Effects of concrete on the environment

Vasavi Kullanakoppal

Bellevue University

DSC 500: Introduction to Data Science

Prof. Matthew Metzger

April 20, 2024

Effects of concrete on the environment

This Study examines the impact of concrete on the environment. One of the most utilized construction materials in the building industry is concrete, owing to its strength, durability, and versatility. It is used in the construction of foundations, walls, floors, bridges, and many other structures. Its importance in the construction industry cannot be overstated, as it forms the backbone of modern infrastructure. However, the production of concrete has significant environmental impacts.

Overview

Concrete is used to create hard surfaces which contribute to surface runoff that may cause soil erosion, water pollution and flooding. Cement contributes to the effects of concrete. The cement industry is one of the two largest producers of carbon dioxide (CO2), creating up to 5% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel.

- Concrete dust - Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution.
- Toxic and radioactive contamination - The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicity and radioactivity.
- Carbon dioxide emissions and climate change - The cement industry is one of the main producers of carbon dioxide, a greenhouse gas. Between 4-8% of total global CO_2 emissions come from concrete. Concrete causes damage to the most fertile layer of the earth, the topsoil.

Analysis:

Google Trend Analysis:

Data is utilized to analyze patterns of online search behavior related to various domains, including the effect of concrete, concrete dust, carbon dioxide emissions, toxic and radioactive contamination.

Figure 1.1, 1.2 and 1.3 shows the public interest gauge and awareness of these issues over 5 years of time and across United States sub regions. By this, we can assess the level of public concern and attention towards these issues. This can provide insights into which issues are gaining traction and which may require more attention or education.

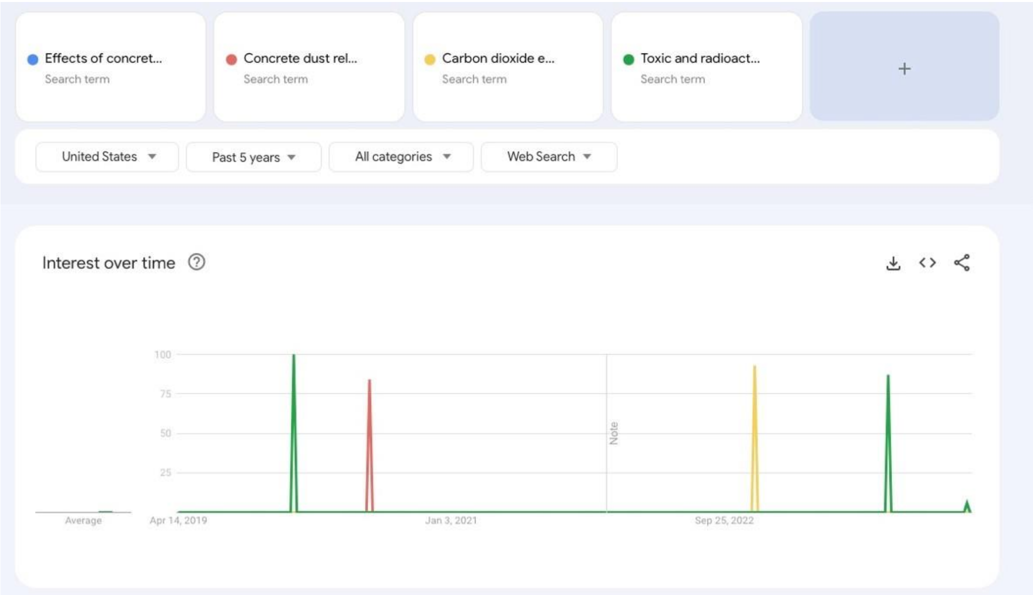


Figure 1.1. Interest Over time (5 years)

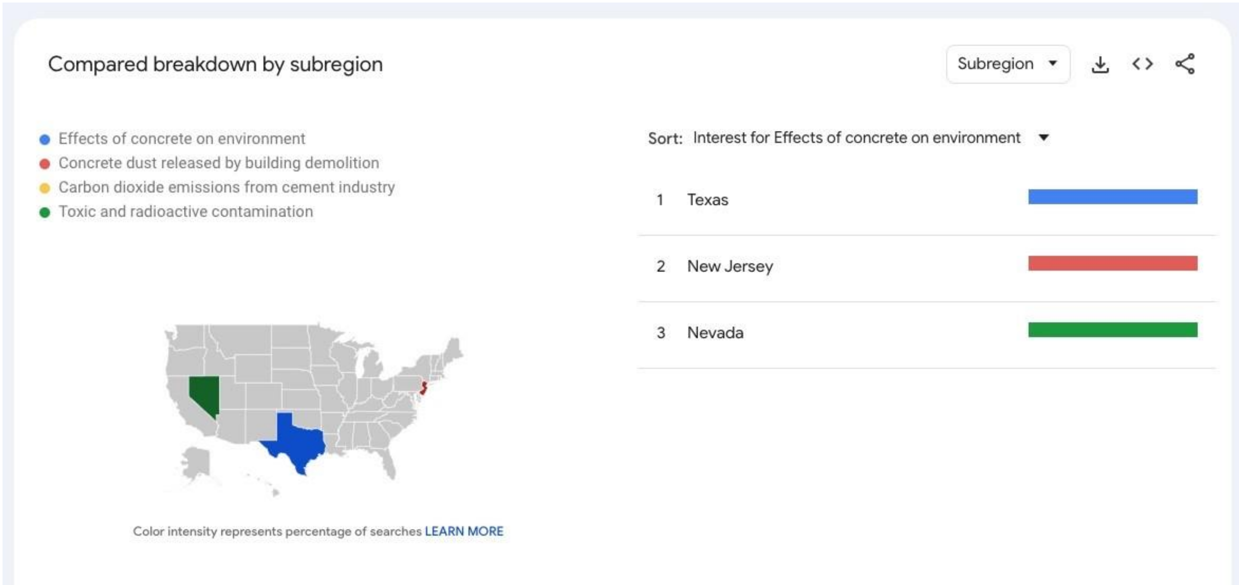


Figure 1.2: Compared breakdown by different metro area in United States

multiTimeline

Category: All categories				
Week	Effects of concrete on environment: (United States)	Concrete dust released by building demolition: (United States)	Carbon dioxide emissions from cement industry: (United States)	Toxic and radioactive contamination: (United States)
2020-01-05	0	0	0	100
2020-06-28	0	84	0	0
2022-12-04	0	0	93	0
2023-10-08	0	0	0	87
2024-04-07	5	0	0	6
2024-04-14	0	0	0	0

Figure 1.3: Geo Map

Life Cycle Assessment Analysis

Numerous scholars have employed life cycle assessment (LCA) to explore the ecological repercussions of various concrete mix design configurations. This approach facilitates the identification of possible environmental problem areas and offers valuable perspectives on how to mitigate such impacts.

LCA is a technique that evaluates the ecological consequences of a commodity or amenity throughout its entire life, from the collection of raw materials to its disposal at the end of its life span. LCA examines every phase of a product’s life cycle, including the procurement of raw materials, the manufacturing process, transportation, utilization, and the methods used to dispose of it when it reaches the end of its life. The aim of LCA is to identify potential environmental impacts and provide a holistic understanding of the environmental footprint of a product or service. LCA can be used to support decision-making in various areas, such as product design, material selection, and waste management.

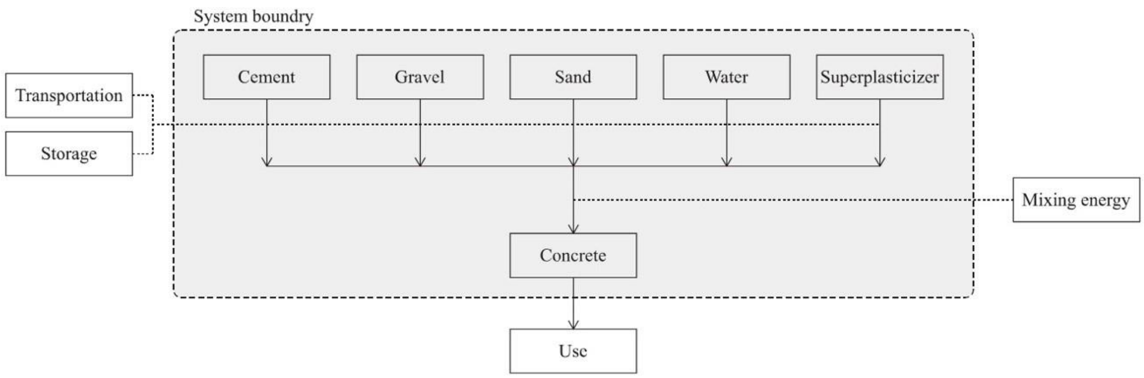


Figure 2.1: Considered System boundaries for the LCA.

Findings/Results and Discussion

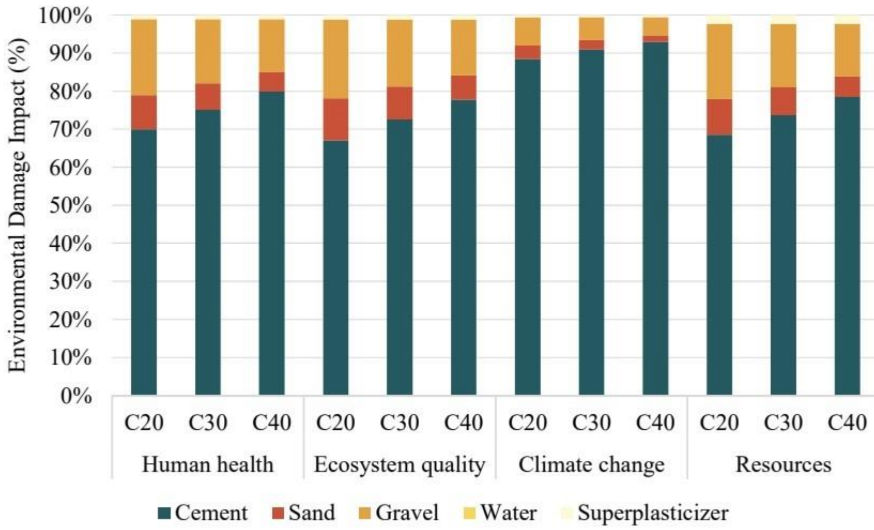
In this section, the environmental impacts of concrete with three different mixing designs are examined. Subsequently, the impact of these mixing designs on the LCA of the structures is evaluated. All the assessments were carried out utilizing SimaPro 9.0.0.48 software developed by PRé Consultants and relied on the Ecoinvent v. 3.5 databases for Life Cycle Inventory (LCI). In this regard, two distinct methodologies were employed, namely IMPACT 2002+ and CML baseline 2000.

Method		Unit of Measurement	C20	C30	C40
IMPACT 2002+	Human health	DALY	0.000133	0.000158	0.000191
	Ecosystem quality	PDF.m^2.yr	42.129	49.750	59.662
	Climate change	kg CO_2 eq.	267.193	332.572	417.819
	Resources	MJ primary	1524.054	1810.962	2183.168
CML baseline 2000	Acidification	kg SO_2 eq.	0.66281	0.79334	0.96335
	Eutrophication	kg PO_4 eq.	0.17710	0.21087	0.25482
	Global warming	kg CO_2 eq.	270.366	336.409	422.518
	Human toxicity	kg 1,4 DB eq.	68.473	80.793	96.761

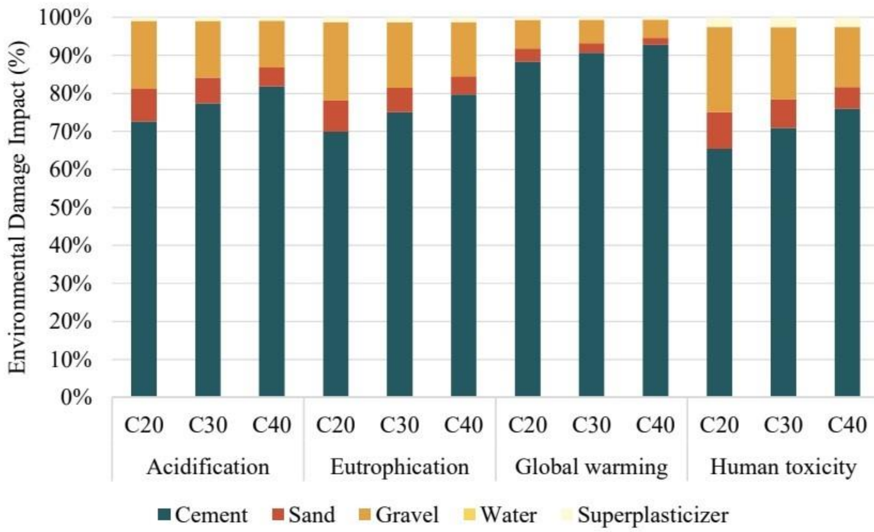
Table 2.1: Total environmental damage impacts for different concrete mix designs.

The Environmental Impacts of the Concrete Mix Design Parameters:

Table 2.1 presents the results of the LCA conducted on 1 m3 of concrete with compressive strengths of 20, 30, and 40 MPa, using two different methods: IMPACT 2002+ and CML baseline 2000. An increase in cement usage in C40 concrete compared to C20 concrete is associated with respective increases of 43.73%, 56.37%, and 41.31% in human health, climate change, and human toxicity indicators. Similarly, the corresponding increased values for C30 concrete compared to C20 concrete are 19.00%, 24.47%, and 17.99%, respectively. Additionally, the results indicate good compatibility between the carbon footprint calculated using two criteria, IMPACT 2002+ (climate change) and CML baseline 2000 (global warming), with a difference not exceeding 1.18% for concrete with different mixing designs.



(a)



(b)

Figure 2.2 LCA results for different concrete mix design parameters based on (a)IMPACT 2002+, (b) CML baseline 2000

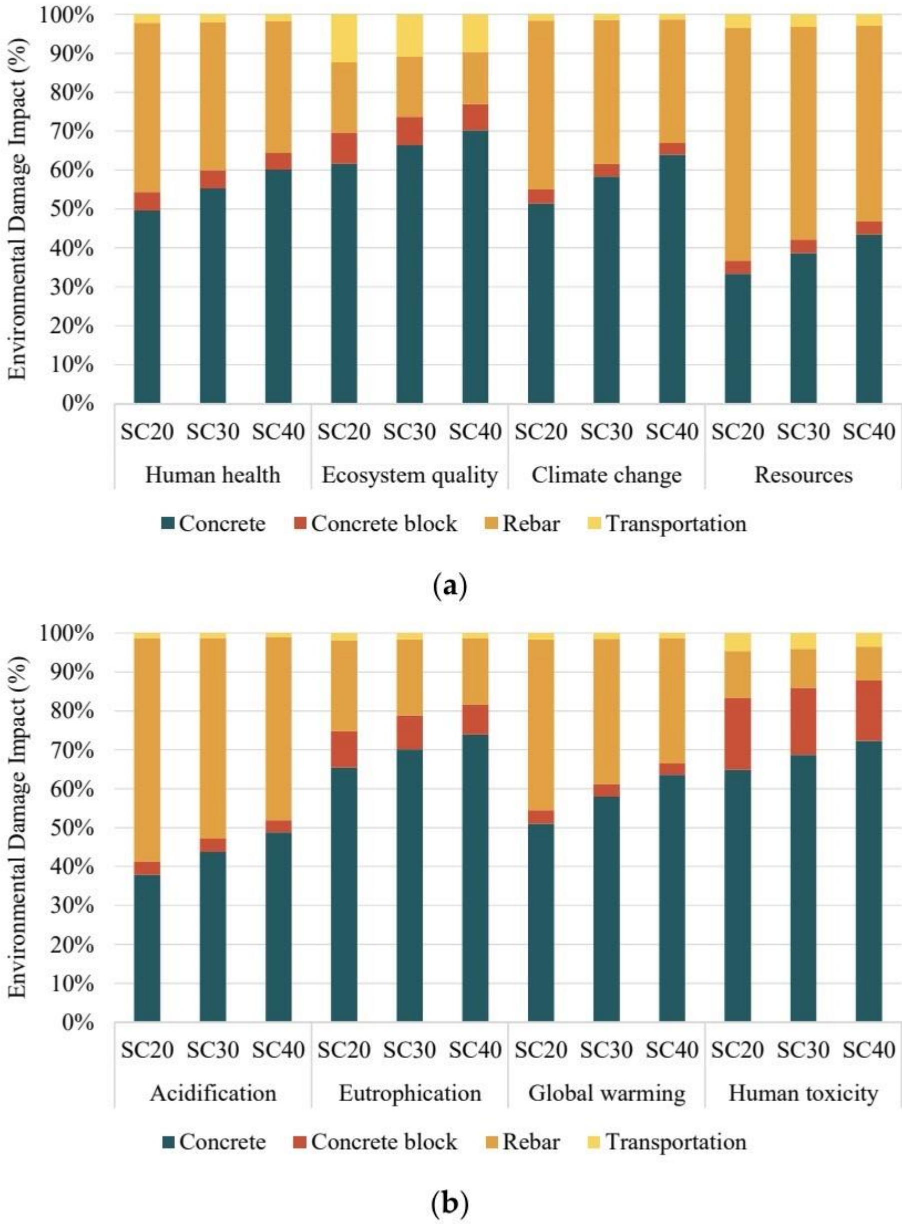


Figure 2.3: LCA results for different structures according to the (a) IMPACT 2002+, (b) CML baseline 2000.

Figure 2.2 illustrates the share of concrete constituents in different mixing designs based on two methods, IMPACT 2002+ and CML baseline 2000. Cement is found to be the primary contributor to the environmental impacts in all indicators of these two methods, constituting approximately 90% of the carbon footprint. Following cement, sand, gravel, and admixtures have the greatest impact on the LCA results. For instance, in terms of the human health category, the share of cement, sand, gravel, and admixtures in C20 concrete is 69.98%, 19.91%, 9.01%, and 1.04%, respectively. It is noteworthy that water usage in concrete has a negligible effect on LCA indicators. Moreover, although the amount of sand used remained constant in the presented mixing design, an increase in cement content led to a decrease in the contribution of sand to the environmental effects.

Concrete is a significant contributor to environmental effects, constituting over 50% of all indicators in these two methods, except for resources and acidification. Notably, the carbon footprint index reveals that the 20 MPa concrete building has a share of approximately 51%, while the building with 40 MPa concrete has a share of about 64%. Meanwhile, the environmental impact of the used rebars outweighs that of other building structure components in the resources and acidification indices. However, the significance of this impact decreases as the compressive strength of concrete in the building increases, reducing the need for rebar. Furthermore, transportation plays an insignificant role in all indicators, except for ecosystem quality, where it has a share of approximately 11% among environmental factors.

Conclusion

Concrete is the second most-used material on earth, surpassed only by water. Concrete is used in construction of roads, bridges, ports, and buildings. Concrete is also responsible for over 8% of annual anthropogenic greenhouse gas (GHG) emissions globally. As population and urbanization increase and existing infrastructure deteriorates, demand for production of concrete will increase, and with it, the environmental burdens from its production. The models used to determine the environmental impacts of producing concrete have considerable uncertainty and variability. This makes it challenging to identify the most effective means of mitigating these burdens. These challenges are exacerbated by the fact that the key drivers for air pollutant emissions and GHG emissions vary. While many are linked to the energy resources used in cement production, there are also notable air-pollutant emissions from quarrying practices. Improved understanding of the environmental impacts from producing concrete and the probability of mitigating such impacts will allow decision makers to examine drivers with the greatest likelihood of yielding meaningful emissions reductions.

Overall urban configurations should remain of concern when making decisions as people are exposed to weather and thermal comfort conditions. The use of high albedo materials within an urban environment can be of positive effect with proper combination of other technologies and strategies such as: vegetation, reflective materials, etc. Urban heat mitigation measures could minimize impacts on microclimate as well as human and wildlife habitats.

References

Delnavaz, M.; Sahraei, A.; Delnavaz, A.; Farokhzad, R.; Amiri, S.; Bozorgmehrnia, S (January 2022). *Production of concrete using reclaimed water from a ready-mix concrete batching plant: Life cycle assessment (LCA), mechanical and durability properties.* https://www.sciencedirect.com/science/article/abs/pii/S2352710221014182?via%3Dihub

Google LLC. (2024). Google Trends. https://trends.google.com/trends/explore?date=today%205-y&geo=US&q=Effects%20of%20concrete%20on%20environment,Concrete%20dust%20released%20by%20building%20demolition,Carbon%20dioxide%20emissions%20from%20cement%20industry,Toxic%20and%20radioactive%20contamination&hl=en

Monteiro, N.B.R.; Neto, J.M.M.; da Silva, E.A (10 December 2021). *Environmental assessment in concrete industries.*

https://www.sciencedirect.com/science/article/abs/pii/S0959652621036957?via%3Dihub

Mostafaei, H., Badarloo, B., Chamasemani, N.F., & Rostampour, M. A. (2023). *Investigating the Effects of Concrete Mix Design on the Environmental Impacts of Reinforced Concrete Structures.* https://www.researchgate.net/publication/370849218_Investigating_the_Effects_of_Concrete_Mix_Design_on_the_Environmental_Impacts_of_Reinforced_Concrete_Structures

Raposo, C., Rodrigues, F., Rodrigues, H (05 October 2019). *BIM-based LCA assessment of seismic strengthening solutions for reinforced concrete precast industrial buildings.* https://link.springer.com/article/10.1007/s41062-019-0239-7

Vaclavik, V., Ondova, M., Dvorsky, T., Estokovaa, A., Fabiánova, M., Gola, L. (25 November 2020) *Sustainability Potential Evaluation of Concrete with Steel Slag Aggregates by the LCA Method*. https://www.mdpi.com/2071-1050/12/23/9873

Wikimedia Foundation (19 April 2024). https://en.wikipedia.org/wiki/Environmental_impact_of_concrete#:~:text=The%20cement%20industry%20is%20one,erosion%2C%20water%20pollution%20and%20flooding.