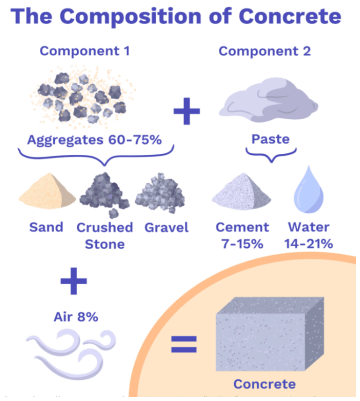
Concrete with Biochar, Ground Plastic & Ground Glass

Concrete is the second most consumed material[1] globally, after water. Every year, about **30 billion tonnes[2] of concrete** are produced globally, contributing roughly **8% of global CO2 emissions**[3]. Traditional concrete is made of cement, aggregates (sand and gravel), and water, each of which poses environmental challenges.

Figure 1: The composition of concrete



Source: ClimateScience[4]

- **Cement:** Cement production generates high CO2 emissions (7% of global total CO2[5]).
- **Aggregates:** Sand and gravel extraction harms ecosystems and depletes natural resources. About 50 billion tonnes of sand are extracted every year, leading to the "sand crisis[6]".
- **Water:** Needed for cement hydration, but excessive use of water not only leads to water stress but also affects strength and durability of concrete.

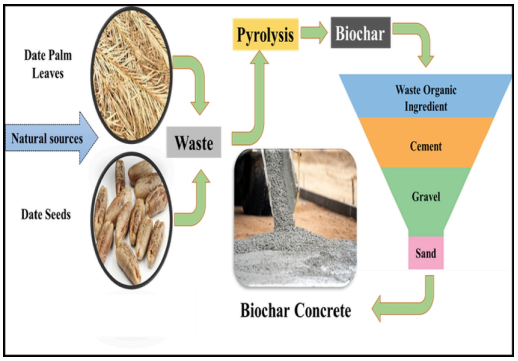
To address these challenges, **biochar, ground plastic, and ground glass** were identified as sustainable alternatives that can partially replace cement and aggregates while enhancing concrete properties.

1. Biochar – Replaces some cement

What it is: Biochar is produced by heating organic biomass without oxygen, creating a carbon-rich material.

Figure 2: Biochar in concrete & its characteristic[7]

[1] Cement and concrete as an engineering material: An historic appraisal and case study analysis - ScienceDirect
[2] We use 30 billion tonnes of concrete each year — here's how to make it sustainable.
[3] Cement is a big problem for the environment. Here's how to make it more sustainable
[4] Construction: Sustainable Steel & Cement | ClimateScience
[5] Cement technology roadmap plots path to cutting CO2 emissions 24% by 2050 - News - IEA
[6] Sand mining is close to being an #environmental crisis. Here's why – and what can be done about it
[7] Biochar-concrete: A comprehensive review of properties, production and sustainability - ScienceDirect



Source: Researchgate[8]

- **Stronger and lighter concrete:** The porous nature of biochar can help to reduce the density of concrete, making it lighter and improve its mechanical properties, such as compressive and tensile strength.
- **Better thermal properties:** The high carbon content of biochar enhances the thermal properties of the composite, effective heat absorption and storage, reducing temperature fluctuations thus save energy cost
- **Reduced Shrinkage**: Biochar's high surface area and porosity increase water absorption and enhance moisture retention within the composite, improve durability, reduce drying shrinkage and improve resistance to cracking
- **Environmental impact:** Locks carbon in concrete, supporting climate change mitigation.

2. Ground Plastic – Replaces sand/gravel

What it is: Waste plastic processed into ground plastic for use as aggregate replacement.

Figure 3. Ground plastic in concrete & its characteristic[9]

Source: ScienceDirect

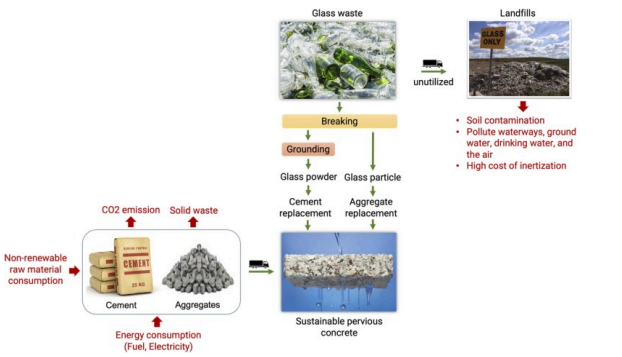
- **Lightweight concrete:** The aggregate comprises the largest and heaviest portion of concrete (85% of its weight). Thus, the use of ground plastic makes concrete lighter, reduces dead load on structures, which can lower costs for steel and other materials.
- **Improved insulation:** Ground plastic with its low density enhances thermal and sound insulation.
- **Improve strength[10]:** Optimal use of ground plastic increases concrete bending strength (up to 15% stronger).
- **Cost savings:** Lighter materials are easier to transport and install, reducing labor and handling costs.
- **Positive environmental impact:** Turns plastic waste into a valuable construction material, substitute for natural aggregates helps to preserve limited natural resources.

3. Ground Glass – Replaces sand/ cement

What it is: Crushed waste glass that reacts with cement components to improve strength.

[8] Production of biochar-based concrete composite
[9] Producing sustainable concrete with plastic waste: A review - ScienceDirect
[10] MIT students fortify concrete by adding recycled plastic | MIT News | Massachusetts Institute of Technology

Figure 4. Ground glass in concrete & its characteristic[11]



Source: ScienceDirect[12]

- **Stronger concrete:** Optimal replacement (15% of sand) can increase compressive strength by ~5%.
- **Environmental benefit:** Uses ground glass reduces landfill waste pressure, reduces the need to extract natural resources, and reduces cement consumption.
- **Cost-effective:** Savings of up to 2% in material costs at optimal proportions as ground glass is generally cheaper than natural sand, reduces the costs associated with material acquisition and transportation.

Table 1. Practical Comparison

Material	Benefits	Key Recommendations
Biochar	Stronger, lighter, reduces cracks, increase thermal properties, carbon storage	~5%[13] of cement replacement
Ground Plastic	Lightweight, thermal/sound insulation, cost savings, waste utilization	Replace 50 - 75%[14] of aggregates
Ground Glass	Improves compressive strength, sustainable, cost-effective	Replace ~15% of sand; replace 10 - 20 %[15] of cement, avoid higher percentages.

Ongoing research is focused on combining all three materials: biochar, ground glass, and ground plastic in concrete. While the combined effect of all three is still under investigation, results from material pairs are promising.

- Biochar & Ground Plastic[16]: Mixing biochar with plastic helps maintain strength while increasing flexibility and crack resistance.
- Ground Glass & Ground Plastic[17]: Combining glass and plastic improves durability against corrosive elements like chlorides.

Together, these materials contribute to stronger, more durable, and environmentally sustainable concrete by repurposing waste and enhancing key properties.

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[11] Improving the Compressive Strength of Concrete with Recycled Ground Glass
[12] Potential use of crushed waste glass and glass powder in sustainable pervious concrete: A review - ScienceDirect
[13] Evaluating environmental and economic benefits of using biochar in concrete: A life cycle assessment and multi-criteria decision-making framework - ScienceDirect
[14] Producing sustainable concrete with plastic waste: A review - ScienceDirect
[15] Effect of partial replacement of the cement by glass waste on cementitious pastes - ScienceDirect
[16] Combined effects of biochar and recycled plastic aggregates on mechanical behavior of concrete - Sirico - 2023.
[17] (PDF) The Combined Effect of Glass and Plastic Waste on Concrete Properties: Experimental Study