Study of Fibre Reinforced Concrete Using Sustainable Materials

Dr. Uma Maguesvari M a, Muthaiyan P b, Yugasini S b, Ammaiappan M c

a Associate Professor, Department of Civil Engineering, Rajalakshmi Engineering College, Chennai and 602 105, India.
b Assistant Professor, Department of Civil Engineering, Rajalakshmi Engineering College, Chennai and 602 105, India.
c Assistant Professor (SS), Department of Civil Engineering, Rajalakshmi Engineering College, Chennai and 602 105, India.

umamaguesvari@gmail.com

Abstract. Our current generation is a pillar of this developing world in construction field, which also leads to decrease in natural raw materials and increase in production of many industrial waste materials creating an impact to living life through flaming and landfilling. Concrete is one of high production material in our daily life and have most probable way to substitute the waste materials. In this present work waste material are used for replacement of materials in developing the fibre reinforced concrete. Workable and mechanical characteristics of fibre reinforced concrete have assessed by substitution of coarse aggregate with recycled aggregate at(0%,10%,20%,30%, and 40%), and fine aggregate as M-sand, waste foundry sand and bottom ash and binder is replaced with silica fume 7% in addition to that fibre content as 0%,0.5%,1% and 1.5% of micro steel fibre and Basalt Fibre by weight of cement. Workability decreases with rise in incorporation of recycled aggregate and also it diminishes workability with the inclusion of fibres. The concrete mixture with replacement of coarse aggregate including micro steel and basalt fibre content have exhibited higher mechanical strength.

Key Words: Silica fume; Bottom ash; Foundry sand; Compressive strength; Sustainability

1. Introduction

A concrete has high crushing strength but less in tension, it is one of the most durable building materials. The material is very cost effective in its production, fluid in its beginning has an ability to mould in any shape and desired strength can be achieved. It has a good resistance to temperature, wind, water and cost to maintain is also low. Despite of many benefits, the concrete get failure due to its brittle in nature. The present ingredients in the concrete has an ability to resist the compressive force to some extent. While carrying the tension force the linkage of the binder and aggregate get separated. The disconnection of the cement material and aggregate cause failure to the structure as propagation of crack.
Nowadays, the traditional natural concrete materials are getting reduced and industrial waste products are increasing more. By disposing the waste materials in landfills, it creates impact and shortage of land. The incorporation of fiber in matrix has a greater influencing property of concrete and various research proved that fibers have increased the hardened characteristics of concrete such as crushing strength, split tensile strength, impact resistance, flexural strength [1]. The inclusion of waste material and fiber has an effect in crushing strength of concrete. It has shown that increase in compressive strength at lower fiber content, whereas decrease in compressive strength at higher content of fibers addition [2]. Fibre type and aspect ratio of fiber also influences the mechanical characteristics on concrete. In which Basalt Fibre is melted and extruded from basalt rock, whereas Glass fibre are formed in a process in which molten glass is drawn in the form of filaments. By comparing both the fibres Basalt fibres has higher tensile strength then Glass fibre [1,3,4].

Investigation have been carried on waste materials like Bottom Ash, it represents that at lower content of 15-20% Bottom ash give more compressive strength, Usage of fibre reduces the workability of concrete [5-8]. It has attempted to utilize the bottom ash as a substitution of fine aggregate in making cellular concrete [9]. Studies have carried on Waste foundry Sand and Coal Cinder CC, it is proven that workability is been decreasing by increase of CC and WFS because water absorbed by fine particles, and crushing strength of WFS is increased by up to 30% of substitution by fine aggregate after that strength reduces gradually [10-13]. Silica fume one of binding material which has a pozzolanic property that replaced for cement at an optimum of 7-12% [14]. Field studies have been carried out for usage of recycled aggregate on foundation system, municipal side walk construction and performance studies have been carried out and collate with normal concrete [15]. Mechanical and transport properties have evaluated the influence of incorporation of recycled aggregate considering various curing conditions [16]. Hardened and durability characteristics have investigated on the recycled aggregate with the use of ternary binder and optimum mixes were arrived with the crushing strength of 52 MPa [17]. Based on the above perspective substitution of coarse aggregate with recycled aggregate at 0%, 10%, 20%, 30%, and 40% and fine aggregate as M-sand, waste foundry sand and bottom ash and binder are replaced with silica fume 7% by weight of cement were used to determine the workable and harden characteristics of concrete. It leads to sustainability, limited negative impact on natural resources and avoids depletion or destruction of natural resources.

2. Materials and mix proportion

2.1. Cement
OPC of grade 53 confirming to IS 12269-1987, used in this present work, which has a specific gravity of 3.15 and 30% of consistency.

2.2. Silica fume
It is an ultrafine powder with a specific gravity of 2.63. The content of silica fume used as 7% for the weight of cement.

2.3. M Sand
Manufactured sand produced from crushing of granite has a specific gravity of 2.74. The sand used has grading conforming to zone II as per IS 383:1970.

2.4. Bottom Ash
Bottom Ash (BA) is by-product of coal which is produced in thermal power plant as a residue in boiler. This product is been collected from Neyveli Lignite Corporation Tamil Nadu. It was observed that specific gravity is 2.4 and 1396 kg/m³ per unit weight.

2.5. Waste Foundry Sand
Waste Foundry Sand (WFS) is waste product from metal casting industry which is obtained from Coimbatore, which has a specific gravity of 2.6 and 1910 kg/m³ of per unit weight.

2.6. Gravel
Blue metal aggregate is used as a coarse aggregate in this work as per IS 2386 (part 3). Which is obtained from locally available quarry of maximum size of 20mm is used for this investigation and which has a specific gravity of 2.74.

2.7. Recycled aggregate
Recycled concrete aggregates produced from typical concrete. Recycled concrete aggregates contain crushed aggregate with hydrated cement paste. The specific gravity of Recycled aggregate as 2.46 with the maximum size of 20mm.

2.8. Water
Pure water is used for making concrete and curing as per IS 456:2000.

2.9. Fibres
Micro Steel fibre of 12mm length and 0.2mm diameter and Basalt fibre of 12 mm length and 13-20µm of diameter, were used in investigation.

2.10. Mix Proportion
This investigation has been carried into two phases. In the first phase binder content as 400 Kg/m³ with the replacement of 7% of silica fume, fine aggregate as the combination of M- sand, Foundry sand and Bottom ash with the percentage of 60:20:20, Coarse aggregate with the replacement of recycled aggregate from Concrete demolition waste with percentage from 0 to 40% with the increment of 10 percentage. The ratio is been arrived for M 40 grade of concrete from the mix design as per IS 10262: 2019 is 1:1.8:2.946 at 0.45 w/c. 5 mixes were used to find the workability characteristics from slump test, mechanical characteristics such as crushing strength and density. One optimum mix is identified from the above mixes. In phase two, from the identified mix two types fibers such as steel fibre and basalt fibres with the percentage of 0.5, 1 and 1.5% are introduced in concrete, 6 mixes are used to measure the workability, crushing strength and split tensile strength of concrete. Totally 5 mixes without fibre and 6 mixes with fibers.

3. Result and Discussion

3.1. Fresh and Hardened characteristics without fibre

3.1.1. Workability. The homogeneity of concrete is tested by slump cone. It is very useful in site construction for making the concrete in good flow by adjusting the water cement ratio. The slump value for variation of replacement of recycled coarse aggregate are shown in Fig. 1. It shows that there is a falling pattern of slump value with the rise in recycled aggregate substitution. There is a gradual reduction in slump value up to 20% replacement then there is a sudden dip in slump value after 20%.

3.1.2. Density. The variation of density for various substitution of coarse aggregate are shown in Fig.2. density of recycled concrete varies from 2360 to 2435 Kg/m3 for aggregate replacement from 0 to 40% with the increment of 10% increase in recycled concrete aggregate. It represents that there is a gradually decreasing trend with the increment of recycled concrete aggregate. This may be due less specific gravity of recycled aggregate and also increased porosity compared to similar virgin aggregates.
3.1.3. Compressive Strength. The crushing strength is found from the average of 3 specimens at 7 and 28 days of cured concrete. The size of the cube 150mm and test is carried out as per IS 516-1959. The variation of crushing strength at the age of 7 and 28 days for various substitution of coarse aggregate as recycled aggregate are given in Fig 3. It is noticed that substitution level of recycled aggregate rise in concrete reduces the crushing strength of concrete. There is a marginal decrease in percentage up to 20% replacement of recycled aggregate with increase in replacement 30% and 40% which is more than 10% reduction in compressive strength.
3.2. Fresh and Hardened characteristics with fibre

3.2.1. Workability of fibre reinforced Concrete. The observed slump Range is shown in Fig.4 with the incorporation of steel and basalt fibre at 0.5%, 1%, 1.5%. The influence of fibres in concrete also reduces workability to some extent among the fibres because it will not allow concrete to segregate, flow, and also high content of fibres which leads to wrap the cement paste around it. Pattern of slump value is same for both the fibres. Slump value of steel fibre is less when compared to basalt fibre of various percentage of fibre addition. The slump value varies between 10 to 35 mm irrespective of the type of the fibre added.

![Fig 4: Variation of slump Value for Percentage of steel and Basalt fibers.](image)

3.2.2. Compressive strength of fibre reinforced Concrete. The change of crushing strength for 7 and 28 days of different fibre percentage of steel and basalt fibres are shown in Fig 5. The crushing strength differ from 47.32 to 50.12 MPa irrespective of fibre type (steel and basalt fibre). There is a gradually increasing compressive strength with the incorporation of steel and basalt fibre in concrete. Percentage rise in crushing strength upto 1% of steel fibre was 5.5% and 4.6% for basalt fibre. With further increment in fibre percentage for type of fibre attained of improvement in compressive strength is less than 1% only. By comparing the compressive strength with steel fibre and basalt fibre, steel fibres exhibited more compressive strength than basalt fibre.

![Fig 5: Variation of Crushing strength for Percentage of steel and Basalt fibers.](image)
3.2.3. **Split Tensile strength of fibre reinforced Concrete.** The variation of split tensile strength with the different percentage of fibres are given in Fig 6. Split tensile strength varies from 4.94 to 7.25 MPa for steel fiber and 4.94 to 6.94 MPa for Basalt fibres for fibres from 0 to 1.5% with the increment of 0.5% of fibre content. There is an increasing pattern of attainment of split tensile strength. Percentage attainment of increment of strength is maximum up to 1% with further increase in percentage of fibre of about 0.5%, percentage attainment is comparatively less than attainment up to 1%. Above behaviour is similar for both steel fibre and basalt fibre. By comparing the attainment of split tensile strength steel fibers shows better than basalt fibre.

![Fig 6: Variation of Split Tensile strength for Percentage of steel and Basalt fibers.](image)

3.3. **Identification of mix and sustainability**

Based on the observation from the crushing strength and split tensile strength mix with 1% steel fibres and basalt fibre have identified for further progress of the research and test. In order to preserve the natural resources, needless losing of natural assets ought to be limited and regulated. Formulation and implementation of appropriate waste management plan can decrease C and D waste. Recycled material can be reuse and greater natural assets is conserved for our subsequent generations.

3.4. **Ultra-sonic Pulse Velocity**

Ultrasonic pulse velocity test is used to measure the integrity of concrete as per IS 13311 (Part 1) – 1992. After 28 days of curing before conducting the test for mechanical properties UPV values was found on all cubes of 100mm which is as shown in Fig. 7. The quality of concrete is examined using UPV and results have exhibited excellent quality of concrete for observed cubes specimen shown in Table 1.

![Fig 7: Ultrasonic Pulse Velocity for Cube specimen](image)
Table 1 Ultra-Sonic Pulse Velocity for 1% fibres content

| Specimen          | Velocity (m/sec) | Quality of concrete |
|-------------------|------------------|---------------------|
| Control mix       | 4870             | Excellent           |
| Steel fibre 20%   | 5010             | Excellent           |
| Basalt fibre 20%  | 4940             | Excellent           |

4. Conclusion
The following conclusion were arrived from the fibre reinforced concrete using sustainable materials.

- Slump value of concrete reduces with the rise in percentage substitution of recycled concrete aggregate.
- Addition of Steel and Basalt Glass fibres decreased in workability of concrete gradually with the increment of fibre percentage.
- Density and crushing strength of concrete diminish with the rise in substitution of recycled coarse aggregate.
- Mix with 20% replacement of recycled concrete aggregate has identified for further work with fibres.
- Inclusion of steel and basalt fibres increases the crushing strength and split tensile of concrete.
- Steel fibres shows better strength than basalt fiber concrete with same percentage of fibre 1%.
- Use of recycled aggregate as coarse aggregate and fine aggregate as M-sand, foundry sand and bottom ash reduce the depilation of natural resources in terms of sustainability.

References
[1] Ahmet B Kizilkanat, Nihat Kabay, Veysel Akyuncu, Swaptik Chowdhury and Abdullah H. Akca 2015 Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study Construction and Building Materials 100 pp 218-224
[2] Piotr Smarzewski and Danuta Barnat-Hunek 2016 Mechanical and durability related properties of high performance concrete made with coal cinder and waste foundry sand Construction and Building Materials 121 pp 9-1
[3] Mehmet Emin and Arslan 2016 Effects of basalt and glass chopped fibres addition on fracture energy and mechanical properties of ordinary concrete: CMOD measurement Construction and Building Materials 114 pp 383-389
[4] Suchita Hirde and Sagar Sheral 2017 Effect of Basalt Fiber on Strength of Cement Concrete International Journal of Current Engineering and Technology Vol 7 No 2 pp 600-602
[5] Navdeep Singh, Mithulraj M and Shubham Arya 2018 Influence of coal bottom ash as fine aggregates replacement on various properties of concretes: A review Resources, Conservation & Recycling 138 pp 257-271
[6] P Aggarwal YAggarwal and S M Gupta 2014 Effect of Bottom Ash as Replacement of Fine Aggregates in Concrete Asian Journal of Civil Engineering Building And Housing Vol 8 pp 49-62
[7] Dinesh Kumar G et al 2016 An Experimental Study on Partial Replacement of Fine Aggregate with Coal Bottom Ash in Concrete IJSAE Vol. 2 pp 39-49
[8] Akkadath Abdulmatin Weerachart Tangchirapat Chai Jaturapitakkul 2018 An investigation of bottom ash as a pozzolanic material Construction and Building Materials 186 pp155-162
[9] Patchara Onprom, Krit Chaimoon and Raungrut Cheerarot 2015 Influence of Bottom Ash Replacements as Fine Aggregate on the Property of Cellular Concrete with Various Foam Contents Advances in Materials Science and Engineering Vol 2015 381704
[10] Piotr Smarzewski and Danuta Barnat-Hunek 2016 Mechanical and durability related properties of high performance concrete made with coal cinder and waste foundry sand Construction and Building Materials 121 pp 9-1
[11] Rafał Siddique and Gurpreet Singh 2011 Utilization of waste foundry sand (WFS) in concrete manufacturing Resources Conservation and Recycling 55 pp 885-892
[12] Vema Reddy Chevuri and S Sridhar 2015 Usage of Waste Foundry Sand in Concrete SSRG-IJCE vol 2 pp 5-10
[13] Amrutha K et al 2017 Partial Replacement of Fine Aggregate by Used Foundry Sand in Concrete IRJET Vol 4 165-169
[14] Chetan S Kankariya Hitesh S Patil Sudarshan Bhamre Mayur D Mhasde 2017 Review Article: Study And Optimization Of Silica Fume in Concrete International Journal of Recent Trends in Engineering & Research Vol 03 Issue 05 pp 562-565
[15] Humera Ahmed Mohammed Tiznobaik Sumaiya B Huda M Shahidul Islam M Shahrain 2020 Recycled aggregate concrete from large-scale production to sustainable field application Construction and Building Materials 262 119979
[16] Ahmed Shaban Abdel-Hay 2017 Properties of recycled concrete aggregate under different curing conditions HBRC Journal 13 271–276
[17] O E Babalol P O Awoyera M.T. Tran D H Lea O B Olalusi A Viloria D. Ovallos-Gazabon 2020 Mechanical and durability properties of recycled aggregate concrete with ternary binder system and optimized mix proportion J Mater Res Tech 9 3 pp 6521–6532