Enhancing Properties of Sustainable Concrete Using Wet Paper Pulp, Steel Slag, and Glass Fiber

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ABSTRACT: The global environmental impact of the building sector is noteworthy, especially when considering resource use and carbon emissions. Consequently, there is an increasing demand for environmentally friendly building materials that might lessen the industry's environmental impact. This study investigates novel ways to enhance concrete's structural integrity and sustainability by adding glass fibre, steel slag, and wet paper pulp. Concrete is one of the most widely utilized building materials in the world. But producing it However, it takes a lot of energy to produce and emits a lot of carbon dioxide. Our research aims to partially replace conventional aggregates in concrete by using wet paper pulp, a plentiful waste resource from the paper industry. By doing this, paper waste is kept out of landfills, and the need for natural aggregates—which are frequently mined from environmentally delicate areas—is decreased. In addition to wet paper pulp, we investigated the use of steel slag, a byproduct of the steelmaking process, as an additional cementitious ingredient. Because of its pozzolanic qualities, steel slag can help lower carbon emissions in the concrete sector. We also examined how strengthening the concrete with glass fibres can enhance its mechanical properties, such as its tensile and flexural strength. Through a series of comprehensive laboratory experiments and analyses, we evaluated the fresh and hardened properties of concrete mixes including varying proportions of wet paper pulp, steel slag, and glass fiber. Workability, compressive strength, durability, and shrinkage characteristics are some of these attributes. We also perform a life cycle study to evaluate these sustainable additives' effects on the environment. Our research's findings show that adding glass fibre, steel slag, and wet paper pulp to concrete not only increases its mechanical performance but also makes it more sustainable. By encouraging the effective use of waste materials and lowering the construction industry's carbon footprint, this research presents a possible path

for the development of greener building materials. This research adds to the ongoing attempts to develop more ecologically responsible construction practices while preserving structural integrity as the globe looks for sustainable solutions to solve environmental concerns.

Keywords: Glass fibre, Steel slag, Wet paper pulp, Flexural strength, Workability, Compressive strength, Durability, Shrinkage.

INTRODUCTION

Concrete is becoming more and more in demand worldwide, so it is critical to investigate creative ways to make the material more environmentally friendly without sacrificing its structural integrity. In this regard, integrating sustainable additives has become more well-known as a potential solution to these issues.To improve the sustainable concrete's qualities, three different additives are added in this research article: glass fibre, steel slag, and wet paper pulp. This study's goal is to investigate how these additives affect the mechanical, long-term, and sustainable qualities of concrete by providing a comprehensive examination of both their individual and combined effects. The findings of this study could lead to a notable advancement in sustainable construction methods bydrastically lowering the environmental impact of concrete production while simultaneously improving its performance.

When waste paper pulp is used in part place of cement, construction expenses are greatly reduced and no environmental risks are created[1].The findings of the investigation indicate that the compressive strength steadily decreases as the volume of thrown paper increases. The use of glass fibres significantly increases the concrete specimens' split and flexural strengths[2].

As waste paper was included in the construction material, there was less cement used. The wastepaper's inherent strength came from hydrogen chains in its microstructure. In terms of energy absorption, papercrete is less expensive than alternative building materials. Papercrete improved low thermal insulation and sound absorption[3].The use of wet paper pulp improves the concrete's compressive strength, split tensile strength, and flexural strength while resolving the issue of waste paper disposal and producing environmentally friendly concrete[4].Wet paper pulp infusion improves the waste paper's tensile, flexural, and compressive strengths while lowering its landfill disposal[5]. Application of steel slag decreased early crack formation and increased crack resistance[6].Tensile strength was highest in concrete pavers when slag was substituted for sand at an ideal 20% ratio[7].The addition of steel slag to concrete results in increased split tensile strength, flexural strength, and reduced acid-induced loss of compressive strength. Additionally, concrete that has some fine and coarse material replaced with steel slag exhibits superior resistance to salt, acid, and sulphate[8].Steel slag has detrimentalimpact on workability when used in place of M-sand, but it significantly improves the hardened characteristics[9].Concrete's modulus of elasticity, compressive, tensile, and flexural strengths can all be increased by partially substituting natural aggregates, up to an ideal replacement value. It has been noted that steel slag can replace fine aggregate up to 36% of the time and improve both compression and tension. Conversely, concrete's qualities with a comparable amount of traditional fine aggregate and steel slag were validated to lack effectiveness. Other ways to reap the benefits include lowering costs, gaining social advantages, and fully using waste. Using steel slag is a possibilityin building as a partial substitute for fine in concrete[10]. Concrete that has been reinforced with glass fibre is more workable than traditional concrete. As the number of curing days increases, so does compressive and flexural strength[11]. Glass fibre reduces concrete's susceptibility to chloride ions by preventing cracks. Concrete works better in a maritime environment when it contains glass fibre[12]. Concrete mixtures with the addition of glass fiber exhibit reduced bleeding, after 28 days, the different grades of glass fiber concrete mixes are compared. the range of 20 to 25 shows the percentage increase in compressive strength[13]. With superior tensile, flexural, and compressive strengths, it can construct lightweight panels, The ultimate compressive strength capability of glass fiber was improved[14]. In comparison to control mixes, compressive strength increased, a concrete mix reinforced with fibres and having a higher water to binder ratio results in increased flexural strength[15].

Materials Used

1. **Cement**

   Ordinary Portland Cement, OPC 53 is used as per IS 12269:1987.Basic properties for the cement are enlisted below

   (a) Specific gravity: - 3.15

   (b) Fineness: - 4.5%

   (c) Consistency: - 31%

   (d) Initial setting time: - 31 minutes

(e) Final setting time: -9hours 47minutes

2. Fine Aggregate

Fine aggregate utilized was locally procured and is as per the standards of IS-383:1970

Its properties are: -

(a) Specific Gravity: - 2.63

(b) Surface moisture: - 2%

(c) Water Absorption: - 1.03%

(d) Fineness Modulus: - 2.44

(e) Grading Zone: - II

3. Coarse Aggregate

Coarse aggregate utilised was also procured locally and then tested as per the standards of IS-383:1970 and the following properties were observed

(a) Size: - 10-20 mm

(b) Specific Gravity: - 2.81

(c) Surface Moisture: - 0% (surface dried)

(d) Water Absorption: - 1.44%

(e) Fineness Modulus: - 7.47

4. Wet Paper Pulp

Wet paper pulp is produced from waste paper acquired from the colleges and universities,

The waste paper is first soaked into water for at least 72 hours and then it is placed in a grinder which run till a consistent smooth paste is obtained. The properties of the paste are enlisted below

(a) Moisture Content: - 3.51%

(b) Specific Gravity: - 0.98

(c) Density: - 798 g/cc

(d) Absorption: - 89%

5. Steel Slag

Steel Slagis acquired from a nearby local steel plant, from galvanizing plants and also from scrap processors. Steel slag properties are as follows

(a) Specific Gravity: - 3.39

(b) Water Absorption: - 2.66%

(c) Crushing Value: - 19

(d) Impact Value: - 18

6. **Glass Fibres**

Scrap glass fibre was procured for local glass fibre manufacturing industry, the properties are as follows

(a) Density: - 2.57 g/cm^3

(b) Aspect Ratio: - 0.67

(c) Specific Gravity 0.9

(d) Tensile Strength: - 16N

Mix Design

According to IS-10262, a concrete mix of M25 grade concrete is designed, and the ratio of cement to sand to aggregate is 1: 1.68: 2.37, with a water/cement ratio of 0.4510% of the cement's weight is substituted with wet paper pulp to replace the cement. Water Absorption test is carried out to determine the suitable percentage of addition of wet paper pulpreplacement with cement the glass fibre composition is set to 1% of weight of dry mix and the fine aggregate replacement with steel slag is taken as 25% by weight of fine aggregate.

METHODOLOGY

1. Three mix design named as M1, M2 and M3 are designed.
2. M1 being M-25 concrete with wet paper pulp included in the design mix.
3. M2 being M-25 concrete with inclusion of wet paper pulp and glass fibre in the design mix.
4. M3 is M-25 concrete with wet paper pulp, glass fibre and steel slag included in the design mix.
5. After undergoing the IS-1199 Slump Cone Test to determine its workability, freshly mixed concrete is cast into 150 x 150 x 150 mm cubes for the compressive strength test. The compressive strength is measured after 7, 14, and 28 days of curing. Prisms measuring 100 x 100 x 400 mm are used to measure the flexural strength, while cylinders measuring 150 mm in diameter and 300 mm in height are used to measure the

split tensile strength. The tests for both flexural and split tensile strength are conducted after 28 days of curing.

6. According to IS-516, curing is carried out. As per IS-5816:1999, split tensile strength tests are carried out.
7. The casted samples are also tested for acid attack resistance and fire resistance and their values are compared with the values for conventional concrete.

Fig 1: Concrete cubes for design mixes M1, M2 and M3 from left to right

Results

Table No. 1 Water absorption percentage for different wet paper pulp composition

Wet paper pulp percentage	Water Absorption Percentage
0	2.4
5	5.43
10	6.57
15	9.17

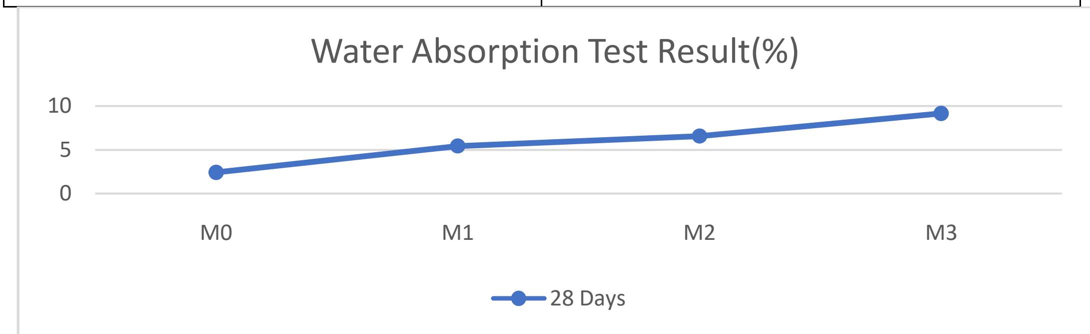

Fig 2: Graph of Water Absorption test results for different mixes

Table No. 2 Slump value for design mixes M1, M2, M3

Mix No.	Slump Value (mm)
M1	72
M2	65
M3	60

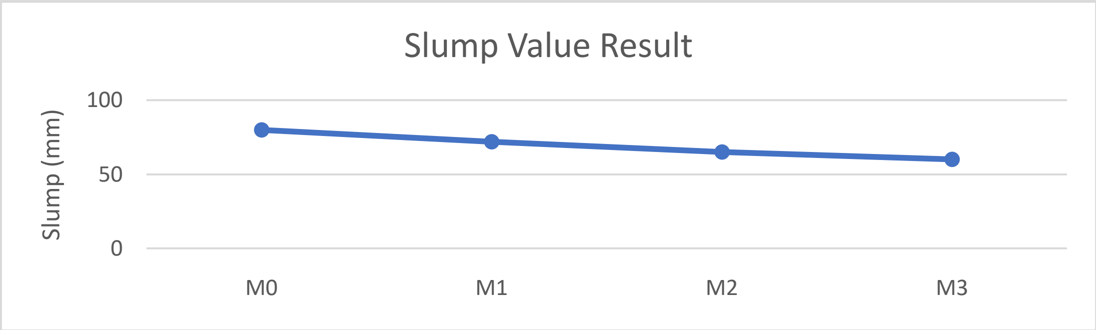

Fig 3: Results of the Slump Value graph for various mixtures

Fig 4: Slump Cone Test

Table No. 3 Compressive strength for design mixes M1, M2, M3 at 7, 14, 28days

Mix No.	Compressive Strength (N/mm2)		
	7 days	14 days	28 days
M1	17.75	25.64	32.54
M2	17.97	26.87	33.47
M3	21.84	29.36	33.56

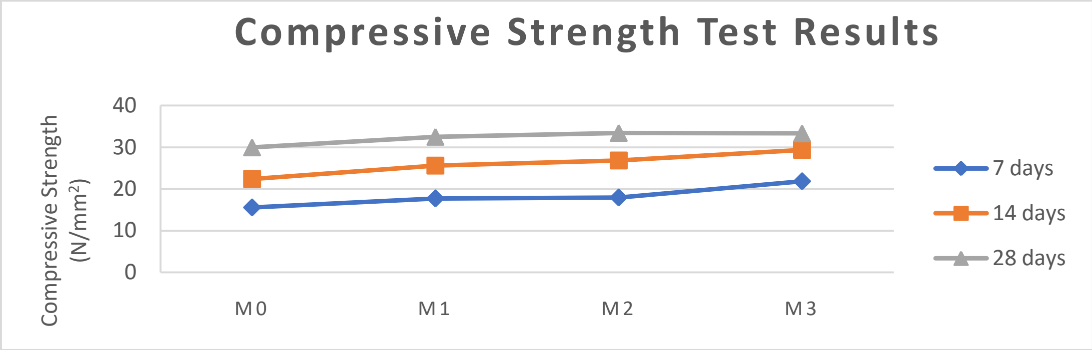

Fig 5: Results of the Compressive Strength test graph for various mixturesat 7, 14, 28 days

Fig 6: Compressive Strength Test

Table No. 4 Split tensile strength for the different design mixes

Mix No.	Split Tensile Strength (N/mm^2)
M1	3.26
M2	3.38
M3	3.43

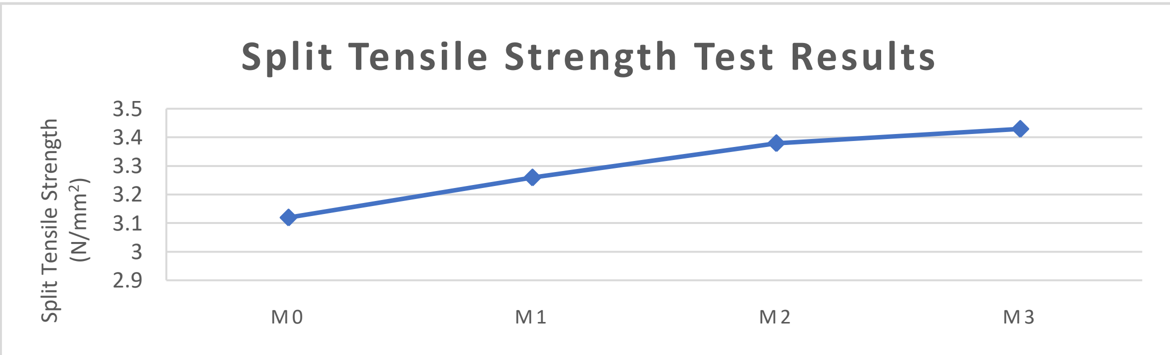

Fig 7: Graph of Split Tensile Strength test results for different mixes

Table No. 5 Flexural strength for the different design mixes

Mix No.	Flexural Strength (N/mm2)
M1	12.56
M2	14.23
M3	14.72

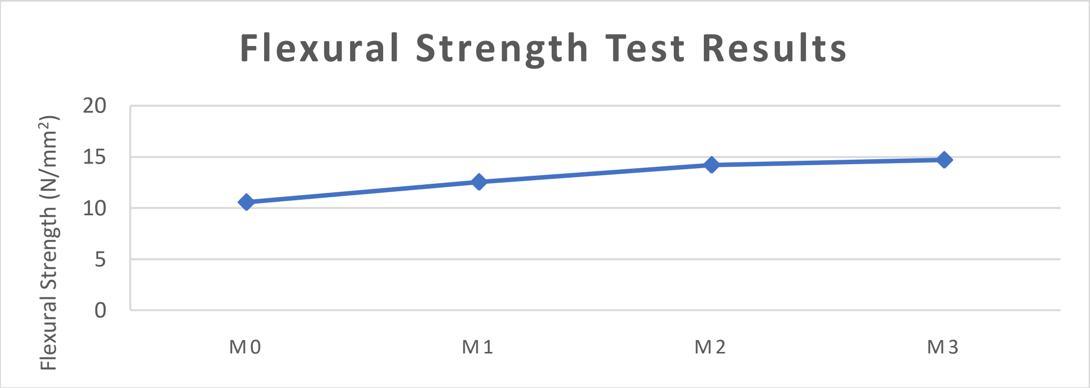

Fig 8: Graph of Flexural Strength test results for different mixes

CONCLUSIONS

1. The infusion of wet paper pulp, steel slag and glass fibre as partial replacement for constituent materials of conventional concrete displays that the overall characteristic properties of the concrete are enhanced with each additional element enhancing a certain property
2. Greater compressive strength than regular concrete after 7, 14, and 28 days
3. Increased flexural strength after 28 days curing when compared with conventional concrete
4. Increased split tensile strength after 28 days when compared with conventional concrete.
5. Less usage of natural resources as a partial raw material substitute lowers the need for them.
6. Effective usage of waste material reduces the amount of landfill disposal, thus making the concrete produced both cost effective, and eco-friendly.

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