Short-Term and Long-Term Needs for Sustainable Concrete—An Overview †

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Abstract: The world’s population is increasing rapidly, which has increased the demand for the construction of new structures. The need for increased construction is not only creating a shortage of natural resources but is also depleting the environment. Not only this, but waste materials such as plastic, glass wastes, etc., are not disposed of properly, which are putting flora and fauna at risk, to the point of extinction. In light of such conditions, ecologists suggested the world opt for “sustainable development”, with the aim of developing the world in such a way that natural resources and the environment are conserved, because concrete is one of the leading contributors of CO₂ emissions into the atmosphere. This approach is about making sustainable concrete by utilizing wastes such as PVC and glass mix as replacements for fine aggregate, i.e., sand. This will help decrease the CO₂ emissions from concrete by a considerable level. This will be done by replacing the PVC-glass mix in different ratios with sand. Thus, this will contribute to the usage of waste materials, which will help in preserving the environment along with flora and fauna that are at the risk of extinction. Additionally, the world’s sustainable concrete demand will be met without compromising concrete strength.

Keywords: sustainable development; environment; flora and fauna; PVC–glass mix

1. Introduction

A literature review for the past decade has been completed in this paper regarding the need for sustainable concrete and its effects in the short and longer run. The sustainable concrete review includes a wide range of different approaches in order to boost the sustainability of concrete. This review identifies easier methods for the production of conventional Portland cement, which tends to be high-quality cement, through the use of relatively simple applications of technology [1]. The concrete industry faces environmental issues due to an increase in the production of concrete. Commonly, there are four main sources of waste which are incorporated into concrete products. Binders are the easiest material to add to concrete. In this paper, we see the effects of adding GGBFS. Some positive responses are seen, such as an increase in durability and workability [2]. Sustainable concrete is needed today to fulfill the wants of our generation without neglecting the needs of our upcoming generations.

Pressure has been put on the concrete industry to reduce its emissions of CO₂ into the atmosphere. As we know, concrete contributes the most to the emission of carbon dioxide, which is depleting the ozone layer. For some sustainable approaches, the use of waste materials in concrete as a replacement for conventional construction materials has widely started. The fresh and hardened properties of concrete determine the feasibility and functionality of waste materials. This paper shows the results of replacing specified percentages of OPC and natural sand with marble dust and glass dust, and then assesses the feasibility and strength of research laboratory mixes. The results show that similar
fresh properties were seen, while sound permeability, thermal conductivity, and water permeability were improved when incorporated with waste materials. Not only that, but it also lowers the environmental impacts, which seems like a good sustainable approach for concrete production [3]. The incorporation of waste materials into conventional concrete is helping achieve better results in terms of early-age flaws, which in turn increases the life of the structure.

Recycled aggregate concrete (RAC) is anticipated to be a justifiable answer to altering virgin aggregate concrete in structural usage. Environmental burdens, through the application of LCA (life cycle assessment), are not enumerated by many studies. RAC, which is a composite material, is assessed by keeping in mind its mixtures along with similar production technologies [4]. The wastage of materials needs to be reduced, and we need to move toward the sustainable construction development of cost-efficient, environmentally friendly concrete. Sustainable concrete is also a necessity within the construction industry as it reduces CO$_2$ emissions into the atmosphere, because OPC is responsible for 7% of CO$_2$ emissions. Sustainable concrete is not only beneficial for the environment but offers improved performance [5]. By delaying early cracks and reducing the emissions of CO$_2$, sustainable concrete increases the expected life of a building. It also aids in the preservation of the environment.

It is clearly seen that sustainable concrete has proved to be the perfect remedy to the current concern of researchers. A lot of work has been carried out, and a lot more is being completed in this regard, as everyone is trying to meet the sustainable development goals. Concrete contributes the most to the discharge of carbon dioxide, which is depleting the ozone layer. Pressure has been put on the concrete industry to reduce its emissions of CO$_2$ into the atmosphere. The usage of leftover materials in concrete as a replacement for conventional construction material is the new normal. In order to meet the needs of our age without jeopardizing the needs of upcoming generations, sustainable concrete is the need of the hour. Waste elements are being used in traditional concrete to help obtain better results in terms of early-age faults and in extending the life of a construction. Sustainable concrete extends the projected life of a structure by delaying early fractures and lowering CO$_2$ emissions. It also contributes to environmental protection.

2. Making Concrete Sustainable

Wastes from building industries and other industries have drastically enlarged during the last decade and are a serious environmental threat. Hence, by using these waste materials in concrete, they can play a significant role in the production of sustainable concrete and preserve natural resources. Not only this, but sustainable concrete made with waste helps in proper waste management. Recycled aggregates with GGBS and lime were used in conventional concrete, and this concrete was used in structural members. Desired strength, environmental benefits, and a solution to waste disposal problems were achieved. Socio-economic benefits cannot be neglected as natural resources are conserved for upcoming generations [6]. Due to its better durability, sustainability, and less environmental effect, lightweight geopolymer concrete has been in the spotlight in present times.

Rapid increases in construction and industrialization have increased the economic as well as environmental concerns of countries that are under development. Additionally, increased industrialization has also increased waste production, be it domestic or industrial. This is a serious threat to human health, wildlife, and marine life; in short, the entire eco system is threatened. This concern has diverted the attention of researchers to using this waste by partially replacing cement in conventional concrete, which will be cost-effective as well as eco-friendly. This study includes the use of wood ash powder and fine seashell powder as a replacement for OPC and many other useful products some of them are enlisted above in Table 1. After testing this, some favorable results were obtained in terms of the mechanical performance of concrete [7]. Waste management is one of the main concerns in this era, which can be solved by incorporating waste materials for useful purposes such as sustainable concrete.
### Table 1. Different materials used in concrete and their observed properties.

<table>
<thead>
<tr>
<th>Alternate Materials As a Replacement to</th>
<th>Properties Seen Experimentation</th>
<th>After</th>
<th>References</th>
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<tbody>
<tr>
<td>Glass</td>
<td>Gives thermal stability, improves water absorption, and lowers shrinkage.</td>
<td>[8]</td>
<td></td>
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<tr>
<td>Poly-Ethylene Terephthalate (PET)</td>
<td>Increases density and ductility and reduces shrinkage cracks.</td>
<td>[9]</td>
<td></td>
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<tr>
<td>Tile and Sanitary Ceramics</td>
<td>Decreases specific weight.</td>
<td>[10]</td>
<td></td>
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<tr>
<td>Clay Bricks</td>
<td>Increases water absorption and workability.</td>
<td>[11]</td>
<td></td>
</tr>
<tr>
<td>Tires and Rubber</td>
<td>Improves resistance to fire and reduces stiffness of concrete.</td>
<td>[12]</td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>Density and bending strength increases.</td>
<td>[13]</td>
<td></td>
</tr>
<tr>
<td>Concrete Waste</td>
<td>Improves drying shrinkage.</td>
<td>[14]  (Zega and Di Maio, 2011)</td>
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<tr>
<td>Agricultural Waste (Coconut Shell Fibers)</td>
<td>Higher compressive strength than concrete containing oil palm shell.</td>
<td>[15]  (Shafigh et al., 2014)</td>
<td></td>
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<tr>
<td>Silica Fumes</td>
<td>Improves mechanical properties but can reduce durability a bit.</td>
<td>[16]  (Heidari and Tavakoli, 2013)</td>
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<tr>
<td>Ceramic Tile</td>
<td>Has pozzolanic properties.</td>
<td>[17]  (Shang, 2000; Toledo et al., 2007).</td>
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<tr>
<td>Clay Brick Waste</td>
<td>Strength equivalent to 91% of the lab sample can be reached.</td>
<td>[18]  (Tourgal and Jalali 2010)</td>
<td></td>
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<tr>
<td>Rice Husk Ash</td>
<td>It has a low energy requirement, and a negligible amount of greenhouse gases is emitted by it.</td>
<td>[19]  (Siddika et al., 2021)</td>
<td></td>
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<tr>
<td>Tile Powder</td>
<td>Improves water absorption and compressive strength.</td>
<td>[20]  (Huang et al., 2017)</td>
<td></td>
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<td>Glass Powder and PVC mix</td>
<td>Reduces pavement temperature and also does not compromise mechanical properties.</td>
<td>[21]  (Anupam et al., 2020)</td>
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Unused concrete is returned in a significant amount to production plants and is a significant threat to natural soil and water. Thus, in this research, it was decided to transform fresh, unused concrete into a man-made aggregate for the production of sustainable concrete. Additionally, after testing, it was found that it could be reused as natural coarse aggregate to produce new concrete [22]. The utilization of unused concrete as aggregate to save money is one unique thought that helps save a lot of money as well as natural resources. Adding alternate materials to simple PCC results in the desired result without affecting the strength of this concrete. A ton of OPC (ordinary Portland cement) uses about 4 GJ of energy and releases the same amount of CO\(_2\). GGBS or AAS (alkali-activated slag) is being utilized as a substitute binder for OPC as part of our commitment to preserve the environment. This concrete is not only environmentally beneficial, but it also alleviates typical concrete’s problems with energy consumption, raw material costs, and manufacturing costs. The cementitious characteristics of GGBFS and AAS make them ideal for use in concrete [23].

When energy-intensive cement is partially replaced with reusable materials, it is one of the best possible solutions for acquiring eco-friendly construction materials. The need for eco-friendly concrete is increasing day by day. This is significant because it not only safeguards the environment and our health, but it also provides a stronger and
longer-lasting alternative to standard concrete. The above table shows the list of alternative materials which can be replaced with cement, sand, or aggregate in conventional concrete. Note that those mentioned above are just some of the materials. Apart from this, there is a long list of materials that are being used for this purpose too. Adding different components to plain PCC achieves the desired result while maintaining the concrete’s strength. CO₂ emissions have been greatly decreased as a result of the use of sustainable concrete, allowing the ozone layer to be conserved.

3. Short-Term Needs for Concrete in Construction Industry

This study provides the findings of early-stage investigational research on used concrete. The effect of recycled gravel and sand (RG and RS) on plastic shrinkage and cracking sensitivity was explored. The initial level of water saturation had no effect on the progression of plastic shrinkage. In the first hour after mixing, before the formation of plastic shrinkage, recycled aggregates showed relatively high absorption. The early-age properties of recycled concrete and cracking sensitivity were affected by a high rate of substitution of recycled gravel or sand, especially when ordinary sand was substituted with recycled concrete sand [24]. Each year, 12 billion tons of OPC is made, which is approximately 2 tons per person. In a concrete structure, crack formation is a major flaw. Scientists have worked and produced a new type called self-healing concrete which fixes all narrow cracks by itself automatically. Sustainable buildings are the need of the hour in order to remove the carbon footprints of concrete in preserving climatic changes [25]. Thus, the strength of concrete structures seems to increase more than average.

Furthermore, plastic shrinkage in concrete is a serious issue, especially in larger surface areas. Concrete that had more cracks was treated with polypropylene and polyester fibers, which removed cracks in the most affected areas of the concrete. The evaporation from the surface of the concrete was handled with ethylene-glycol and curing-based compounds and decreased the rate of evaporation very well [26]. (Plastic cracking is very common in concrete structures and can cause a decrease in the durability of the structures as well as reduce the lifecycle of the buildings if it is not prevented. As a result, plastic cracking has come to mean both plastic settlement cracking and plastic shrinkage cracking. Several plastic cracking mitigation measures have been proposed, including fogging, using fewer particles, and utilizing fibers, among others [27]. Polyester fibers prove to be useful in stopping early-age faults in concrete, such as plastic shrinkage, cracking, etc., which automatically makes a building more durable.

4. Long-Term Needs for Sustainable Concrete

The massive usage of (NA) natural aggregate attained by broad diggings and mining is now an unavoidable aspect of highway building due to the continuous paving of roads round the world. Overall, RCA appears to be a promising option to replace the excessive use of NA in the future building of good-quality, long-lasting asphaltic pavements [30].
Portland cement is the main ingredient in the construction industry, but it emits a lot of CO$_2$ and energy into the atmosphere. The construction industry is under increasing pressure to develop substitute additional cementitious materials to replace Portland cement in concrete because it is produced in such massive amounts.

The static and dynamic properties of coir-fiber-reinforced concrete beams as structural members have been examined. The impact of damage on the load-transmitting behavior of CFRC beams along with alterations in their dynamic properties is addressed. The growth of damage is simulated by increasing the static load slowly up to a certain deflection preceding to each dynamic test. It has been detected that with increasing damage, the transmitted force is enlarged [31]. The dynamic behavior of coir-fiber-reinforced concrete (CFRC) structural members is practically unknown. The dynamic properties of CFRC beams were investigated experimentally using impact loading with a calibrated hammer for the different stages of damage in beams. It was observed that the damping is increased by up to 229% and the natural frequency is decreased by up to 63% when a CFRC beam with 3% fiber content goes from an uncracked to a cracked stage [32]. Thus, we can conclude with the fact that fiber-reinforced concrete is a way forward for sustainable concrete.

Fly ash (FA) is abundantly available and can be used to make upcoming-generation green concrete for up-to-date buildings. In the presence of water, FA becomes a pozzolanic material with high alumina and silica content that has a cementitious attribute. As a result, geopolymer concrete based on FA (FA-GPC) appears to be a supreme alternative to normal concrete that should be pursued. FA makes a durable FA-GPC which is a relatively new, innovative, and long-lasting design of composite material with a number of advantages, including high early strength and an increase in durability qualities (such as reduction in permeability) against harsh conditions [33]. Fly ash silica-fume coconut fiber concrete showed better results in terms of mechanical properties as compared to FA-SPC [34]. Fly ash is abundantly available and can be used to make next-generation green concrete for modern buildings. A study showed that a PVC–glass mix can be fused into concrete pavements. This will be cost-effective and eco-friendly as well as efficient. A sample of glass particles and PVC particles can be seen in Figure 1.

Structures’ safety is usually related with the materials used in construction. In this research, the behavior of jute-fiber-reinforced concrete (JFRC) under impact and dynamic loadings is experimentally studied. The impact resistance of JFRC is enhanced up to 6 times as compared to PC. The dynamic elastic modulus and damping ratio are also improved by 68% and 100%, respectively. Steel reinforcement in slabs of concrete can be minimized by up to 28% by the use of short jute fibers in concrete slabs. In the study, flexure and split-tension strengths were shown to be improved by 8% and 20%, respectively [35]. For impact testing, a modified pendulum impact apparatus was used. At various levels of damage, dynamic properties were determined [32]. Jute-fiber-reinforced concrete with steel rebar is an effective, eco-friendly, and reasonable way to bear impact loads in important structures. The long-term results related to jute fiber are yet to be explored.

Figure 1. (a) Glass particles; (b) PVC particles (Anupam et al., 2020).
5. Conclusions

Waste materials, when incorporated into concrete, can support in the creation of more sustainable, durable, and ductile concrete. Faults in concrete structures can reduce a structure’s durability and service life. Sustainable concrete construction is a footstep toward greener and eco-friendly concrete construction practices to resolve universal ecological problems. The conclusions drawn from this literature review are as follows:

- Using waste materials in PC or recycling unused concrete can make concrete sustainable. GGBS, wood ash dust, etc., are some of those waste materials.
- Sustainable concrete has shown improved results in terms of short-term needs such as shrinkage cracking, resistance to elevated temperatures, etc.
- In longer terms, sustainable concrete is proven to be environmentally friendly, economical, and durable with an increased life due to a delay in early-age cracking.

Hence, by adopting sustainable concrete, the world can progress at the same pace without depleting the environment with an economical approach.

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References


