REVISTA MATÉRIA
V.28 N.01
ISSN 1517-7076 articles e20220315, 2023

Pineapple fibre as an additive to self-compacting concrete

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ABSTRACT

As concrete being widely used in the field of construction, the demand for the materials used is increased rapidly. To meet the growing demand it is necessary to use alternative materials to meet the requirements. The Pineapple leaf fibre (PALF) is a highly available material in larger quantity with lesser water content and higher fiber content which makes it as a desirable material as natural fibre. The workability characteristics of Self compaction Concrete (SCC) like flowability, filling ability, passing ability, resistance to segregation and bleeding of concrete were out by using slump cone, U-box, L-box, V- Funnel and J-ring test. The test result shows satisfactory results on the workability of SCC. The fresh and hardened properties of concrete were found at the ages 7 days, 14 days and 28 days for various addition of PALF and various replacements of granite powder with the fine aggregate. The addition of PALF has achieved maximum compressive strength and split tensile strength in all ages of concrete at PALF0.2. The replacement of granite powder with fine aggregate seems to be promising in achieving the maximum compressive strength and split tensile strength at the 10% of replacement.

Keywords: Pineapple fibre (PALF); SCC; Natural fibre; Granite Powder.

1. INTRODUCTION

The selfcompacting concrete (SCC) has higher workability, flowability, passability, fillability, self compaction, etc. compared to normal concrete. With these properties the application in complex structures, thinner structures and highly reinforced areas makes its highly workable and develop higher strength. SCC is a type of concrete with a high percentage of uniformity that can be disseminated and cemented inside the framework by its weight, that is levelled by evacuation of air trapped and tamping, even in the severely reinforced parts of the structure and smallest portions, without the need for vibration; that does not produce segregation and bleeding and retains cohesiveness [1].

In instances where mechanically compacting fresh concrete is difficult, such as submerged concreting, cast in-situ piles, and columns or walls with packed reinforcing, SCC can also be done without honeycombing. Furthermore, it may be delivered to significant elevations in elevated structures without separation [2–4]. When the economics, strength, and durability necessary for unique constructions are considered, the use of Self Compacting Concrete with much increased compressive strength of concrete is becoming increasingly common in the construction sector, and it is recognised as an optimised option [5, 6]. Because of so many benefits, SCC is utilised in large structural buildings in various parts of the world [7–10]. As a result, some SCC proportioning guidelines were developed, such as lowering the water/powder ratio, rising paste quantity, managing the overall amount of coarse aggregate and its maximum particle density, and utilizing a powerful super plasticizer in combination with a great number of powders and/or viscosity-modifying admixtures (VMA) to smooth the stability between visco-elastic properties and consistency [11–13].

To maintain the mix steady and reduce bleeding and segregation, powders or VMA (Viscosity Modifying Agent) are necessary [14]. A high powder concentration is typically required in SCC. In contrast, a high cement percentage raises the heat of hydration, creep, and shrinkage. Mineral additions are thus necessary to achieve the powder requirement in SCC. Mineral additions widely used in SCC include industrial by-products such as limestone powder, fly ash, and crushed granulated blast furnace slag [15]. Similarly, if testing proves that industrial by-products are suitable, utilising them as mineral additions in SCC may be a tempting solution to their disposal.

Sand mining is a major threat to the biodiversity. Due to this heavy usage of sand in construction, the river beds natural deposition is getting depleted [16]. In order to maintain a proper ecosystem, manufactured

Corresponding Author: Yesudhas Abisha Received on 24/11/2022 Accepted on 21/12/2022

DOI: https://doi.org/10.1590/1517-7076-RMAT-2022-0315

sand is used in accordance with natural sand as permitted in IS 383:1970 [17]. The manufactured sand is angular and cubical shaped. This leads in better interlocking of particles and improved strength [18]. Industrial waste is increasing day by day causing great problem in disposal. Many researches are being carried out to dispose them in a sustainable manner [19]. Many researches has been carried out in different waste materials such as glass fiber [1], brick dust, saw dust, spent garnet, etc in concrete. Granite is an igneous rock and has better durability, good resistance to heat and cold [20]. They are used in construction industry in various forms. The addition of granite dust in normal concrete has showed improved mechanical properties [21, 22]. Millions of tons of waste are being generated from the granite industry causing various landfill problems to the environment [23]. If it can be used as a partial substitute in the building industry, the volume of its landform occupancy is limited.

A variety of additives are being used in construction to create various mixtures with properties that outperform many conventional concrete properties. Fibres are being employed as reinforcing material in concrete instead of steel. The natural fibres are lower in cost compared to synthetically prepared fibres, such as pineapple leaf fibre, can minimize splitting and enhance the tensile strength of concrete [14]. When the leaves of the pineapple plant are eliminated and treated, they generate strong natural fibre that can be utilized to manufacture yarn, weaving fabrics, woven knits, non-woven mats, and other items. Pineapple leaf fibres are lengthy and have one of the highest fineness indices among the vegetable fibres, making them appropriate for a wide range of industrial applications [1].

The fundamental purpose of this research is to investigate the strength parameters when a natural additive such as pineapple leaf fibre is added in a certain percentage to the self-compacting concrete and also to find their durability and mechanical properties in detail.

2. MATERIALS

2.1. Binder materials

2.1.1. Cement

Portland Pozzolana Cement (PPC) is used in this SCC as the binder material, adhering to IS code 1489-1991 was employed. PPC has finer particles compared to Ordinary Portland Cement (OPC). Hence the pores will be thoroughly filled and reduces the permeability of the concrete. The compressive strength of the PPC is found out to be 22.08 MPa and 33.3 after 7 and 28 days of curing respectively. The PPC is highly recommended for higher performance concrete because the performance seemed to be improved with the usage of PPC because of the pozzolanic material in it which emits lesser heat of hydration. The properties of the cement used in the given Table 1.

2.2. Fine aggregate

2.2.1. Manufactured sand

Manufactured sand (M-Sand) is used for the investigation. Crushed aggregates with a particle size of less than 4.75 mm were obtained from a nearby crushing plant for this experiment. Around the world, M-sand has become a more cost-effective, beneficial, and common alternative to river sand. IS: 383-1970 code book used in this study. Table 2 shows the properties of coarse and fine aggregate used. The sieve analysis of M-Sand and granite powder at different proportions as indicated in Figure 1.

Table 1: The important properties of cement.

SL. NO.	PROPERTIES	OBSERVATION
1	Specific gravity	2.92
2	Normal consistency	28%
3	Initial setting time	50 min
4	Final setting time	350 min
5	Compressive strength 7 days 28 days	22.08 N/mm^2 33.30 N/mm^2

Table 2: The properties of coarse and fine aggregates.

PROPERTIES	FINE AGGREGATE	COARSE AGGREGATE
Fineness Modulus	3.02	6.80
Specific Gravity	2.7	2.60
Bulk Density (kN/m^3)	18.50	17.80

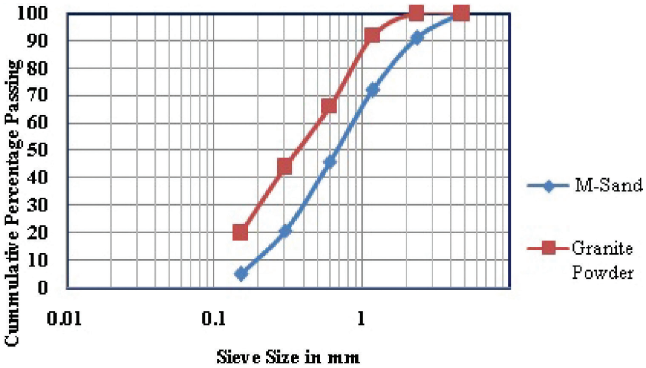

Figure 1: The sieve analysis of M-sand and granite powder at different proportions.

2.2.2. Granite powder

Granite powder is a residue that is collected from the granite industry when granite is being cut and polished. There are many granite industries in India; they produce tons of waste every year in the form of slurry. This slurry consists of lime, residues and granite powder [24]. The disposing of slurry in land destroys the soil fertility also causes pollution to the groundwater. The particle size distribution of granite powder and M-sand is shown in the Table 3.

2.3. Coarse aggregate

This experiment makes use of coarse aggregate obtained from a nearby crushing plant. The coarse aggregate size that was used was below 20 mm.

2.4. Super plasticizer

The super plasticizer serves to increase the workability of fresh concrete for a specific ingredient. It is a chemical composed of Sulphonated naphthalene polymers. It is a condensed polymer which acts as a water reducing agent and can achieve high workability. Sulphonated naphthalene polymer is added about 1.35% to the SCC as Super plasticizer to increase the workability.

2.5. Pineapple leaf fibre

Bio-composites and material science can benefit from PALF composite material. Because of its prudent and inexhaustible nature, PALF has proven to be an acceptable replacement for produced strands [2]. Without the use of any further preparation, the explicit quality of normal strands leads to the enhancement of the physical

Table 3: Sieve analysis of M-sand and granite waste.

SL. NO	IS SIEVE SIZE	% PASSING OF M-SAND	% PASSING OF GRANITE POWDER
1	4.75 mm	9	1
2	2.36 mm	19	8
3	1.18 mm	26	35
4	600 µm	25	12
5	300 µm	16	24
6	150 µm	5	20

Table 4: The mix designation and its proportions of SCC.

MIX DESIGNATION	CEMENT (kg/m³)	FINE AGGREGATE (kg/m³)	GRANITE POWDER (kg/m³)	COARSE AGGREGATE (kg/m³)	WATER (LITRE/m³)	SP (%)
G0	546.79	845.26	0	796.54	202.31	1.35
G10	546.79	760.73	84.53	796.54	202.31	1.35
G20	546.79	676.21	169.05	796.54	202.31	1.35
G30	546.79	591.68	253.58	796.54	202.31	1.35
G40	546.79	507.16	338.1	796.54	202.31	1.35
G50	546.79	422.63	422.63	796.54	202.31	1.35

and mechanical quality of the polymer grid [3]. PALF is one of the materials that have a lot of potential as a thermoplastic composite support. The use of these fibres in concrete decreased energy consumption enhanced biocompatibility and reduced dumping costs [4]. PALF used for this experiment has an aspect ratio of 100 and the weight fraction to be up to 0.5%.

3. MIX DESIGN

Various trial mixes were adopted by following the EFNARC guidelines trial mix proportions to get the appropriate water content, water/cement ratio and dosage of SP etc. These alterations were made to get the required properties of SCC like workability, flow ability, passing ability and filling ability. SP dosage was not varied. Mix proportion which passed the fresh state tests were considered for the preparation of specimen which were then subjected to hardened state tests. The optimal combination ratio was obtained on the basis of the hardened state test data. With one mix without any substitution called the control mix. Six sample mixes were prepared and named after the control mix. The remaining mix was prepared on replacing the fine aggregate with granite powder by 10%, 20%, 30%, 40%, 50%. The binder content was maintained as 546.79 kg/m^3 for all the mixes. Table 4 shows the quantity of materials used for various mix designations.

4. EXPERIMENTAL RESULTS

4.1. Fresh state properties

The fresh properties of concrete like workability, setting time, etc were found out. The fibre material used here is pineapple leaf fibre. The fibre diameter was 0.5 mm, the length was 50 mm, and the aspect ratio was 100. Fibre materials are commonly used to stop small cracks in concrete. It accelerates the tensile strength of concrete. To be considered a SCC, concrete must have a satisfactory filling ability, passing ability, and segregation resistance in the plastic state. Slump flow, L-box, V-funnel, and J-Ring tests were performed on the freshly mixed concrete. Six sets of concrete mixes were made by varying the percentage of fibre in the SCC. These mixes were then tested in their fresh state to see how they behaved, and the results are shown in the Table 5.

The filling ability that is found out by slump flow test using Abram's cone is satisfactory. The range is between 682 mm to 707 mm which has moderate viscosity of concrete and the filling ability is good.

Based on the V-funnel test results the filling ability of the concrete is found to be good and the concrete has good segregation resistance. The L-box, U- box and J-ring tests were conducted in fresh concrete to find out the passing ability of the concrete. Based on the test results, the passing ability of the concrete is good. Since the viscosity of the concrete is moderate, it shows that good resistance to segregation and bleeding.

Table 5: The specimens vs fresh state properties.

SPECIMEN	SLUMP FLOW (mm)	V-FUNNEL (Sec)	L-BOX	U-BOX (mm)	J-RING (mm)
PLF0	682	8.06	0.36	15	12
PLF0.1	687	8.78	0.39	16	13
PLF0.2	691	9.25	0.43	18	15
PLF0.3	696	9.96	0.45	20	15
PLF0.4	701	10.54	0.48	21	17
PLF0.5	707	11.08	0.51	23	19

4.2. Hardened state properties

4.2.1. Compressive strength

The determination of compressive strength is one of the essential material properties of hardened concrete. In concrete the load carrying capacity is based on some factors such as size of aggregates, surface texture, super plasticizer, water-powder ratio and so on. The addition of granite powder in SCC does not affect the strength up to 10%. The strength was reduced for other mix proportions compared to the control mix. The substitution of M-sand with granite powder had a higher compressive strength compared to standard concrete. When granite powder is replaced by fine aggregate, there is an improvement in compressive strength [25]. As per IS: 516-1959, the compressive strength of SCC is checked. The 150 mm × 150 mm × 150 mm cubes have been tested for M40 grade concrete. The cubes were tested on a compression testing machine for 7 days, 14 days, and 28 days and the values as indicated in Table 6. In Figure 2 shows the compressive strength of different mixes of concrete after 7, 14 and 28 days curing.

From the test results it is found to be increased in strength in the 10% replacement of fine aggregate with granite powder from the control mix. The increase in compressive strength is found out to be 3.89%, 3.92% and 3.92% after the 7, 14 and 28 days curing respectively.

A cube specimen measuring 150 mm × 150 mm × 150 mm was subjected to a compressive test. According to IS516, compression tests were performed on the 7th and 28th days. The trial used pineapple leaf fibre content up to 0.5% because the de-bonding of fibre in the concrete was expected above this percentage. Trials were carried out to investigate the mechanical property of concrete for various pineapple leaf fibre contents. PLF0, PLF0.1, PLF0.2, PLSF0.3, PLF0.4, and PLF0.5 were the specimen numbers. Figure 3 depicts the compressive strength of FRC.

All of the sets meet the workability requirements, but the workability decreases as the fibre content increases. The strength properties of the specimens cast from these sets were tested. The compressive strength of specimens with 0.1% and 0.2% fibre content was comparable to that of specimens without pineapple leaf fibre. The PLF0.2 has achieved increase in compressive strength of about 7.26%, 5.74% and 4.8% after the 7, 14 and 28 days curing respectively. The compressive strength then decreased from 0.3% to 0.5% fibre content.

Table 6: The compressive strength of the various proportions of the concrete.

CONCRETE MIX	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
G0	31.33	43.38	48.2
G10	32.55	45.08	50.09
G20	29.26	40.52	45.03
G30	27.84	38.55	42.84
G40	26.70	36.98	41.09
G50	25.48	35.28	39.21

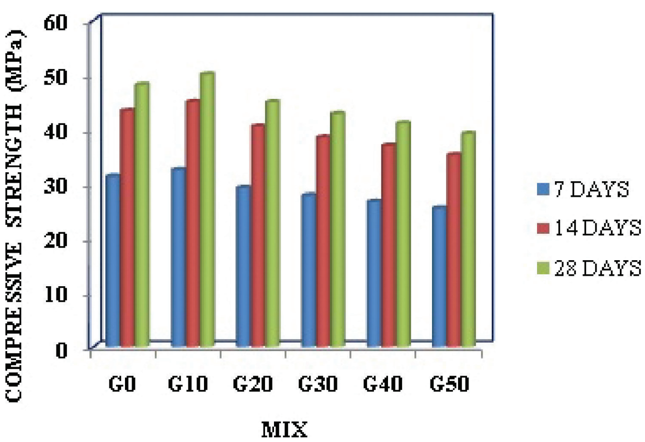

Figure 2: Compressive strength for different mixes of concrete.

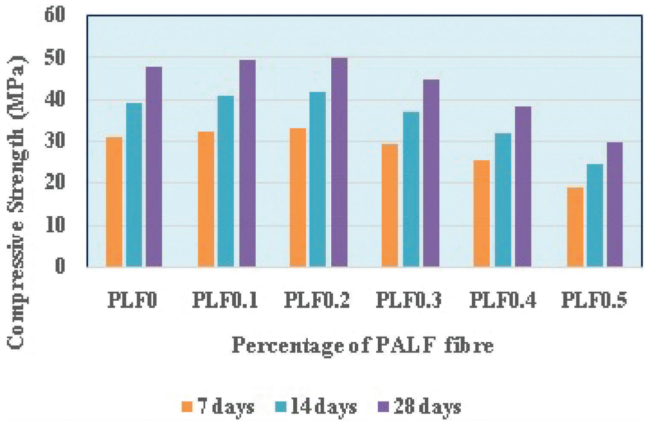

Figure 3: The compressive strength of various addition of PALF.

However, the ultimate load was observed to be retained for a long time after the failure. The crack gap and propagation appeared to be reduced because the fibre bridged the crack.

4.2.2. Tensile splitting test

In accordance with IS 5816-1970, a cylindrical sample of 300 mm in length and 150 mm in diameter was used to determine the tensile strength of the SCC. The tensile strength for replacement of 10 percent by granite powder was increased as indicated in Table 7. The tensile strength of the specimen improves by up to 10 percent relative to the control mix [26]. Figure 4 shows the split tensile strength for various concrete mixes.

This test was performed to determine the tensile splitting strength of concrete at 7 days and 28 days using a cylinder specimen with a 15 cm diameter and a 30 cm length by IS5816. The cylinder specimens were put through their paces on compression testing equipment with a capacity of 2000 kN. Ascertain that the surface was free of loose sand and other debris. The weight was applied at a consistent pace until the specimen broke. The highest load achieved was recorded. A base plate was used to hold the cylinder horizontally. For 0.1% and 0.2% fibre content, the value was nearly identical to that of the mix without fibre. From 0.3% to 0.5% fibre concentration, the split tensile strength dropped as depicted in Figure 5.

Table 7: The split tensile strength vs concrete mixes.

CONCRETE MIX	7 DAYS (MPa)	14 DAYS (MPa)	28 DAYS (MPa)
G0	2.75	3.81	4.24
G10	2.93	3.99	4.44
G20	2.76	3.77	4.19
G30	2.67	3.65	4.06
G40	2.61	3.56	3.96
G50	2.45	3.34	3.72

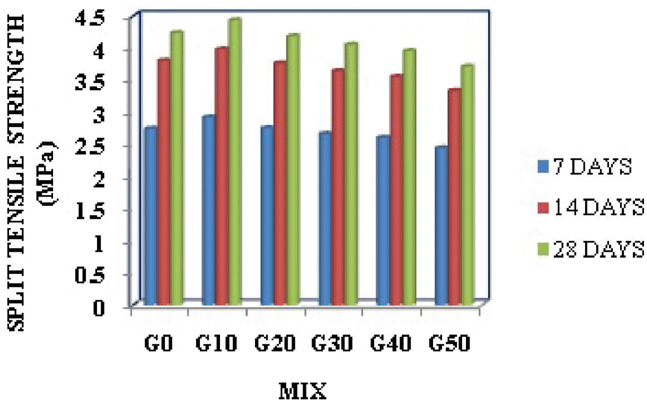

Figure 4: The split tensile strength for different mixes of concrete.

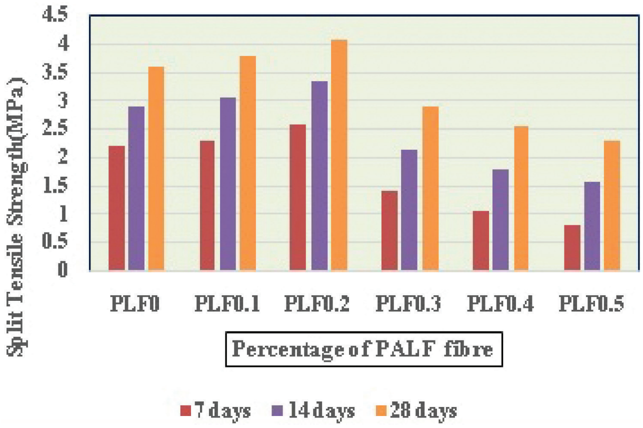

Figure 5: The split tensile strength vs various percentages of PALF fibre.

5. CONCLUSIONS

The conclusion of the research work of pineapple fibre as an additive to self-compacting concrete as given below.

- When M-Sand was replaced with granite powder the slump value decreased compared to the control mix. To preserve the slump value, the dosage of super plasticizer was raised and the slump value was kept as a constant of 700 mm.
- When granite powder was replaced by 10% with the fine aggregate, the compressive strength of concrete was more than the control mix at all the ages.
- The strength decreased slightly due to the addition of granite power from 20% replacement from fine aggregate, compared to the control mix for the other mixes.
- According to the experimental results, when the percentage addition of PALF in SCC exceeds 0.3% of cement weight, the Self Compacting Concrete becomes less workable. The 0.2% addition of PALF fibre, increased the Split Tensile strength by 13.89%. Whereas the compressive strength is increased by 7.26% after 28 days curing.

The crushing value of aggregate along the PALF is lower than that of ordinary aggregate. PALF has demonstrated that it can contribute to the field of SCC construction by reducing cracks in the structure and improving the tensile and flexural properties. Since PALF bonded concrete has a lower breaking value and greater strength than ordinary concrete, it may be used to pave airport and commercial mall walkways.

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