# Study on the Performance of Hybrid Fibres in Precast Composite Beam Joint for Earthquake Resistant Structure

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***Abstract-* This paper aims at developing a strong, ductile and energy dissipating joints for precast composite concrete beam in seismic zone. Precast members are generally preferred for construction due to its construction efficiency and saving in time and cost. But it is not preferred in seismic prone zone due to the poor performance of joints and lack of design recommendation. To improve the performance of precast joints during earthquake, an experimental investigation has been carried out by placing a cast-in-place hybrid fibre composite with different percentage of hybrid fibres in between the precast concrete composite beams. The composite beams were subjected to cyclic loading using a hydraulic jack. The parameters like initial crack load, ultimate load, load deflection behaviour, ductility, energy absorption, and stiffness and failure pattern of the joint have been studied. The results of the composite beam joints were compared with the composite beam joint made up of conventional concrete.**

***Keywords*— Cyclic Loading, Hybrid Fibres, Hysteresis loop, load deflection, stiffness.**

## 1. INTRODUCTION

Precast concrete structures have been widely used in construction industry. This is due to the fact that precast concrete members can be manufactured economically, easy to handle and simple to erect [1]. Due to advancement in technology, most of the construction started using precast concrete elements. But in a high seismic zone, this type of construction is still not preferred due to the performance of joints.

Due to rapid growth in the urbanization, there is a tremendous pressure on industry to deliver faster construction. In such situation, Pre-cast construction technology becomes a popular choice. This technology has already addressed several issues like quality, durability and safety during construction. However, when it comes to earthquake safety, there are several questions which need to be addressed. It has been observed that during past few (Bhuj 2001, Chile 2010) events performance has not been satisfactory. To study the behavior of joints under seismic load, various experimental and analytical studies have been carried out since three decades. To incorporate the research finding into practice, several international codes of practices for earthquake resistant design have been undergoing periodic revisions One such development is the use of fibers which will increase the strength, ductility of the joint, stiffness and energy absorption capacity.

In the last decade, an innovative type of fibre reinforced concrete is developed, which improves both the tensile strength and the ductility [2-4] titled as “The Hybrid Fibre reinforced Concrete (HFRC)”. Hybridization refers to combination of different types of fibres. The purpose of combining the fibres is to improve the multiple properties of concrete mixture. The behavioural efficacy of this composite material is far superior to that of plain and mono fibre reinforced concrete. The predominant role of a fibre in concrete is to hinder the propagation of cracks. When load is applied, macro cracks is formed which propagate throughout the specimen and failure occurs [5]. FRC have the ability to carry major stresses over a relatively large strain capacity in the post cracking stage. The addition of steel fibres not only improves strength, but also provides high energy absorption capacity, enhances the ductile behaviour of the concrete [6]. When polypropylene is added, it helps in inhibiting the formation of micro cracks and prolongs the failure of the specimen [7].
In this paper, an attempt has been made to study the effect of hybrid fibres in joints using precast composite beam under cyclic loading.

## 2. MATERIALS USED

The materials used for this experimental work are cement, river sand, coarse aggregate, water, steel fibres, and polypropylene.

Cement: The cement used for this study is Ordinary Portland Cement conforming to IS 12269 – 1987 of grade 53.

Fine Aggregate: Locally available sand zone II with specific gravity 2.70, water absorption 2.46% and fineness modulus 3.14, conforming to I.S. – 383-1970.

Coarse aggregate: Crushed granite stones of 20 mm size having specific gravity of 2.75, fineness modulus of 8.04, impact value of 33% and water absorption of 0.75 conforming to IS 383-1970 have been used.

Water: Potable water was used for the experimentation.

Steel Fibres:- In this experimentation Crimpled Steel fibres with aspect ratio 50 has been used. The length and diameter of steel fibre is 50mm and 1mm respectively.

Polypropylene:- These fibres when used have a tendency to control propagation of cracks.

## 3. EXPERIMENTAL INVESTIGATION

All the beams are reinforced with 2 nos. of 10 mm diameter and 2 nos. of 12 mm diameter Fe 415 grade steel at top and bottom of the beam and 8 mm diameter 2 legged stirrups at 150 mm c/c. Figure 1. shows the reinforcement details of the beam specimen.

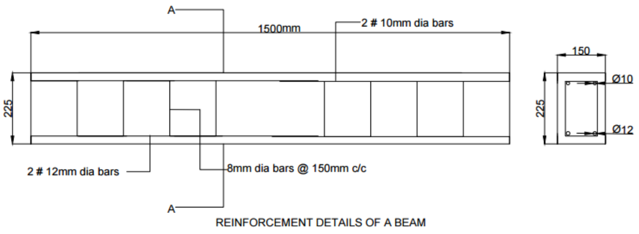



Figure 1. Reinforcement Details of the Beam

The experimental investigation consists of 4 beams casted and tested for forward and reverse cyclic loading. The specimen was tested in a structural engineering laboratory. Figure 2. shows the test setup used for cyclic loading.

Figure 2. Experimental test setup of cyclic loading

The transverse loading was applied on the tip of the beam. The transverse loading was gradually applied in the increments of 0, 0.25, 0.5 tones etc. up to the maximum load level in that particular cycle. The load is applied using a hydraulic jack. The loading was withdrawn at the same interval and the corresponding deflections were noted. This loading sequence is called as forward cyclic loading. When the load is applied at bottom tip of the beam, it is known as reverse cyclic loading. One forward and reverse cycle forms the entire hysteresis loop of a load deflection curve. The beams had hybrid fibres in the combination as shown in the Table 1.

Table 1. Designation of beam used in the study

| DESIGNATION | % OF STEEL FIBRE | % OF POLYPROPYLENE FIBRE |
|---|---|---|
| CC | 0 | 0 |
| H1 | 0.25 | 0.25 |
| H2 | 0.325 | 0.325 |
| H3 | 0.5 | 0.5 |

## 4. RESULTS AND DISCUSSION

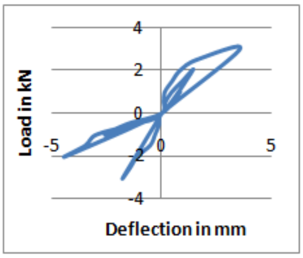
To study the effect of joints of a precast composite beam during cyclic loading, four test specimens is used varying the percentage of hybrid fibers used. Four sets of composite beam with conventional concrete as joints, different percentage of hybrid fibers as joints has been used for the experiment. Different parameters such as load, deflection, stiffness, ductility factor and energy absorption factor are tabulated.

Table 2 Experimental Results of RCC Composite Beam

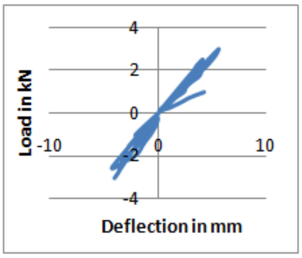
| Designation of Specimen | First Crack Load (kN) | Ultimate Load (kN) | | Deflection (mm) | |
|---|---|---|---|---|---|
| | | Forward Cycle | Reverse Cycle | Forward Cycle | Reverse Cycle |
| CC | 2.5 | 6.5 | 6 | 3.29 | 2.66 |
| H1 | 6.5 | 12.5 | 12 | 6.75 | 3.89 |
| H2 | 4.5 | 10.5 | 9.5 | 4.25 | 3.97 |
| H3 | 3.5 | 8.5 | 8.25 | 3.54 | 0.32 |

### *A. LOAD DEFLECTION BEHAVIOUR*

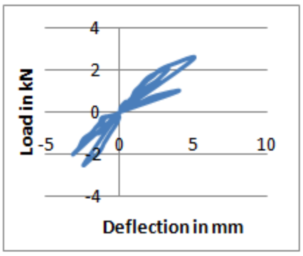
Figure 3. shows the load deflection hysteresis loop for CC, H1, H2 and H3 composite beams under forward and reverse cyclic loads. For better understanding and comparison of the hysteresis loop of load deflection behavior, the envelopes of all specimens are plotted in a single graph. The envelope is obtained by joining the peak deflection of each cycle. It can be seen that in the conventional concrete composite beam, the first crack has occurred at 2.5 kN itself where as in H1 composite beam, due to the addition of hybrid fiber the crack has occurred only at 6.5 kN.



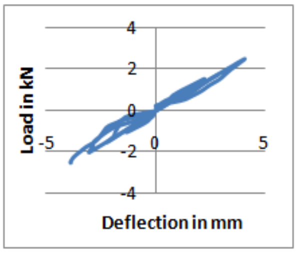

Hysteresis loop for CC




Hysteresis loop for H1




Hysteresis loop for H2




Hysteresis loop for H3

Figure 3. Hysteresis loop for all specimens

## B. *DEGRADATION OF STIFFNESS*

The stiffness is defined as load required to produce unit deflection in the composite beam joint. The stiffness can be calculated using the recorded load and deflection values of the hysteresis loop. As the load increase, there will be stiffness degradation. In general, stiffness is used as a quantitative measure to show the stiffness degradation in the specimens is calculated using a parameter called secant stiffness. i.e. by joining the line of maximum peak load and the origin as shown in Figure 4.

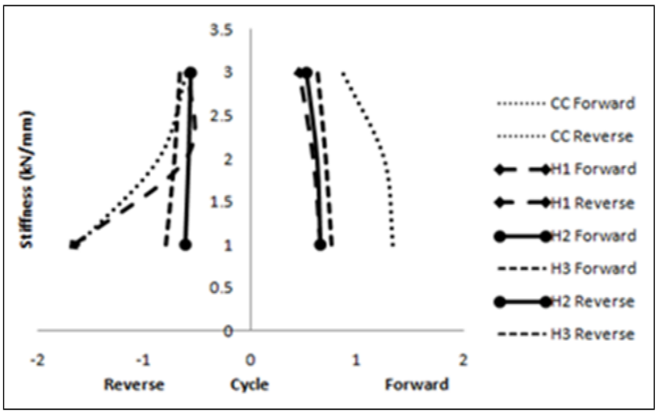



Figure 4. Comparison of Stiffness Degradation for all specimens

## C. *DUCTILITY FACTOR*

Ductility is defined as an ability of a structure undergoes deformation beyond the initial yield deformation until it sustain load. The ductility factor can be calculated using the formula.

$$\text{Ductility Factor} = \frac{\text{Ultimate Displacement}}{\text{Yield Displacement}}$$

The yield displacement can be calculated from the hysteresis loop. It is calculated by drawing a tangent from the origin the peak point of each cycle. Figure 5. shows the calculation of yield displacement.

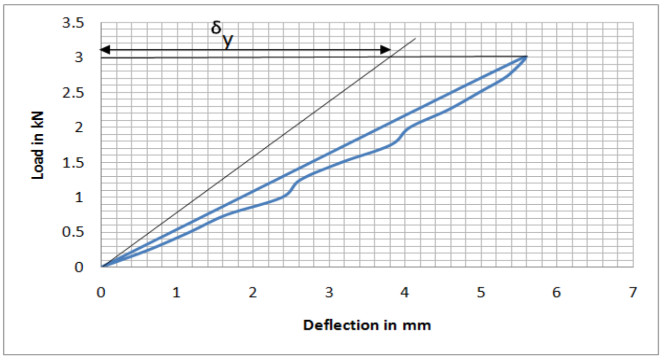



Figure 5. Procedure to calculate yield displacement

Table 3. shows the displacement ductility factor of different specimens and it can be seen that the ductility factor of hybrid fiber composite beam joint is more than that of conventional concrete beam joint.

Table 3. Ductility factor of different specimens

| Beam Designation | Ultimate Displacement | Yield Displacement | Displacement Ductility Factor |
|---|---|---|---|
| CC | 3.54 | 3 | 1.18 |
| H1 | 6.75 | 2.6 | 2.6 |
| H2 | 3.98 | 2 | 1.99 |
| H3 | 4.25 | 3.8 | 1.19 |

## D. *ENERGY ABSORPTION CAPACITY*

Energy absorption capacity is defined as the energy absorbed in each cycle equal to the work done in deforming the beam up to the limit of deflection. It is calculated using the area under hysteresis loop for each cycle in load deflection curve. Figure 3 shows the energy dissipated during each cycle of different specimen.

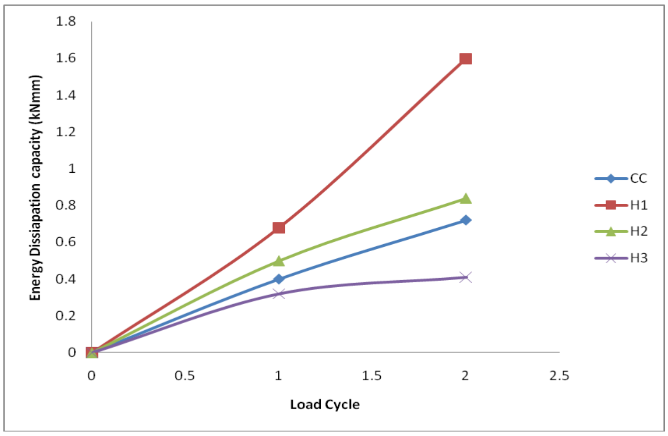


Figure 5. Energy absorption capacity of all specimens

It can be seen that specimen containing hybrid fibers have more energy absorption capacity than the conventional concrete.

## 5. CONCLUSION

This study deals with experimental investigation on behaviour of hybrid fibres in precast composite beam joint for earthquake resistant structure.

a) The hybrid beam joint showed a significant increase in first-crack strength and ultimate strength, as well as better ductility and energy-dissipation capacity
b) Energy absorption capacity and displacement ductility factor increased by 1.22 times and 1.22 times respectively for hybrid fibre joint specimen with 0.25% steel and 0.25% polypropylene fibres when compared to conventional concrete.
c) On comparing, it can be seen that hybrid fibers behave better than conventional concrete in joints for earthquake resistant structure which is evident from the fact it shows higher ductility factor and more energy absorption capacity.
d) The use of polypropylene prolongs the occurrence of first crack which is evident from the initial crack load which has occurred at 6.5 kN hybrid fibre joint specimen with 0.25% steel and 0.25% polypropylene fibres when compared to conventional concrete, it has occurred in 2.5 kN itself.
e) As the polypropylene content increases, it starts widening the macro cracks which can be seen from initial crack load, ultimate strength and lesser energy absorption capacity and ductility factor.

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