ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

# AN EXPERIMENTAL STUDY ON THE BEHAVIOUR OF POLYPROPYLENE AND STEEL FIBRE REINFORCED SILICA BASED BENDABLE CONCRETE

S.Divya[1], K.Thiyagu[2],R.Elanchezhiyan[3]
[1]PG Student – Structural Engineering, Department of Civil Engineering,
Muthayammal College of Engineering, Rasipuram,Namakkal ,Tamilnadu 637408.
[2,3]Assistant Professor, Department of Civil Engineering,
Muthayammal college of Engineering, Rasipuram, Namakkkal, Tamilnadu 637408.
divyasathiyabama@gmail.com[1]
kthiyagu.civil@gmail.com[2]
elanchezhiyanme@gmail.com[3]

***ABSTRACT***

**This paper highlights the material properties of the Bendable concrete for the effective development of new structures and maintenance of existing structures. The material researchers have conducted a lot of experiments based on sustainability, durability and safety point of view. As a result of the attempts, finally a new material was established in the last decade. The proper selection of the fiber, mixing of the composite exhibit strain hardening and multiple cracking behaviour of the material. The strain hardening behaviour of the Bendable concrete gives significant advantage under flexural loading. The crack width developed under loading is very small when compared with conventional concrete due to the bridging effect of the fiber. The material properties of Bendable concrete reinforced with following 0.5%, 1.0%, 1.5%, 2% of steel fiber and 0.1%, 0.15%, 0.2%, 0.25% of polypropylene fiber. The optimum strength attained at 1.0% of steel fiber and 0.1% of polypropylene fiber and has been claimed to be the most promising proportion of the fiber content. A series of experiments were carried out to determine the compressive strength, tensile strength and flexural characteristics of Bendable concrete.**

## *Introduction*

Concrete is most widely used material for the construction. Now a day, the concrete construction industry faces lot of problem due to availability of material and bad environmental conditions. Due to this bad effect, cracks and strength losses occurr in the construction.To avoid the over consumption of natural resources, supplementary cementitious materials such as fly ash, rice husk ash, silica fume are used for the structure.Bendable concrete is a cement based material containing a mix of cement, supplementary cementitious material, sand, water and chemical admixtures, reinforced randomly distributed fibres. Bendable concrete material can improve the tensile strength, ultimate strain capacity and large strain hardening properties than conventional concrete.

The Bendable concrete can resist large load by the crack bridging properties in the failure mode of structure. This material is also used for repairing and maintenance work also. This paper illustrates potential effect of application of Bendable concrete in the construction industry.

### *Definition*

Bendable concrete is “a special type of high performance fibrereinforced concrete containing small amount of short random fibres micromechanically designed to achieve high damage tolerance under severe loading conditions and high durability under normal service conditions”.

Bendable concrete, is an easily mortar based composite reinforced with specially selected short random fibres, usually polymer

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fibres. The Bendable concrete has ductile characteristics, when compared with normal concrete which shows brittle nature. The Bendable concrete material also forms high performance fibre cementitious composite family. The Bendable concrete is prepared with short random fibres for the effective formation of the fibre matrix as well as to the increase the bond strength. The addition of fibre improves the tensile strength, toughness along with strain capability, and it shows high damage tolerance.

Strain hardening is the ability of the material to increase the level of loading after first crack while undergoing large deformation. The addition of polypropylene fibre converts the material in to elastic. The material under loading, load bearing capacity is shows higher than the nominal concrete. High ductility results of the interaction between cement paste and fibre delayed the crack propagation under higher load.

*Propertiesof Materials*

*Cement*

The ordinary Portland cement (OPC) of 53 Grade was used for the production of the cementitiouscomposite.

*Table. 1:Properties of cement*

| Sl.No | Property | Results |
|---|---|---|
| 1 | Fineness | 5% |
| **2** | Initial setting time | 30 minutes |
| **3** | Specific gravity | 3.15 |
| 4 | Standard consistency | 31% |

*Fine Aggregate*

The fine aggregate used in this investigation is natural sand and it has a specific gravity of around 2.65. The fineness modulus of sand is taken as 1.18 mm passed sieve.

*Table. 2:Properties of Fine Aggregate*

| Sl.No | Property | Results |
|---|---|---|
| 1 | Specific gravity | 2.65 |
| 2 | Bulking of sand | 20% |
| 3 | Fineness modulus | 2.78 |
| 4 | Voids ratio | 0.21 |

*Coarse Aggregate*

Coarse aggregate of maximum size of 20 mm was used in concrete which has been specified in the codal provisions.

*Table. 3:Properties of coarse aggregate*

| Sl.No | Property | Results |
|---|---|---|
| 1 | Specific gravity | 2.65 |
| 2 | Water absorption | 0.5% |
| 3 | Fineness modulus | 6.42 |
| 4 | Crushing strength | 2.57 $N/mm^2$ |
| 5 | Impact value | 7.2% |
| 6 | Abrasion value | 4.05% |

*Silica Fume*

It has white colour in the powder appearance, it gives high sulphate resistance, corrosion resistance and high strength.Silica fume can reduce the pores in the composite. Thus its density is increased also it produce C-S-H gel at the time of hydration process.

*Table. 4:Properties of silica fume*

| Sl.No | Property | Results |
|---|---|---|
| 1 | Colour | Whitish powder |
| 2 | Physical Properties | Silica fume |
| 3 | Average diameter | 0.5 |
| 4 | Specific surface area ($m^2$/Kg) | 22500 |
| 5 | Density ($g/cm^3$) | 2.65 |
| 6 | $SiO_2$ | >95 |
| 7 | $Al_2O_3$ | <5 |

*Steel Fibre*

The steel fiber of 0.45 mm diameter along with length of 12.5 mm is used for the production of composite which gives multidirectional reinforcement detailing. It increase crack resistance, ductility, and energy absorption of the composite. Also it provides better the impact resistance and fatigue resistance to composite.

*Polypropylene*

The polypropylene fiber of 18 µm diameter along with a length of 12 mm is used for the production of cementitious composite. It improves the impact resistance, shatter and abrasion resistance. Increase residual strength and durability.

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*Table. 5:Properties of fiber*

| Fiber Type | Diameter | Length (mm) | Tensile strength (MPa) | Density (Kg/m$^3$) |
|---|---|---|---|---|
| Steel | 0.45 mm | 12.5 | 1100 | 7850 |
| Polypropylene | 20 µm | 12 | 300 | 946 |

*MIX RATIO*

The mix proportion used for the study was grade $M_{20}$ concrete.

*Table. 6: Mix Ratio*

| w/c ratio | c/s ratio | Silica fume | Steel fibre | PP fibre |
|---|---|---|---|---|
| 0.45 | 1:3 | 5% (wt) | 0.9 – 1.2% | 0.09-0.12% |

*Table. 7:Size of Specimens*

| Type of Mould | Size(in mm) |
|---|---|
| Cube | 70.6 x 70.6 x 70.6 |
| Beam | 1100 x 100 x 150 |

*Determination of Strength*

*Compressive Strength*

The cubes were prepared in 70.6 mm x 70.6 mm x 70.6 mm size moulds and properly compacted. Specimens were demoulded from mould after 24 hours and in water for curing for 7 days and 28 days. Four hybrid fiber combinations were taken in account along with control specimen. After curing, the samples were measured for 7 days and 28 days compressive strength.

*Table. 8:Compressive strength of cubes with steel fiber*

| Sl.No | Steel fibre content (in volume percentage) | 28 days (N/mm$^2$) |
|---|---|---|
| 1 | 0 | 12 |
| 2 | 0.5 | 19.10 |
| 3 | 1.0 | 20.08 |
| 4 | 1.5 | 16.62 |
| 5 | 2.0 | 15.50 |

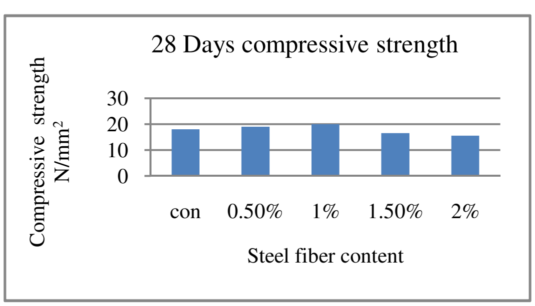


*Fig. 1:Compressive strength of cubes with steel fiber*

*Table. 9:Compressive strength of cubes with polypropylene fiber*

| Sl.No | Polypropylene fiber (in volume percentage) | 28 days (N/mm$^2$) |
|---|---|---|
| 1 | 0 | 12 |
| 2 | 0.10 | 19.07 |
| 3 | 0.15 | 10.50 |
| 4 | 0.20 | 15.08 |
| 5 | 0.25 | 14.02 |

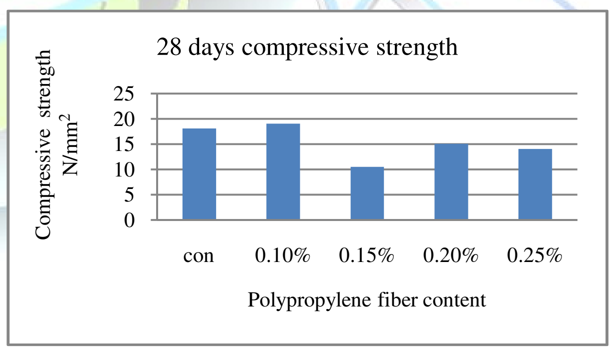


*Fig. 2:Compressive strength of cubes with polypropylene fiber*

*Table. 10:Compressive strength of cubes with hybrid steel-polypropylene fiber*

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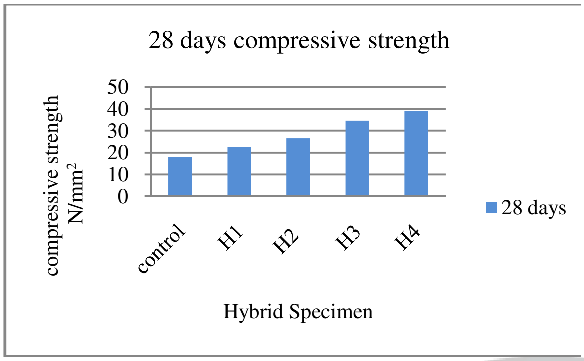


| Sl.No | Hybrid fiber | 28 days ($N/mm^2$) |
|---|---|---|
| 1 | Control | 18.08 |
| 2 | $H_1$ | 20.10 |
| 3 | $H_2$ | 26.62 |
| 4 | $H_3$ | 34.67 |
| 5 | $H_4$ | 39.18 |

*Fig.3:Compressive strength of cubes with hybrid steel-polypropylene fiber*

*Energy Absorption*

The energy stored in the conventional beam under loading is $138.44 \times 10^3$Nmm. The energy absorption capacity of the specimen increased 1.9% than the control specimen when compared with hybrid composite.

*Table. 11: Energy absorption of the specimen*

| Sl.No | Specimen | Energy absorption (Nmm) |
|---|---|---|
| 1 | Control | 138.40 |
| 2 | $H_1$ | 244.52 |
| 3 | $H_2$ | 401.48 |
| 4 | $H_3$ | 260.60 |
| 5 | $H_4$ | 190.42 |

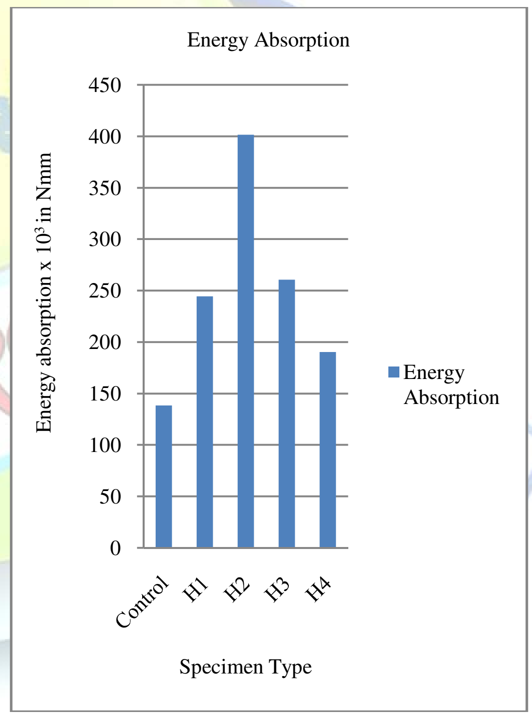


*Fig. 4: Energy absorption of the specimen*

*Stiffness*

The stiffness is the load required to produce unit displacement. The stiffness of the control specimen is 2.24 N/mm. The stiffness of the specimen is increased 4.95% in the hybrid cementitious composite beam. The stiffness is increased 3.8% in the hybrid composite beam.

*Table. 12:Stiffness of the specimen*

| Sl.No | Specimen | Stiffness (N/mm) |
|---|---|---|
| 1 | Control | 2.28 |
| 2 | $H_1$ | 7.09 |
| 3 | $H_2$ | 10.56 |
| 4 | $H_3$ | 4.21 |
| 5 | $H_4$ | 13.23 |

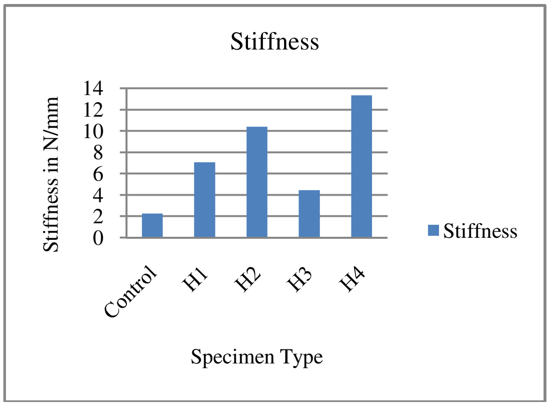


*Fig. 5:Stiffness of the specimen*

*Ductility Factor*

The ductility is the ability of the material to width stand large load under deformation without failure. The ductility factor is the ratio between deformations at the first crack load to deformation at the ultimate load. The ductility factor of the control specimen is 2.75.

*Table. 13:Ductility Factor of the Specimen*

| Sl.No | Specimen | Ductility factor |
|---|---|---|
| 1 | Control | 2.74 |
| 2 | $H_1$ | 3.45 |
| 3 | $H_2$ | 4.27 |
| 4 | $H_3$ | 3.32 |
| 5 | $H_4$ | 3.50 |

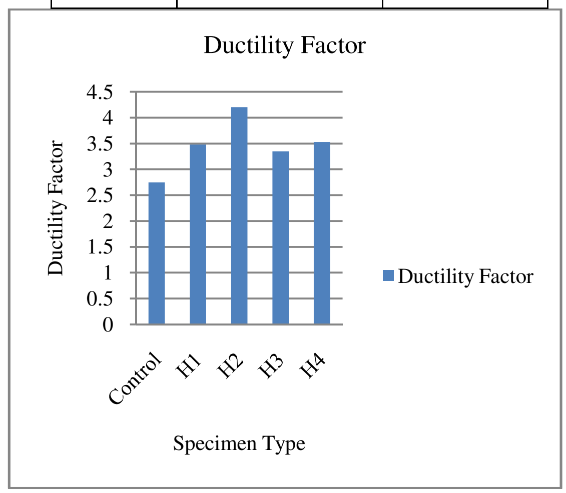


*Fig. 6:Ductility factor of the specimen*

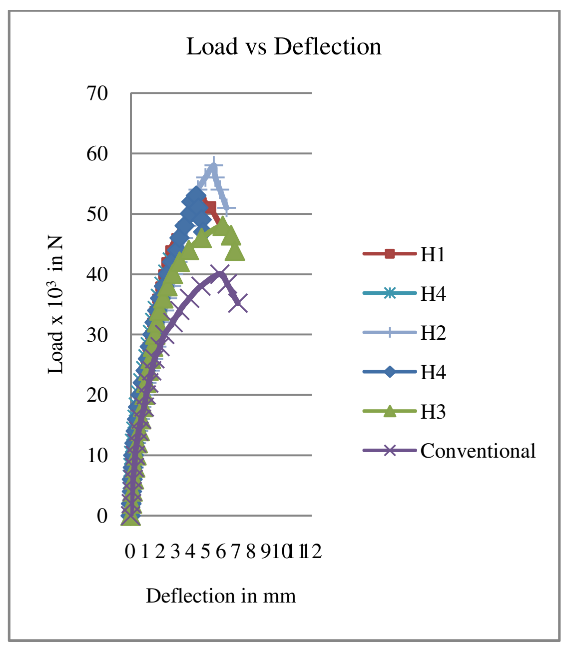


*Fig. 7:Load Vs Deflection behaviour of beams*

*Conclusion*

From the literature review and experimental work, the following conclusions were obtained.

- The study concluded that the compressive strength of the cementitious composite improved 1.2% than the control specimen, the silica content in cementitious composite increased the strength and fibers counteract with strength and ductility.
- The energy absorption capacity of the material is increased 1.9% than the control specimen. The fibers are acting as a multi directional reinforcement. The energy absorption capacity is mainly due to the polypropylene fiber content.
- The voids on the samples are very small and very less when compared with control specimen. The voids are reduced by the addition of silica fume due to fineness of it, also the bond strength between the fibers to binding material is very strong in samples.
- The stiffness is the load required to produce unit displacement. The stiffness of the samples is increased due to the fiber content. The stiffness of the samples improved 4.95% than control specimen.
- The ductility is the ability of the material to withstand large load with small deformation without failure. The ductility is mainly provided by polypropylene fiber. The ductility factor is improved 5.0% of the control specimen.
- The first crack load is increased in the samples due to the fiber content as well as multiple cracks developed due to the bridging effect of the fiber. It increased the load carrying capacity with reducing the crack width. Beyond the limit any of the crack is widening and slowly failure is occurred.
- From the load vs. deflection curve, the load capacity is very large obtain at steel fiber content of 1% and polypropylene fiber of 0.1%. The compressive strength of the cementitious composite is also increased.

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