Experimental Study of Strength and Durability Properties of Hybrid Fiber Reinforced Concrete for M25 Grade

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Abstract: This paper presents a novel design method of asynchronous domino logic pipeline, which focuses on improving the circuit efficiency and making asynchronous domino logic pipeline design more practical for a wide range of applications. The data paths are composed of a mixture of single-rail and dual-rail domino gates. Dual-rail domino gates are limited to construct a stable critical data path. Based on this critical data path, the handshake circuits are greatly simplified, which offers the pipeline high throughput as well as low power consumption. Moreover, the stable critical data path enables the adoption of single-rail domino gates in the noncritical data paths. This further saves a lot of power by reducing the overhead of logic circuits. Synchronization logic gates, which have no data dependency problem, are used in the design to construct the reliable data path. Three phase dual-rail precharge (TDPL) logic is used for evaluating the proposed pipeline method. A high-throughput and ultralow-power asynchronous domino logic pipeline design method, targeting to latch-free and extremely fine-grain or gate-level design.

Keywords: Polypropylene Fiber, Crimped Steel Fiber, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Concrete is a very commonly used construction material. Concrete made with this cement has certain characteristics. It is relatively strong in compression but weak in tension and tends to be brittle. Because of the load and environmental changes, a micro crack appears in cement products. Therefore cement based materials have low tensile strength and cause brittle failure. Cement mortar and concrete made with cement is a kind of most commonly used construction material in the world. These materials have inherently brittle nature and have some dramatic disadvantages such as poor deformability and weak crack resistance in the practical usage. Also their tensile strength and flexural strength is relatively low compared to their compressive strength. The weakness in tension can be overcome by the use of sufficient volume fraction of certain fibers. In order to improve the mechanical properties of concrete it is good to mix cement with fiber which have good tensile strength. Adding fibers to concrete greatly increases the toughness of the material. The use of fibers also alters the behavior of the fiber matrix composite after it has cracked, thereby improving its toughness.

A. Fiber Reinforced Concrete

Fiber reinforced concrete is a concrete mix that contains Short, Discrete fibers, that are uniformly distributed and randomly oriented. The characteristics of fiber reinforced concrete are changed by the alteration of quantities of concretes, fiber substances, geometric configuration, dispersal, direction and concentration. The addition of fibers to the conventional concrete is varying from 1 - 2 % by volume depending on the geometry of fibers and type of application. Fiber Reinforced Concrete is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers each of which lend varying properties to the concrete. In addition, the character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. In a hybrid, two or more different types of fibers’ are rationally combined to produce a composite that derives benefits from each of the individual fibers. The hybrid combination of metallic and non-metallic fibers can offer potential advantages in improving concrete properties as well as reducing the overall cost of concrete production. Basically fibers can be divided into following two groups

- Fibers whose moduli are lower than the cement matrix such as cellulose, nylon, polypropylene
- Fibers with higher moduli than the cement matrix such as asbestos, glass, steel etc.

The fibers are able to prevent surface cracking through bridging action leading to an increased impact resistance of the concrete. The combination of two or more different types of fibers is becoming more common, with the aim of optimizing overall system behaviour. The intent is that the performance of these hybrid systems would exceed that induced by each fiber type alone. We in ancient time fibers are used as reinforcements. In mortars horse hair is used and in mud, bricks straw is used. In 1950’s fiber reinforced concrete got great importance. By 1960’s fibers such as steel, glass, synthetic fibers such as polypropylene fibers, polyolefin fibers has got great importance. Fibers have great role to control cracking due to plastic shrinkage and due to drying shrinkage. Fibers such as polypropylene
when added to concrete reduce the compressive strength, but increases both split tensile strength and flexural strength. They are more porous compared to the plain concrete. Moreover the bridging effect by this fiber leads to the improvement in the tensile and flexural strength. The fiber also improves the resistance to ion penetration which results in corrosion reduction of reinforcing bars.

B. Role of Fibers in Concrete

Fibers are available in different sizes and shapes. They can be classified into two basic categories, namely those having a higher elastic modulus than concrete matrix (called hard intrusion) and those with lower elastic modulus (called soft intrusion). High modulus fibers improve both flexural and impact resistance simultaneously where as low modulus fibers improve the impact resistance of concrete but do not contribute much to flexural strength. Steel fiber reinforced concrete (SFRC) offers good tensile strength, ultimate strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Some researches show that SFRC shows a slight tendency to reduce the young’s modulus as the fiber content decrease. Some of the experimental results show that the beams reinforced with steel fibers shows a similar or even better post cracking behavior than beams with minimum amount of transverse reinforcement. Steel fiber also reduce the width of shear cracks, thus improve durability as shown in Fig.1. The surface corrosion of steel fiber reinforced concrete mostly depends on the cover and the water -cement ratio. In some other research the combined effect of silica flume and steel fiber improved the impact resistance and mechanical properties of concrete.

Fig.1. Plate1 steel fiber.

When fibers are added to concrete, it becomes homogeneous, isotropic and transforms it to a ductile material. These fibers will act as secondary reinforcement in concrete and reduces crack formation and propagation. Fiber reinforced concrete can be defined as a composite material consisting of cement, concrete and discontinuous, discrete, uniformly dispersed suitable fibers. If more than one fiber is used in concrete, it is called Hybrid Fiber Reinforced Concrete (HFRC). If the fiber used is large and strong, it will control crack formation and if it is small and soft, it reduces the crack formation and propagation. Researches shows that when the fibers are used in the hybrid form-steel and polypropylene, increases ductility. Steel fiber bridging across cracks in concrete mix will increase joint shear strength. The synthetic fiber increases the ductility and energy dissipating capacity. Further researches were done to study about the fracture properties and impact properties of hybrid fiber reinforced concrete. Other research works with steel and polyolefin show that they increase the compressive strength, flexure, modulus of rupture and ductility.

Fig.2. Plate 2 polypropylene fiber.

Polypropylene fibers are new generation chemical fibers. They are manufactured in large scale and have fourth largest volume in production after polyesters, polyamides and acrylics as shown in Fig.2. About 4 million tones of polypropylene fibers are produced in the world in a year. Subsequently, the polypropylene fiber has been improved further and is now used as short discontinuous fibrillated material for production of fiber reinforced concrete or as a continuous mat for production of thin sheet components. These fibers are manufactured using conventional melt spinning. Polypropylene fibers are thermo plastics produced from Propylene gas. Propylene gas is obtained from the petroleum by products or cracking of natural gas feed stocks. Propylene polymerizes to form long polymer chain under high temperature and pressure. However, polypropylene fibers with controlled configurations of molecules can be made only using special catalysts. Polypropylene fibers were formerly known as steal the, these are micro reinforcement fibers and are 100% virgin homo polymer polypropylene graded monofilament fibers. They contain no reprocessed Olefin materials. The raw material of polypropylene is derived from monomeric C3H6 which is purely a hydrocarbon. For effective performance, the recommended dosage rate of polypropylene fibers is 0.9 kg/m3, approximately 0.1% by volume.
II. OBJECTIVE
The main objective of this research include
- To develop proper mix proportion for hybrid concrete.
- Testing the mixes of hybrid fiber reinforced concrete for compressive strength, split tensile strength and flexural strength.
- Comparing the results and finding the optimum percentage of hybrid fibers.

III. MATERIALS
Cement: Ordinary Portland cement of 53 grade was used in this experimentation conforming to I.S-12269 : 1987.
Coarse Aggregates: Locally available, maximum size 20 mm, specific gravity 2.79.
Sand: Locally available sand zone I with specific gravity 2.28, water absorption 2% and fineness modulus 2.92, conforming to I.S. – 383-1970
Water: Potable water was used for the experimentation.
Fiber: The fibers used were steel and polypropylene fiber. Polypropylene fiber was straight and the steel fiber was crimped type. Properties of fibers used are shown in the Table.1 below

### TABLE I: Properties of Fiber Used

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Steel Fiber</th>
<th>Polypropylene Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Crimped</td>
<td>Straight</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>

Concrete Mix Proportion: In this study M25 and M30 grade of concrete was used. The concrete mix design was done using IS-10262:2009. The mix proportions are shown in Table 2 and Table 3.

### TABLE II: Concrete Mix Proportion For M25 Grade

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>428.26</td>
<td>1</td>
</tr>
<tr>
<td>Sand</td>
<td>1116.56</td>
<td>2.64</td>
</tr>
<tr>
<td>C.A</td>
<td>608.3</td>
<td>1.42</td>
</tr>
<tr>
<td>Water</td>
<td>198</td>
<td>0.45</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL METHODOLOGY
A. Compressive Strength Test
For compressive strength test, both cube specimens of dimensions 150 x 150 x 150 mm were cast for M25 and M30 grade of concrete. The moulds were filled with 0% HFRC 50.5P0.5 fibers. Vibration was given to the moulds using table vibrator. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7 days, 14 days and 28 days. After 7, 14 and 28 days curing, these cube were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each category, three cubes were tested and their average value is reported. The compressive strength was calculated as follows: Compressive strength (MPa) = Failure load / cross sectional area.

B. Tensile Strength Test
For tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 7, 14 and 28 days. These specimens were tested under compression testing machine. In each category, three cylinders were tested and their average value is reported. Tensile strength was calculated as follows as split tensile strength:

\[
\text{Tensile strength (MPa)} = \frac{2P}{\pi DL},
\]

Where, \(P\) = failure load, 
\(D\) = diameter of cylinder,
\(L\)=length of cylinder from the present work of experimentation results of all the parameters are calculated and tabulated below.
V. RESULTS

A. Compressive Strength Test Results

From the fig.3 it is clear that at 0.5% addition of fibers the compressive strength is 32.74 N/mm². As the percentage of fibers is increased to 1% and to 1.5% the compressive strength is 37.62 N/mm², 39.55 N/mm² respectively. From this we can conclude that as there is an increment in the fiber content there is also an increment in the compressive strength. Thus compressive strength increases with the increase of addition of fibers in the mix. When compared with controlled concrete the increase in the compressive strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 10.75%, 27.26%, 33.79% respectively.

![Fig.3. Graph showing the results of compressive strength of HFRC.](image)

B. Tensile Strength Test Results

From the above fig.4 it is clear that at 0.5% addition of fibers the tensile strength is 2.46 N/mm² and at 0.5% addition of fibers there is decrease in strength compared to conventional concrete i.e. 2.71 N/mm². As the percentage of fibers is increased to 1% and to 1.5% the split tensile strength is 3.39 N/mm², 3.96 N/mm² respectively. From this we can conclude that for 0.5% addition of fibers there is decrease in results thereafter addition of fibers i.e. 1%, 1.5% there may increase in strength. When compared with controlled concrete the increase in the split tensile strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 9.22%, 25.09%, 46.12% respectively.

![Fig.4. Graph showing the results of split tensile strength of HFRC.](image)

C. Flexural Strength Test Results

From the fig.5 it is clear that at 0.5% addition of fibers the flexural strength is 4.25 N/mm². As the percentage of fibers is increased to 1% and to 1.5% the flexural strength is 4.68 N/mm², 5.20 N/mm² respectively. From this we can conclude that as there is an increment in the fiber content there is also an increment in the flexural strength. Thus flexural strength increases with the increase of addition of fibers in the mix. When compared with controlled concrete the increase in the flexural strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 8.97%, 20%, 33.33% respectively.

![Fig.5. Graph showing the results of flexural strength of HFRC.](image)

D. Impact Strength Test Results

![Fig.6. Graph showing the results of impact strength of HFRC.](image)
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From the above fig 6 it is clear that as the percentage of fibers increases the no of blows required to failure the specimen also increases. From this we can conclude that as there is an increment in the fiber content there is also an increment in the impact valve or strength. Thus impact strength increases with the increase of addition of fibers in the mix. When compared with controlled concrete the increase in the impact strength with fiber addition in percentages of 0.5%, 1%, 1.5% respectively.

E. Sorptivity Test Results

From the fig 7 it is clear that conventional concrete and 0.5% addition of fibers have same Sorptivity valves thereafter Sorptivity valves may increases for addition of fibers at 1% and 1.5%. so from this results we conclude that as the percentage of fibers is increases the Sorptivity will be increase.

F. Slump and Compaction Factor Results

In the above fig 8 as addition of fibers is increasing there is a decrease in the slump values. It is so because as the fibers are added the bleeding will be reduced and the mix will become harsh. From this we can conclude that as the percentage of fiber content is increased the workability will be decreased.

VI. CONCLUSION

From my experimental investigation I concluded the following points.

- There is improvement in Compressive strength of HFRC compare to conventional concrete because of addition of fibers. The maximum increase in compressive strength observed at having hybrid ratio 1.5% i.e. 0.75% steel fiber and 0.75% polypropylene fiber and When compared with controlled concrete the increase in the compressive strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 10.75%, 27.26%, 33.79% respectively.
- Tensile strength may be decrease for the ratio 0.5% of fibers compare to conventional concrete, thereafter it may increase in tensile strength and hybrid ratio having 1.5% gives maximum strength compare to other proportion. From this we can conclude that for 0.5% addition of fibers there is decrease in results thereafter addition of fibers i.e 1%, 1.5% there may increase in strength When compared with controlled concrete the increase in the split tensile strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 9.22%, 25.09%, 46.12% respectively.
- Flexural strength may be maximum for hybrid ratio 1.5% compares to conventional concrete. From this we can conclude that as there is an increment in the fiber content there is also an increment in the flexural
strength. Thus flexural strength increases with the increase of addition of fibers in the mix. When compared with controlled concrete the increase in the flexural strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 8.97%, 20%, 33.33% respectively.

• Impact strength of HFRC increases as the percentage of fibers increases the no of blows required to failure the specimen also increases. Thus impact strength increases with the increase of addition of fibers in the mix. When compared with controlled concrete the increase in the impact strength with fiber addition in percentages of 0.5%, 1%, 1.5% respectively.

• Slump cone valves is decrease with Addition of fibers is increases. It is so because as the fibers are added the bleeding will be reduced and the mix will become harsh. From this we can conclude that as the percentage of fiber content is increased the workability will be decreased. As the percentage increase in fibers the compaction factor values decreases. From this conclusion we can see that the workability of the mix decreases as the fiber content in the concrete increases.

• Sorptivity will be more as the percentage of fibers addition is increase. From results we can conclude that 0.5% addition of hybrid fibers gives same Sorptivity value compare to conventional concrete.

• The optimum percentage of fibers addition is 1.5%. Addition of fibers up to 1.5% gives best results in all strength parameters compare to other mix proportion.

VII. REFERENCES


