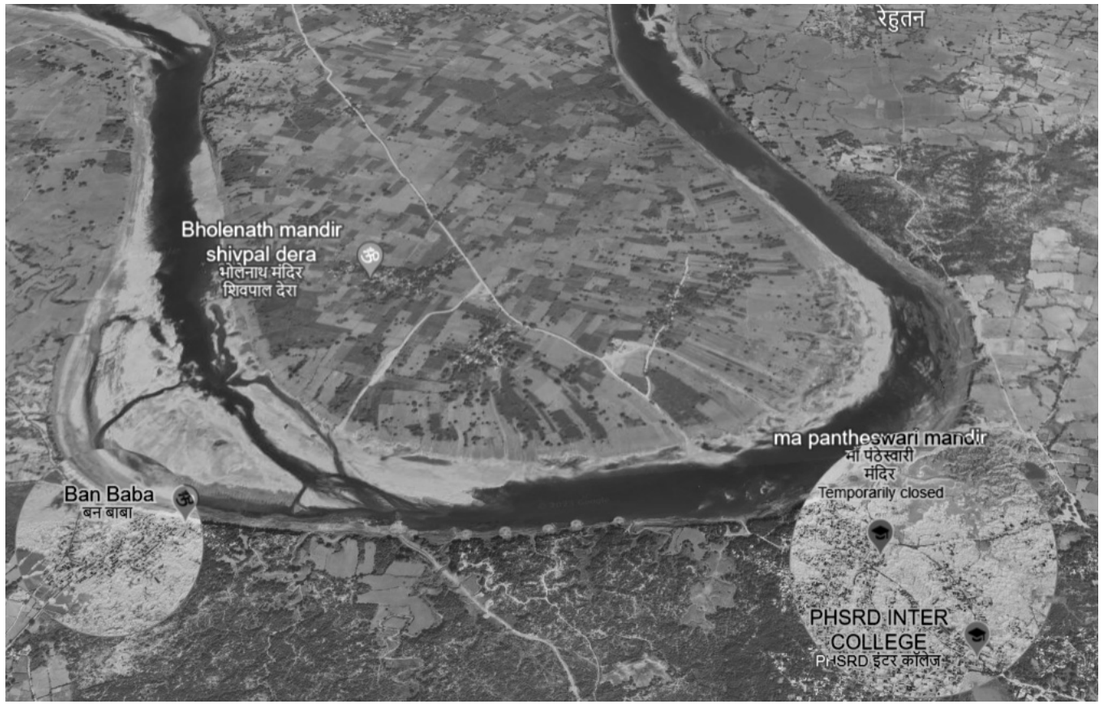


13. Boats are parked for several kilometers along the banks of the Son River in the state of Bihar, June 23. Mathias Depardon for “LE MONDE (2023) Illustrated by Elsie Gribbon (2023).

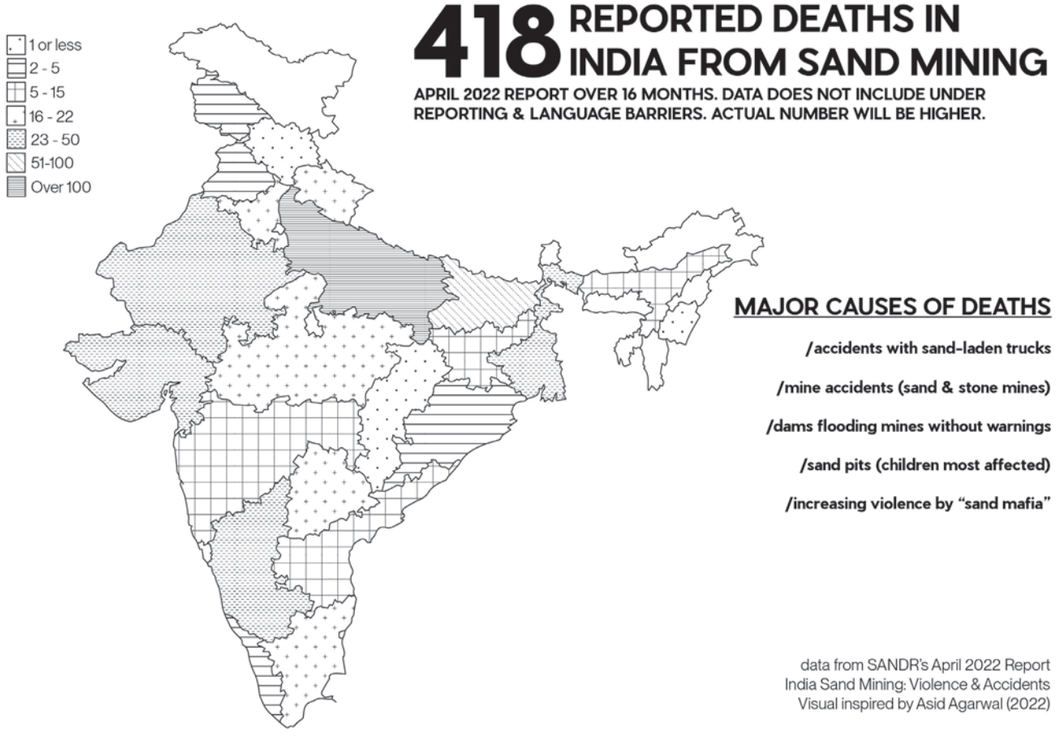


14. Diagram of changes to river bed from sand mining. Elsie Gribbon (2023).

“THIS MINDLESS, UNRESTRAINED AND UNREGULATED ACTIVITY IS POSING THREATS OF WIDESPREAD DEPLETION OF WATER RESOURCES WHICH MAY LEAD TO AVOIDABLE FOOD SHORTAGES AND HARDSHIPS FOR THE PEOPLE”
-PROLOY BAGCHI (2010)

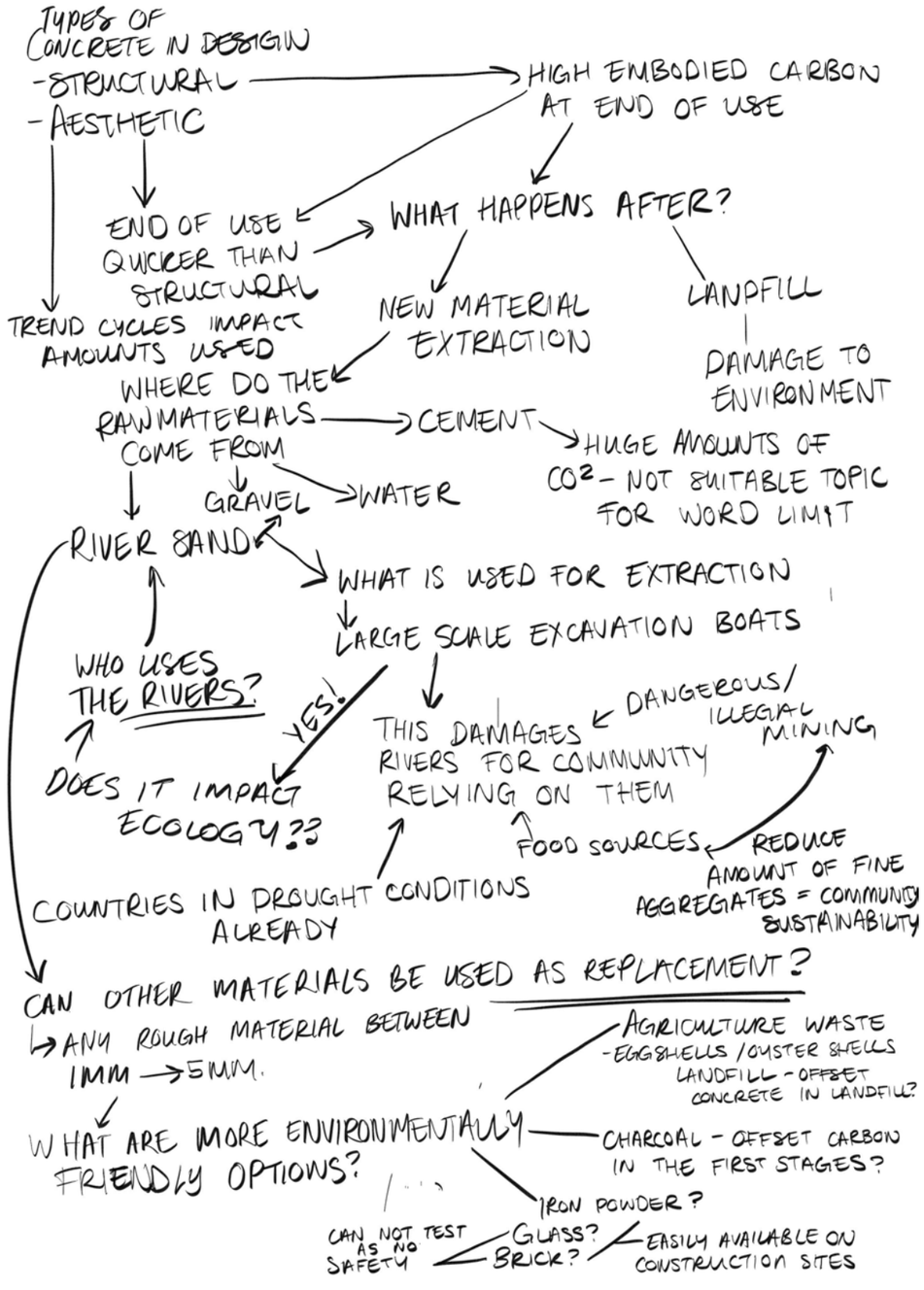


15. Ken Riverbed mining activities blocking active flow channel of the river in Khaptiha Kala, Banda. Google Earth December 2023. Edited by Elsie Gribbon (2023)



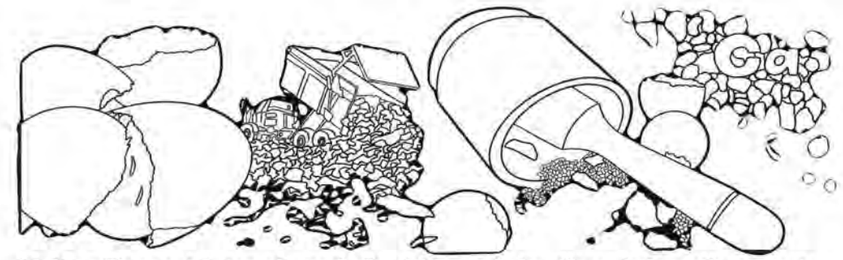
16. Infographic by Elsie Gribbon (2023)

IS THERE A SOLUTION?

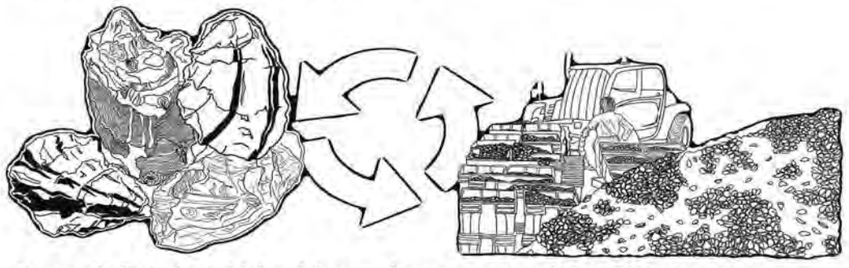


17. Research Mindmap by Elsie Gribbon (2023)

Design and the larger built environment is intrinsically linked to the use of concrete within projects and as the people who specify materials, we have an opportunity to influence the market for river sand. Alternatives for fine aggregates to replace the unethical mining of sand were investigated and four promising solutions were found in academic papers.

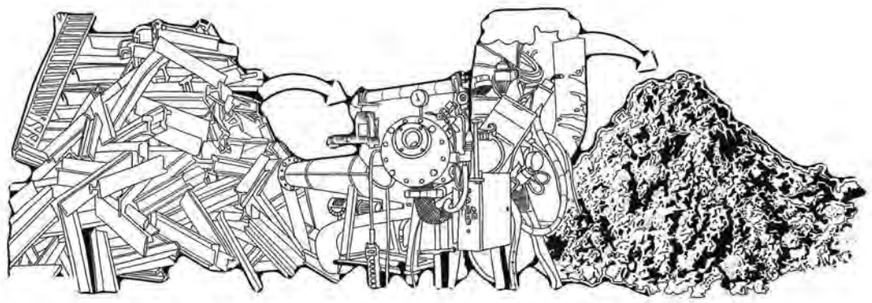


"8.58 million metric ton of eggshells which are being discarded mostly as waste. This calcium-rich commodity is dumped into landfills, leading to various environmental issues" (Aadil et al. 2020).



Oyster shells "whose high calcium carbonate content (80–95%) gives them the potential for use as raw material for several other products" (Galindro et al 2012)

Activated Charcoal - also known as activated carbon is "an absorbent that can be used efficiently for removal of a broad spectrum of pollutants from air" (Ansari, R & Mohammad-Khah, A 2009)



Waste Iron Powder is an "industrial byproduct generated from the workshops, steel mills, and factories in powder form, which is not commonly used [when recycling iron waste]" (Ali, M et al 2022)

18. Alternative Aggregate Illustration by Elsie Gribbon (2023)

19.Material Creation by Elsie Gribbon (2023)

DESIGN & TACTILITY

20. Hapticitly by Elsie Gribbon (2023)

"Touch is the sensory mode which integrates our experience of the world and of ourselves." - Juhani Pallasmaa (1999).

Design is not purely theoretical. The design process allows ideas to become tangible; it is a discipline in which we use our senses to explore ideas. As I read research on alternative aggregates, I found it difficult to contextualise the concretes and whether the process was accessible to the Design industry.

Pallasmaa (1999) discussed the value of hapticity within design and the importance of architecture being a multi-sensory experience as opposed to a visual observation.

To further research the alternative aggregates discussed in academic research papers and analyse their suitability for interior use, it was important to physically experiment to understand the materials, their properties and their sensory qualities, experiencing the alternative concretes, in line with the idea of a "strengthened sense of materiality and hapticity, texture and weight, density of space and materialised light" (Pallasmaa, 1996).

21. Mortar by Elsie Gribbon (2023)

ORIGINAL MORTAR
- VERY GRAINY
- NICE COLOUR
- ROUGH TO TOUCH

22. Eggshell by Elsie Gribbon (2023)

EGG SHELL
- POOLS ONE SIDE
- VISIBLE WHEN BROKEN - INTERESTING
- COLOUR VARIATION FROM SHELLS
- LOOKS LIKE TRADITIONAL MORTAR
- SMELLS A BIT DURING PREPARATION
- EASY TO WORK WITH; BEST WET CONSISTE

23. Charcoal by Elsie Gribbon (2023)

CHARCOAL
- COLOUR IS PERSONAL FAVOURITE
- COULD BE TOO DARK FOR EVERYDAY USE
- DRIES QUICKLY
- USES A LOT OF WATER COMPARED TO OTHERS
- SLIGHTLY CHALKY
- PIGMENT TRANSFERS TO SKIN MINIMALLY
- MESSY TO WORK WITH WET

24. Iron by Elsie Gribbon (2023)

IRON POWDER
- VERY SMOOTH TEXTURE
- CLEAN FINISH
- IRON POOLS IN AREAS
- NOT MAGNETIC
- VERY GRAY COLOURING
- WATERY MIX
- IRON RISES TO SURFACE DURING MIX

25. Oyster by Elsie Gribbon (2023)

OYSTER SHELLS
- ODOUR IS BAD DURING MIX AND LINGERS WHEN CURED
- LOOKS SIMILAR TO ORIGINAL MORTAR
- FEELS SIMILAR TO ORIGINAL MORTAR
- TEXTURE QUITE ROUGH

26. Notes on Hapticity
Annotations by Elsie Gribbon (2023).

27. Process Photography by Elsie Gribbon (2023)

JUST IN THEORY OR A **POSSIBILITY?**

After critical observation of the new combination aggregate mortars and preferring the properties to the feel and aesthetic of the standard mortar mix, the question arose as to why these materials are not currently being implemented in the design stages?

There are two potential reasons for this - strength and cost. To determine if the strength of the material was compromised, the compressive strengths of alternative material in mortars was calculated. Following this 8% of the aggregate was replaced. The materials were compared to each other after 3 and 28 days to create an average to determine their practical usability within Interior Design.

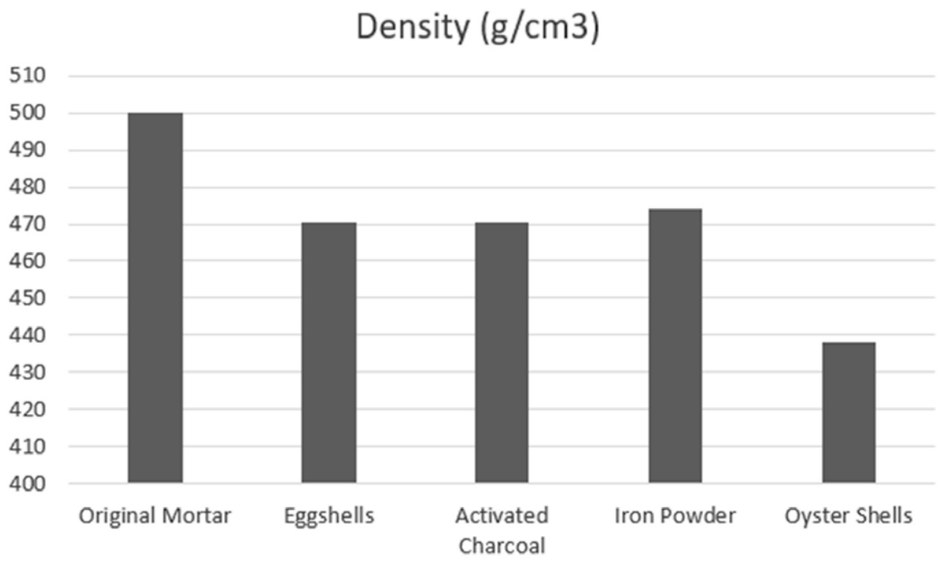
All of the experimental aggregates provided substantially stronger results in terms of their compressive strength than traditional mortar, meaning the product could be used feasibly be used within designs.

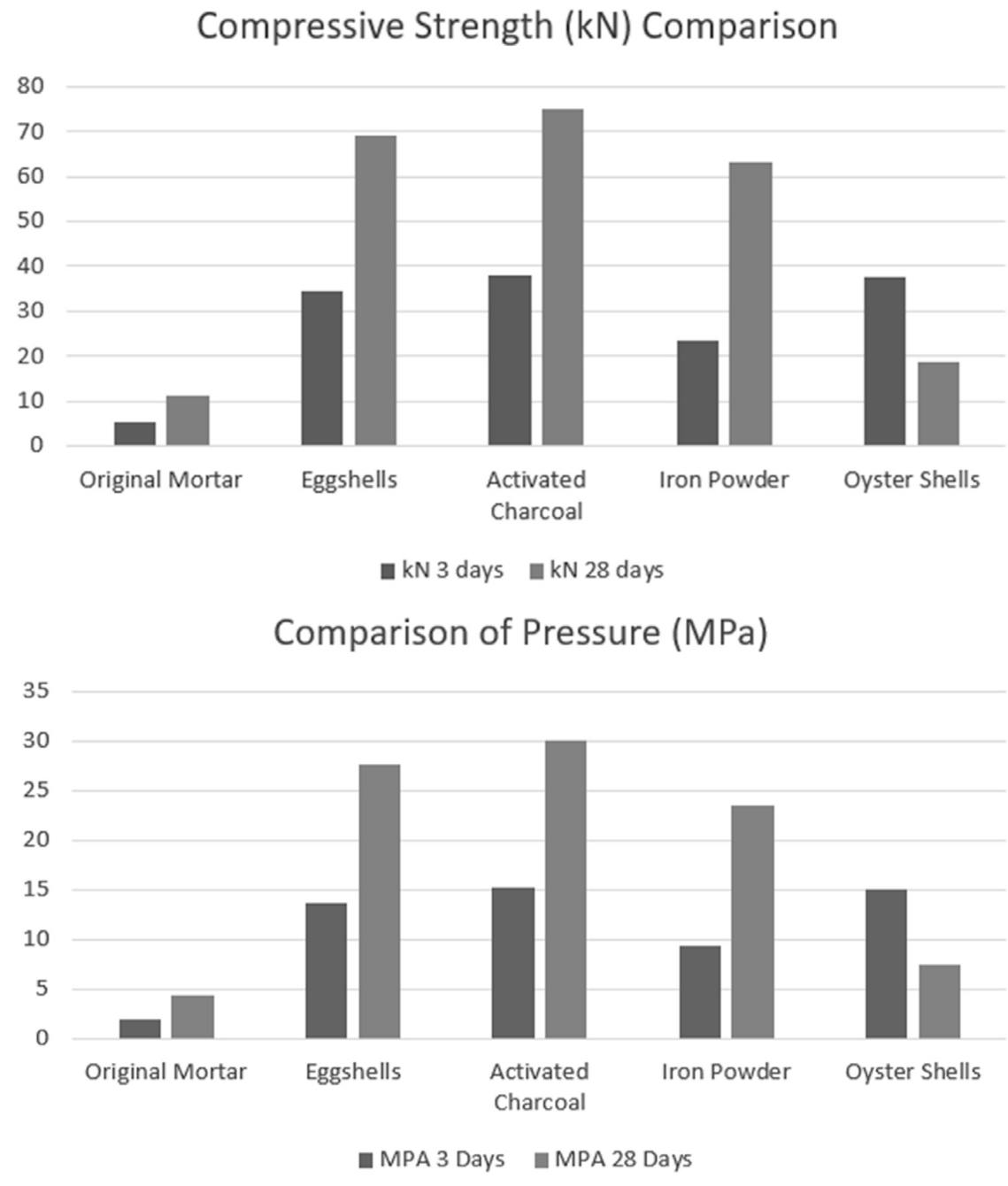
28. Table of Photography by Elsie Gribbon (2023)

RESULTS & COMPARISON

		COMPRESSIVE STRENGTH				
	DENSITY	3 DAYS		28 DAYS		
MATERIAL	g/cm3	kN	MPA	kN	MPA	OBSERVATIONS
ORIGINAL MORTAR	500	5.1	2.05	11.0	4.42	Traditional Mortar mix has the lowest kN and MPA across both experiments.
EGG SHELLS	470.3	34.3	13.74	69.0	27.58	Eggshell kN & MPA have doubled over 28 day curing period.
ACTIVATED CHARCOAL	470.3	38.1	15.22	75.2	30.06	Strongest concrete created in testing process. Carbon MPA 6x higher after 28 days.
IRON POWDER	437.9	23.3	9.32	63.3	25.53	Highest increase in kN and MPA over 28 days.
OYSTER SHELLS	437.9	37.5	14.99	18.8	7.53	Decreased in strength after 28 days, could be due to aggregate dispensing evenly in batch? 28 day more accurate than 3 day.

29. Table of Results by Elsie Gribbon (2023)





30. Graphs Analysis of Three Results Sets by Elsie Gribbon (2023)

ORDINARY MORTAR

OYSTER SHELL

OBSERVATIONS - VERY SMELLY

ACTIVATED CHARCOAL

OBSERVATIONS - DRIES QUICKLY
- NEEDS EXTRA WATER
- MESSY

IRON POWDER

OBSERVATIONS -
- IRON RISES TO SURFACE
- WATERY

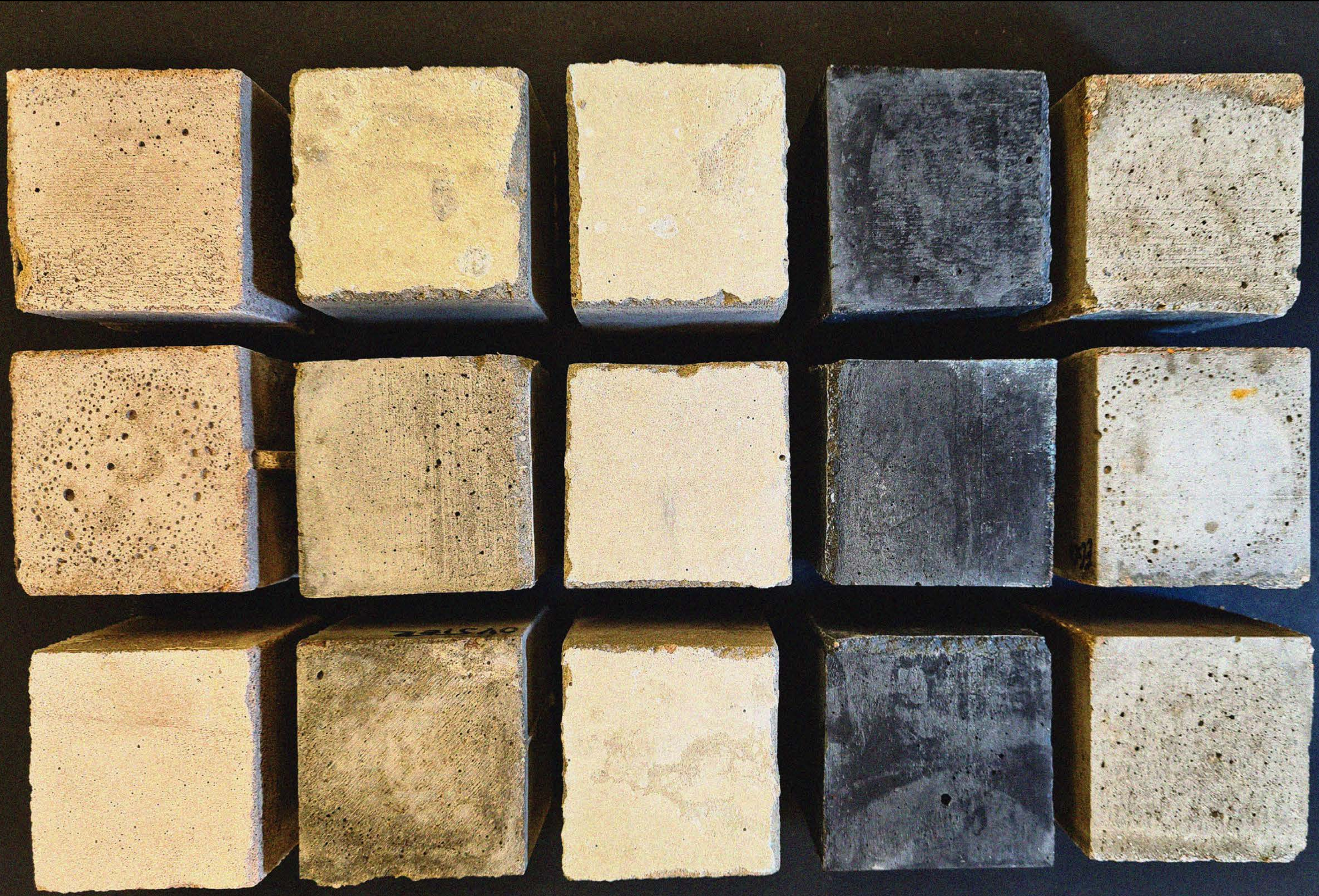
EGG SHELL

OBSERVATIONS -
- BEST CONSISTENCY
- EASY TO WORK WITH
- ONLY SMELLS A BIT

31. Curing in Moulds by Elsie Gribbon (2023)

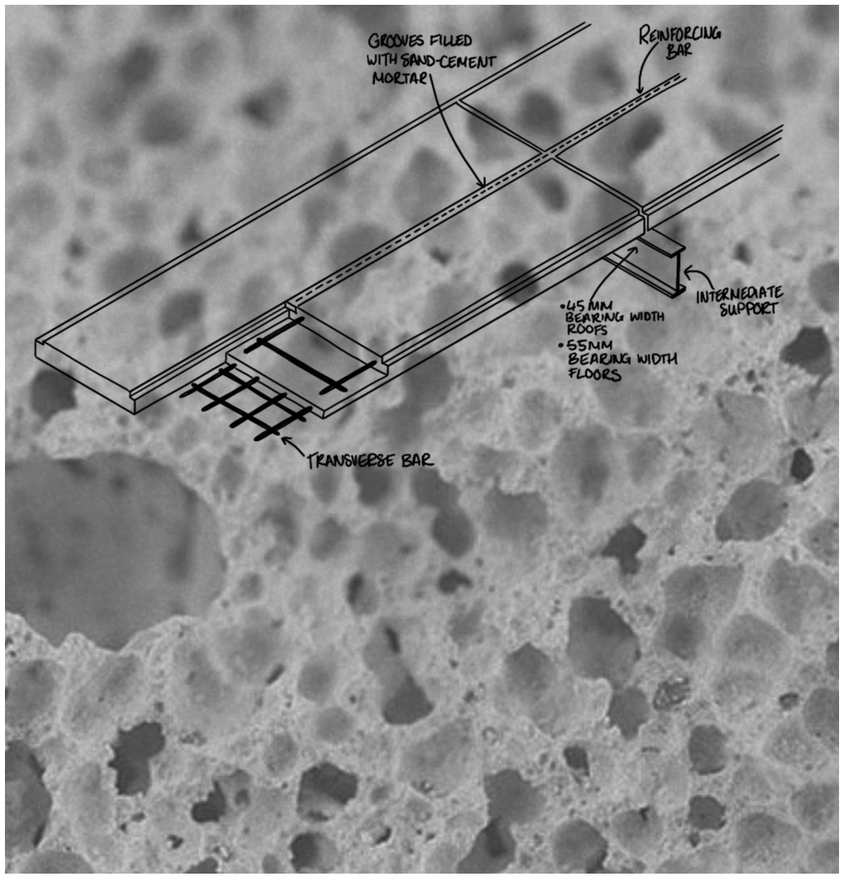
“CONCRETE OFFERS SOMETHING UNIQUE TO ARCHITECTS, IN THAT WHILE FOUNDED IN ‘SCIENTIFIC’ KNOWLEDGE AND EXPERIMENT – IT STILL OFFERS OPPORTUNITIES FOR EXPERIMENTATION TO ANYONE.”

– ADRIAN FORTY (2012)



32. Dried Alternative Aggregate Mortars by Elsie Gribbon (2023)

CONVERSATIONS ON
IMPLICATIONS



33. RAAC Cross section - original source LABC from BIMplus.com
Illustration by Elsie Gribbon (2023) based on diagram by Currie & Matthews (1996)

The practical use of alternative materials however, is more complex. One of the main benefits to the traditional concrete as a building material over alternatives is it's strength and safety.

In the 1930's Reinforced Autoclaved Aerated Concrete was invented that included aeration agent. Cured in an autoclave, it resulted in a lower density concrete used in the Construction Industry in the 1950s. "The inherent weakness arises from the presence of these air voids, which compromise the material's structural integrity... RAAC can be more susceptible to damage over time, especially in adverse environmental conditions or when subjected to excessive loads" (Thomas, 2023) However, recent problems have occurred due to use beyond it's expectancy. "This is not a bad material. It is behaving exactly as it would have been expected. This is a failure of maintenance, refurbishment and rebuilding." (Purnell, 2023)

With this in mind, it is important to consider that Interior Design has a much shorter service than construction; "service life is considered to be the lifetime of materials and components" (Andersen & Brandt, 1999). To be able to implement alternative materials structurally, we must comprehensively understand their life expectancy, and one way of doing so could be through Interior finishes rather than structural components.

A DESIGNERS GUIDE
TO CHANGE

DO YOU KNOW WHAT THE RAW MATERIALS IN THE PRODUCT ARE & WHERE THEY COME FROM?

YES

NO

RESEARCH

IS THERE POTENTIAL EXPLOITATION OF NATURAL ECOLOGY AND/OR IMPACT ON COMMUNITY

YES

NO

USE MATERIAL

ARE THERE ALTERNATIVE PRODUCTS THAT ALREADY EXIST ON THE MARKET?

YES

USE THIS

NO

IS THERE ANY RESEARCH ON LESS DESTRUCTIVE MATERIALS?

YES

WILL THE MATERIAL BE USED FOR STRUCTURAL FOR FOR FINISHES?

STRUCTURAL

USE SPARINGLY

FINISHES

HOW LONG IS THE EXPECTED LIFE CYCLE OF THE DESIGN?

UNDER 20YR

USE NEW MATERIAL IN NON-STRUCTURAL AREA & RECORD MATERIAL BEHAVIOURS FOR FUTURE RESEARCH

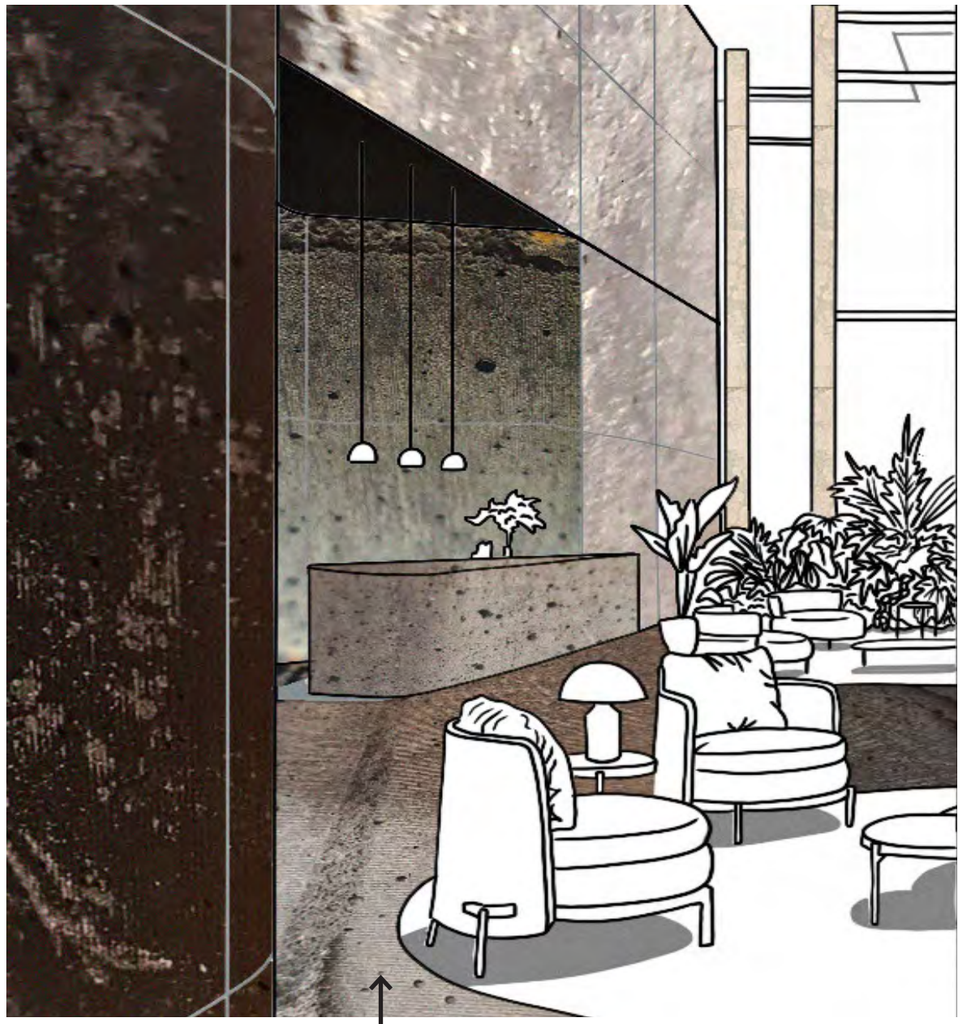
OVER 20YR

FURTHER RESEARCH NEEDED ON NEW MATERIAL

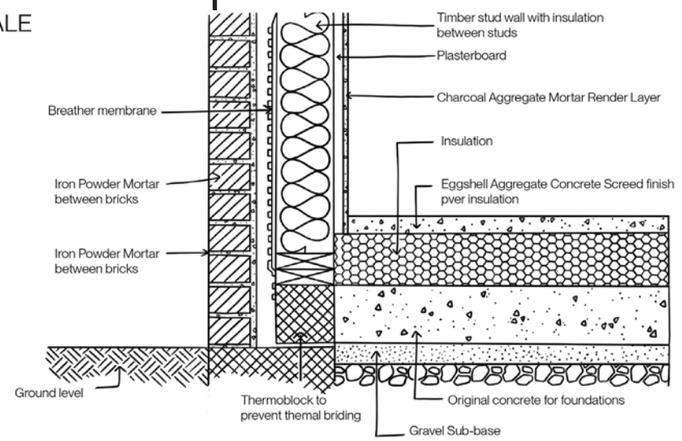
NO

USE SPARINGLY

34. Interior Design Guide. Elsie Gribbon (2023)



NOT TO SCALE



35. Speculative Usage. Elsie Gribbon (2023)
36. Detail of usage. Elsie Gribbon (2023)

APPLICATIONS & CONCLUSION

As designers, it is our responsibility to ensure the materials we use are considered and not based solely on convenience and cost. For an industry that places importance on innovations in sustainability, we must also consider the sustainability of communities affected by the choices we make at every stage in the materials specification process.

The recent problems with the life-cycle of structural RAAC concrete has shown the difficulties implementing alternative concretes without long term testing in structural elements. Within Interior Design, residential buildings have been proposed to have a renovation cycle of 20–50 years, whereas the interval decreases to 10–20 years for offices and 3–5 years for department stores (Andersen & Brandt, 1999). This provides Interior Designers an opportunity to use these alternatives within our designs and monitor their performance over longer periods of time than traditional testing methods, but also in more realistic conditions. The first hand research has not only shown they are more aesthetically versatile and haptically interesting, but also stronger than original mortars.

In the book Concrete & Culture, Forty (2012) outlined the relationship Designers have with concrete and the persistence of it's use throughout the trend cycles. Rather than continuing this trend with the traditional methods we can incorporate aggregate experimentation in to our finishes. The use of these materials within Interior settings can potentially help inform further study in to their uses and aid in supporting the research in practical context so the construction industry can move towards a more long term solution. In the short-term, we as an industry can stop supporting a destructive mining practice that not only damages the ecosystem but negatively impacts communities that rely on the river in which "75% of [...] consumption is in drought and water-stressed regions" (Watts, 2019).

When I started researching for this paper, I was initially interested by the thought of the embodied carbon within the concrete that is left behind after demolition. But an integral part of my practice has always been the importance of using design to empower and build communities and the use of this material in finishes implicitly contradicts what I stand for as a responsible and ethical designer when alternatives are widely available and are fit for purpose.

ELSIE-MAY GRIBBON
ARC 6110 - CRITICAL STUDY
BIRMINGHAM CITY UNIVERSITY

WORD COUNT: 2683

37. Iron after compressive strength analysis. Elsie Gribbon (2023)

FUTURE OPPORTUNITIES

To continue this investigation further the mortars tested will undergo increased percentages of replacement aggregates included and the experiments repeated. They can then be implemented in small scale interior projects with the results monitored yearly to see the effect heavy wear and use has on their structural integrity.

From a wider contextual view, there is scope for research on the effect that resource mining for sand has on communities in regions undergoing large scale urban redevelopment, such as China. Throughout this research I found evidence of organised crime and Government corruption within illegal sand mining - a topic where a thorough and in depth study will need conducting.

DESIGN MANIFESTO

What started as a study in to a construction material has transcended it's origin and in the process taught me about capitalism, environmental sustainability, empathy, creativity, design thinking and innovation. I have gained a deep appreciation of the complexities behind the choices we make, and the knowledge that creativity is the key to change in society. From the findings within my critical study, I have identified four important areas that I will use as my principles and mission going forward. I will continue to build on these foundations throughout not only my design work but in my personal growth and development.

38. Experimentation. Elsie Gribbon (2023)

DESIGN IS NON-LINEAR THINKING

As designers, we need to be flexible enough to follow ideas down new routes as new information is presented. We understand that sometimes we need to relinquish control of an idea and let it evolve naturally. As we find new research, our perspective and our plans develop and we must be willing to adapt. This propensity for growth allows us to appreciate new elements and to see a larger picture alongside understanding our part within it.

Design thinking allows us to challenge our own ideas which is fundamental in academic exploration.

EXPLORATION SHOULD BE CREATIVE

Design is a discipline in which we actively explore and test our ideas; unique in that it allows us to learn through failure as well as success. Utilising our haptic and sensory understanding and applying it to theoretical research and abstract concepts brings a deeper understanding to our research. The skills we learn through the design process are not only ways of thinking but ways of exploring and learning that are often overlooked.

These creative skills and the ability to find enjoyment in trying new processes and understanding complex subjects is what differentiates design as a discipline.

KNOWLEDGE IS USED TO INNOVATE

As designers, we have the ability to not just implement our knowledge conceptually but transform it in to something tangible. We can understand how our changes can make an impact and we are in a position to make them. The understanding that sustainability is a complex and interdisciplinary problem to solve allows us to play our part and become innovators in the field, testing, evaluating and learning collaboratively.

We push the boundaries of design and collaborate to find exciting new solutions that we can use within our work.

DESIGN CHOICES ARE NOT ISOLATED

When designing we must pro-actively research the products we use and rigorously hold ourselves to the standards of industry ethics. When we identify problems within the supply of our materials we must strive to choose the path that causes the least harm, be it to the ecology, communities or future generations. As designers we have a responsibility to stay informed about current issues and utilise potential alternative solutions and advocate for change. Systemic changes start with personal changes.

If we do not consider the cost to people's environments at the expense of our design choices, we are complicit in the damage it causes.

WORD COUNT: 500

BIBLIOGRAPHY

PRINTED WORKS

Calder, B. (2016). Raw Concrete: The Beauty of Brutalism. Random House. [online] Pages 16-18
Available at: https://books.google.co.uk/books?hl=en&lr=&id=6P-qBAAAQBAJ&oi=fnd&pg=PT4&dq=brutalism+and+concrete&ots=I05xE1g-E3&sig=FihpyqMk7ZdxOzkMWIQ9jqM-Ods#v=onepage&q&f=false [Accessed: 1 October 2023].

E. Shaji, Pradeepkumar, A.P. and Thrivikramaji, K. (2014) National Seminar on Mineral Resources of Kerala. University of Kerala. Pages 84-92

Forty, A. (2016) Concrete and culture. London: Reaktion Books. Pages 73, 174-175, 306

Pallasmaa, J. (2012) The eyes of the skin. Chichester Wiley. Pages 28, 64

Reyner Banham (1968) The new brutalism : ethic or aesthetic? London: Architectural P. [online] Page 63
Available at: https://www.jstor.org/stable/3331537?seq=2. [Accessed: 02 Nov. 23]

ACADEMIC PAPERS

Alfvin, G. (2019). The killers of sand A case study on how a shortage of sand is breaking down India from within. [online]
Available at: https://www.diva-portal.org/smash/get/diva2:1440347/FULLTEXT01.pdf [Accessed 11 Nov. 2023].

Alvarenga, R.A.F. de, Galindro, B.M., Helpa, C. de F. and Soares, S.R. (2012). The recycling of oyster shells: An environmental analysis using Life Cycle Assessment. Journal of Environmental Management, 106, pp.102–109.
Available at: https://doi.org/10.1016/j.jenvman.2012.04.017. [Accessed 11 Nov. 2023].

Andersen, T. and Brandt, E. (1999). THE USE OF PERFORMANCE AND DURABILITY DATA IN ASSESSMENT OF LIFE TIME SERVICEABILITY Performance and durability data. [online]
Available at: https://nrc-publications.canada.ca/eng/view/supplement/?id=49c7996a-27aa-4c44-bcaa-5f6df2ea4f1b&dp=179 [Accessed 1 Dec. 2023].

Buildings & Infrastructure Priority Actions for Sustainability Embodied Carbon Concrete. (2023).
Available at: https://www.istructe.org/IStructE/media/Public/Resources/ARUP-Embodied-carbon-concrete_1.pdf. [Accessed 11 Nov. 2023].

Currie, J. and Matthews, S. (1996). Reinforced autoclaved aerated concrete planks designed before 1980 [online].
Available at: https://www.brebookshop.com/details.jsp?id=325330 [Accessed 30 Sep. 2023].

Hardin, G. (1968). The Tragedy of the Commons. Science, [online] 162(3859), pp.1243–1248.
Available at: https://www.jstor.org/stable/1724745 [Accessed 11 Nov. 2023].

Irwanda, W. (2009). Activated Charcoal: Preparation, characterization and Applications : A review article. www.academia.edu, [online] 1(4), pp.859–864.
Available at: https://www.academia.edu/28520677/Activated_Charcoal_Preparation_characterization_and_Applications_A_review_article [Accessed 23 Nov. 23].

Madyise, T. (2013). CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE. [online]
Available at: https://core.ac.uk/download/pdf/43174281.pdf [Accessed 15 Nov. 23].

Miah, M., Paul, S., Kong, S., Babafemi, A. and Miah (2021). Magazine of Civil Engineering Waste iron powder as aggregate and binder in mortar production. Magazine of Civil Engineering., 108(8).
Available at: https://doi.org/10.34910/MCE.108.10. [Accessed 15 Nov. 23].

Thomas, D.J. (2023). Cracks in the Facade: Unmasking the Hidden Threats of Reinforced Autoclaved Aerated Concrete (RAAC)—A Tale of Failure, Consequences, and Redemption. Journal of Failure Analysis and Prevention.
Available at https://doi.org/10.1007/s11668-023-01783-9. [Accessed 15 Nov. 23].

UKEssays (2018). Concrete Mix Design Using DoE Method. [online] UKEssays.com.
Available at: https://www.ukessays.com/essays/engineering/concrete-mix-design-using-doe-method.php [Accessed 12 Nov. 2023].

Waheed, M., Yousaf, M., Shehzad, A., Inam-Ur-Raheem, M., Khan, M.K.I., Khan, M.R., Ahmad, N., Abdullah and Aadil, R.M. (2020). Channelling eggshell waste to valuable and utilizable products: A comprehensive review. Trends in Food Science & Technology, 106, pp.78–90.
Available at https://doi.org/10.1016/j.tifs.2020.10.009.[Accessed 15 Nov. 23].

LECTURES

Pallasmaa, J. (1999). Hapticity Vision. Architectural Design, RIBA Discourse Lecture[online] 75(4), pp.137–138.
Available at: https://doi.org/10.1002/ad.119. [Accessed: 18 Nov. 2023].

ONLINE ARTICLES

Bagchi, P. (2010) Unregulated Sand Mining.
Available at: https://www.boloji.com/articles/4488/unregulated-sand-mining [Accessed: 17 Nov. 2023].

O'Callaghan, J. (2023) Why are concrete schools crumbling in the UK — and what can be done? Nature, 621.
Available at: https://doi.org/10.1038/d41586-023-02834-9. [Accessed: 02 Oct.2023].

SANDRP (2022) North India: 136 people killed in sand mining violence & accidents in 16 months.
Available at: https://sandrp.in/2022/04/03/north-india-134-people-killed-in-sand-mining-violence-accidents-in-16-months/ [Accessed: 15 Oct. 2023].

Watts, J. (2019) Concrete: the most destructive material on Earth.
Available at: https://www.theguardian.com/cities/2019/feb/25/concrete-the-most-destructive-material-on-earth [Accessed: 30 Oct. 2023].

ONLINE WEBSITES

Embodied carbon: What it is and how to tackle it (n.d.).
Available at: https://www.rpsgroup.com/services/environment/sustainability-and-climate-resilience/what-is-embodied-carbon/ [Accessed: 28 November 2023].

Law Insider (n.d.) FINISHES Sample Clauses: 162 Samples.
Available at: https://www.lawinsider.com/clause/finishes. [Accessed 1 Dec. 2023].

MI News Network (2019) Different Types of Dredgers Used in the Maritime Industry. Available at: https://www.marineinsight.com/types-of-ships/different-types-of-dredgers-used-in-the-maritime-industry/ [Accessed: 8 Nov. 2023].

IMAGE REFERENCES

1. Title Page - Image created by author. Elsie Gribbon (2023)

2. Image created by author. Elsie Gribbon (2023)

3. Shanin, V. (n.d.) Dusty cement Stock Photo. Available at: https://stock.adobe.com/uk/images/dusty-cement/25576372 [Accessed: 13 December 2023]. Edited by Elsie Gribbon (2023)

4. 4. Unite d'Habitation - Catrina Beevor in Dezeen (2014).
Image available at: https://www.dezeen.com/2014/09/15/le-corbusier-unite-d-habitation-cite-radieuse-marseille-brutalist-architecture/ [Accessed 25 Sept. 2023]. Edited by Elsie Gribbon (2023)

5. Image created by author. Elsie Gribbon (2023)

6. Image created by author. Elsie Gribbon (2023)

7. Image created by author. Elsie Gribbon (2022)

8. Image created by author. Elsie Gribbon (2021)

9. Image created by author. Elsie Gribbon (2023)

10. Image created by author. Elsie Gribbon (2023).
Based on Table by Nithin Kumar (2023)
Available at: https://www.quora.com/What-are-the-ratios-of-cement-sand-and-water-in-mortar [Accessed 14 Dec. 2023]

11. Image created by author. Elsie Gribbon (2023)

12. Image created by author. Elsie Gribbon (2023)
Based on photography from Justin Jin (2019)
Available at: https://www.ribaj.com/products/unregulated-sand-mining-for-aggregate-construction-developing-world-wwf-stephen-cousins [Accessed 02 Oct. 2023]

13. Hybrid image created by author. Illustration by Elsie Gribbon (2023)
Photography by Depardon, M. (2022) India's "sand mafias have power, money and weapons." Le Monde.fr, 12 September.
Available at: https://www.lemonde.fr/en/environment/article/2022/09/12/in-india-sand-mafias-have-power-money-and-weapons_5996639_114.html. [Accessed 08 Oct. 2023]

14. Diagram created by author. Elsie Gribbon (2023)

15. Google Earth Image Capture
Google Earth (2023).
Available at: https://earth.google.com/web/search/ban+baba/@25.68014279 [Accessed: 3 Dec. 2023].
Edited by Elsie Gribbon (2023)

16. Infographic created by author. Elsie Gribbon (2023)
Based on image from Asid Agarwal (2022) Image Available at: https://twitter.com/sidagarwal/status/1521739647038091264. [Accessed on 19 Nov. 2023]
Using data from:
SANDRP (2022) North India: 136 people killed in sand mining violence & accidents in 16 months.
Available at: https://sandrp.in/2022/04/03/north-india-134-people-killed-in-sand-mining-violence-accidents-in-16-months/ [Accessed: 15 Oct.2023].

17. Image created by author. Elsie Gribbon (2023)

18. Image created by author. Elsie Gribbon (2023)

19. Image created by author. Elsie Gribbon (2023)

20. Image created by author. Elsie Gribbon (2023)

21. Image created by author. Elsie Gribbon (2023)

22. Image created by author. Elsie Gribbon (2023)

24. Image created by author. Elsie Gribbon (2023)

25. Image created by author. Elsie Gribbon (2023)

26. Image created by author. Elsie Gribbon (2023)

27. Image created by author. Elsie Gribbon (2023)

28. Image created by author. Elsie Gribbon (2023)

29. Table created by author using data collected by author. Elsie Gribbon (2023)

30. Graphs created by author using data collected by authot. Elsie Gribbon (2023)

31. Image created by author. Elsie Gribbon (2023)

31. Image created by author. Elsie Gribbon (2023)

33. Hybrid Image created by author. Elsie Gribbon (2023)
Using image RAAC Cross section, LABC (2022)
Available at: https:// BIMplus.com [Accessed 02 Oct. 2023]
Referencing diagram from Currie, J. and Matthews, S. (1996). Reinforced autoclaved aerated concrete planks designed before 1980 [online].
Available at: https://www.brebookshop.com/details.jsp?id=325330 [Accessed 30 Sept. 2023].

34. Image created by author. Elsie Gribbon (2023)

35. Image created by author. Elsie Gribbon (2023)

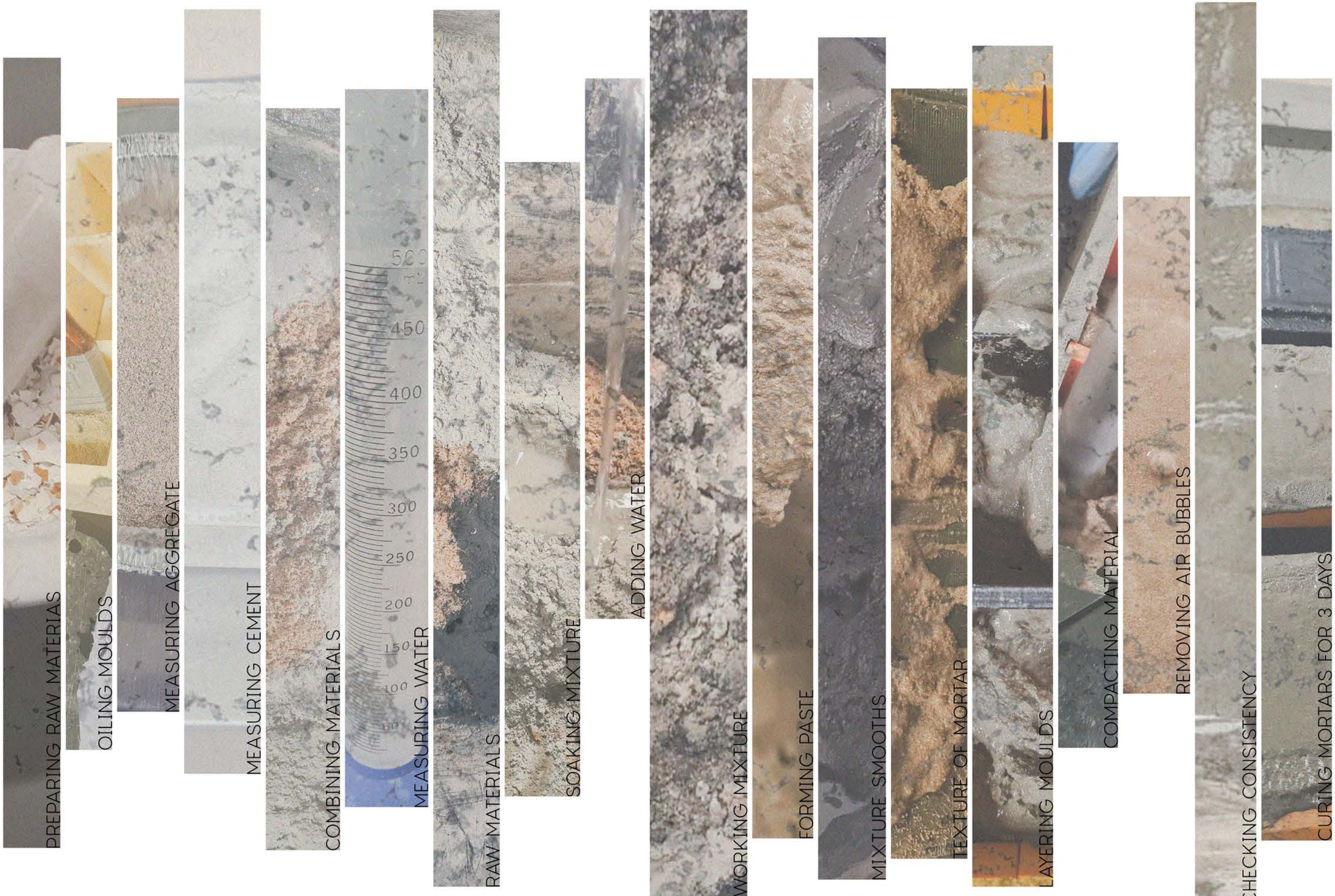
36. Detail created by author. Elsie Gribbon (2023)

37. Image created by author. Elsie Gribbon (2023)

VIDEO REFERENCES

1. Video created by author. Elsie Gribbon (2023)

APPENDIX -



A TIMELINE OF MATERIAL EXPLORATION

Image created by author. Elsie Gribbon (2023)