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Experimental Investigation on the Behaviour of Concrete Beams with Minimum Stirrups and Steel Fibre under Static and Impact Loading

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ABSTRACT: This study investigated the effects of steel fibers and stirrups on structural behaviour of RC beams under static, and impact loading conditions, were adopted, and five different volume fractions (vf) of hook end steel fibers, i.e., 0, 0.5, 1, 1.5 and 2% were considered. The addition of steel fibers results in ductile behaviour, increased shear and energy absorption capacities, and enhanced impact resistances of RC beams in terms of reduced maximum and residual displacements. In general, higher enhancement of structural performance of RC beams were obtained when higher amount of steel fibers was incorporated. The use of stirrups was effective in increasing the shear capacity of the RC beams under static, impact loads. On the other hand, the addition of 1 vol % fibres, which is typically sufficient for replacing the minimum shear reinforcement, was not adequate to prevent shear failure for any of the three loading rates in this study. To investigate the effect of the reinforcement ratio on the flexural behavior of ultra-high-performance fiber-reinforced concrete (UHPC) beams under static, impact loading, a total of four large-sized (1200x150x200 mm) beams were tested using a static and drop-weight impact test machine. The addition more than one fibre in concrete is known as Hybrid Fibre Reinforced Concrete. This experimental work it is been concluded that Maximum percentage of steel fibre can be used in concrete as reinforcing material is 1% for positive results. Problem that we faced during this research work is mixing of Steel fibre in concrete. The combined using of stirrups and fibers demonstrates great positive hybrid effect on the load-bearing capacity of beam subjected to bending and shear, such as post-peak behavior and failure pattern. The concrete mix design is done for M20 and M25 grade of concrete with water cement ratio 0.5. The steel fiber reinforced concrete containing fibers of 0.5%, 1.0%, 1.5% and 2% volume fraction of hooked end steel fibers of 60 aspect ratio were used. The cube size is 150mm x 150mm x 150 mm for testing the compressive strength of concrete. Flexural strength is checked by testing beams of size 1200 mm x 150 mm x 200 mm beneath two points loading. From experiment, it was concluded that the most optimum fiber content that gives maximum compressive strength and flexural strength was 1% respectively. Steel fibers reinforced concrete (SFRC) construction is more economical than conventional construction. In addition to cost reduction, SFRC has other beneficial properties such as higher stiffness, higher ductility, lightweight, low repair costs, and better post-cracking and dynamic behaviour.

KEYWORDS: Steel fiber; reinforcement; compressive strength; flexural strength; stirrup.

I. INTRODUCTION

Concrete is mostly wide construction material in the world due to its ability it can be mould and shape. However concrete has some deficiencies as listed below, Low tensile strength, Low post cracking capacity, Brittleness and low ductility, Low impact strength. These properties can be improved by the use of steel fiber reinforced concrete. The addition of fibers improves the post cracking response of the concrete, i.e., it improves its energy absorption capacity and apparent ductility, and also provides crack resistance and crack control. This research is aimed at studying the improvement in properties of concrete like compressive strength and flexural strength which increases with adding steel fibers with different percentages in concrete. The optimum percentage of volume fraction of steel fiber by weight

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of cement is determined at which it gives more compressive and flexural strength. The study also aims at determining the flexural strength of the concrete beams based on the cross sectional dimensions, span and amount of Steel Fibers used and compared with actual strength obtained based on experimental results. The research findings will help engineers to understand the overall performance of concrete for compressive strength, flexural strength. In this paper, an attempt has been made to study the strength properties of concrete with different percentages of hooked end steel fibers. The concrete mixture design is done for M20 and M 25 grade of concrete with water cement ratio 0.5. The steel fiber reinforced concrete containing fibers of 0.5%, 1.0% 1.5% and 2% volume fraction of hooked end steel fibers of 60 aspect ratio were used. The cube size is 150mm x150mm x150 mm for testing the compressive strength of concrete. Flexural strength is checked by testing beams of size 1200mm x 150 mm x 200 mm beneath two points loading. shows Impact on the impact resistance of the materials but it is only up to a certain limit. The aim of this study is to investigate the change in mechanical properties of concrete with the addition of steel fiber in high strength concrete .Steel Fibers in Concrete can improve: Crack, Impact and Fatigue Resistance, Shrinkage Reduction, Toughness- by preventing/delaying crack propagation from micro-cracks to macro-cracks.SFRC has been used extensively in construction of industrial floors, bridge deck overlays, airport runways, highway pavements, tunnel linings, spillways, dams, slope stabilizations, and many precast products. Steel fibers can improve the characteristics of hardened concrete, and polypropylene fibers can have a significant effects on the fresh concrete. Fibers are mostly used in concrete to control cracking due to various circumstances. Some recent researches shows that using fibers in concrete Ultra-high performance fibre-reinforced concrete (UHPFRC) is a relatively new building material, which has superior durability, ductility and strength in comparison with Normal Strength Concrete (NSC) and Fibre Reinforced Concrete (FRC). The fibers can improve the shear resistance capacity under the combined action of shear and bending.

SCOPE AND OBJECTIVE

To experimentally compare the compressive strength, flexural strength of hybrid fibre reinforced concrete with that of normal concrete. The specimens are cured in water having almost a neutral pH level, on the 7th, 28th day.

- To experimentally compare the compressive strength of hybrid fibre reinforced concrete with that of normal concrete to hybrid fibre reinforced concrete.
- To compare the compressive strength and the optimum percentage of hybrid fibre using in concrete.
- The aim of this study is first to develop hybrid fibre reinforced concrete (HFRC) and then to characterize and enumerate the benefits obtained by the concept of hybridization. Compressive strength, flexural strength is the measured mechanical properties of the HFRC mixes in this study.
- The appropriate interpretation of the obtained results, it can be possible to make various optimization analyses like optimization for a desired mechanical property or optimization for a certain fibre type and content.
- The improvement in properties of concrete like compressive strength and flexural strength which increases with adding steel fibers with different percentages in concrete. The optimum percentage of volume fraction of steel fiber by weight of cement is determined at which it gives more compressive and flexural strength.

II. METHODOLOGY

PROPERTIES OF STEEL FIBER REINFORCEMENT NOVOCON 1050.

Material :Hook end- steel fibre, with ends.

Conformance: ASTM A 820/A 820M, Type I.

Fire Classification: UL Report File No. R14701 (N).

Tensile Strength: Minimum 152,000 psi (1,050 MPa).

Fiber Length: 30 mm

Equivalent Diameter: 0.039 inch (1.0 mm).

Aspect Ratio: 50.

Appearance: Bright and clean wire.

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Fig 1.Hook end-Steel fiber

III. EXPERIMENTAL PROGRAM

3.1 Details of test specimens

The experimental program consisted of two phases: static and impact tests. Four reinforced SFRC beams, divided into two groups, were fabricated and tested under various loading rates to investigate the effect of steel fibers and shear reinforcement in RC beams. The details of the specimens are listed in Table 1. The fiber volume fraction and details of shear reinforcement were considered as variables. As illustrated in Fig. 1, all specimens were 150mm in width, 200mm in height, and 1200mm in length, and longitudinal reinforcements, which consisted of two deformed steel reinforcing bars of diameter of 16mm (denoted as D19). Two specimens of each test series incorporated shear stirrups that were designed according to the minimum shear requirements of 12mm and hook end steel. The compressive strength test, cube specimens of dimensions 150 mm × 150 mm × 150 mm and 100x100x500mm height cylinders were cast using M20 and M25 grade of concrete with 0.5%, 1%, 1.5% & 2% of hybrid weight of cement, separately. The specimens were placed in compressive testing machine capacity of 2000KN and tested for compressive strength. The flexural strength of concrete beam was determined by using beam specimens of size 1200 mm x 150 mm x 200 mm were casted using M20 and M25. The samples were demoulded after 24 hours from casting and kept in a water tank for 28 days curing. The specimens were placed in flexural testing machine capacity of 200 Ton and tested for flexural strength.

3.2 Material properties

The concrete properties and mix proportions are summarized in Tables 1 and 2. All specimens were fabricated with an identical mixture that had a water-to-cement ratio of 0.5, sand-to-aggregate ratio of 0.88, and maximum aggregate size of 20 mm. Moreover, 30mm hooked-end steel fibers were used in the concrete, and the fiber content varied among 0, 0.5, 1, 1.5 and 2%. The compressive and flexural strengths were measured based on ASTM C39 [23] and C1609 [24], on cylinders with a diameter of 100mm and height of 200 mm, and beams with a cross-section of 150×200mm and a length of 1200 mm.

Table No: 1 The Steel Fibre Mix on Concrete

Fibre content(M20)	W/C ratio	Water (l)	Cement (kg)	Fine.agg (kg)	Coarse.agg (kg)	Steel fibre (g)
0%	0.5	192	383	568	1280	0
0.5%	0.5	192	383	568	1280	0.0956

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1%	0.5	192	383	568	1280	0.1912
1.5%	0.5	192	383	568	1280	0.2868
2%	0.5	192	383	568	1280	0.3824

Table No: 2 The Steel Fibre Mix on concrete

Fibre content(M25)	W/C ratio	Water (l)	Cement (kg)	Fine.agg (kg)	Coarse.agg (kg)	Steel fibre (g)
0%	0.5	192	384	685	1155	0
0.5%	0.5	192	384	685	1155	0.0966
1%	0.5	192	384	685	1155	0.1932
1.5%	0.5	192	384	685	1155	0.288
2%	0.5	192	384s	685	1155	0.384

3.3 Test procedure

3.3.1. Static test

The static two-point flexural tests were carried out on the five specimens with quasi-static loading rate of 0.02 mm/s. As part of the tests, crack patterns were also examined. The clear span was 1000mm, and the distance from the loading plates to the supports was 100 mm, resulting in a clear shear span–depth ratio (a/d) of 1.5. A load testing frame with maximum load capacity of 200Ton was used for applying monotonic flexural loads, and 160×25mm steel bearing plates were placed at the location of the loading and supports to prevent local crushing of the concrete.

3.3.2. Drop-weight impact test

The test setup for the drop-weight impact test. The boundary conditions of the impact tests were similar to those of the static test. The test setup consists of several components: guide beams, drop hammer, and supports. The guide beams were fabricated using two steel H-beams (150×150 × 75 mm). The centers of the guide beams were aligned with the center of the specimen. The hammer was composed of three components: mass blocks, guide blocks, and a weight tup. The mass blocks were fabricated by bolting several rectangular steel blocks. The mass of the hammer could be adjusted by varying the number of bolted blocks. The guide blocks were attached to the mass block, and aided the hammer to drop along the guide beams. The drop weight tup was hemispherical, with a diameter of 150 mm. The supports were fixed on the strong floor of the laboratory and designed to prevent rebounding of the specimens under impact load. Two load cells of capacity 80 kN were mounted on the supports to measure the reaction forces, and a load cell of capacity 1960 kN was used in the drop-weight to measure the impact force.

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IV. REINFORCEMENT DETAILS

Main reinforcement: 2 nos of 12 mm dia HYSD bars, Secondary reinforcement: 2 nos. of 16 mm dia HYSD bars,

Shear reinforcement: 2 nos of 16 mm dia at 300 mm c/c.

The yield strength of steel reinforcement used in this experimental program was determined by performing the flexural test on the four specimens of each grade of concrete.



Fig 3 Reinforcement details



Fig 4 Applying on the concrete and vibrating the mould



Fig 5 curing process

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V. EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Static response

The load-deflection curves and summary of test results obtained from the static tests are presented in Fig. 7 and Table 6. The specimens with stirrups, SFRC 1.0% failed in shear critical mode. SFRC-0% sustained a maximum reaction force of 420 kN and exhibited brittle-shear failure at a relatively marginal load and deflection. The addition of 1.0 vol% of fibers resulted in an increase of 30% in the maximum load (Fmax): Fmax= 450 kN. The maximum force of shear-deficient specimens, which implies twice the shear strength (Fmax=2V), increased monotonously. The shear strength of the RC beams increased with increase in the volume fraction of steel fibers, because of the enhanced fiber bridging capacity at the crack surface. Although several studies reported that a fiber content of 1% is typically sufficient to avoid shear failure, the addition of 2% fibers was not adequate to cause flexural-failure in this test. The final crack profiles of the static test specimens. All the specimens with shear reinforcements failed with severe diagonal cracks, which originated at the loading point, and propagated downward at angles of 29, 31, and 35°, respectively. The number of cracks increased as the amount of steel fibers increased. On the other hand, the specimens with shear reinforcements, designed according to the minimum shear requirements of CSA A23.3-2014, exhibited flexural-failure with concrete-crushing at the loading point. The maximum reaction force of these flexure-critical specimens was determined to be approximately 462 kN. Although these specimens failed at similar maximum loads, SFRC-1 %-S, which was reinforced with both steel fibers and stirrups, exhibited the highest energy dissipation capacity calculated by Eq. (1). The calculated energy dissipation capacities are presented in Table 6.

$$E_{diss} = f_0^{3.5\delta_{max}} Fd^\delta$$



Fig 6 static load test

Table 3: The static load capacity of the specimen

Fibre content	Flexural failure load (KN)	Deflection at max. load, δ_{max} (mm)	Static energy Dissipation capacity, Ediss (kJ)	Failure Mode
Normal beam (M20)	420	27.07	9.75	Shear
Normal beam (M25)	425	29.37	10.24	Shear

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SFRC Beam with 1%(M20)	450	34.27	11.24	Flexural
SFRC Beam with 1%(M20)	462	35.08	12.09	Flexural

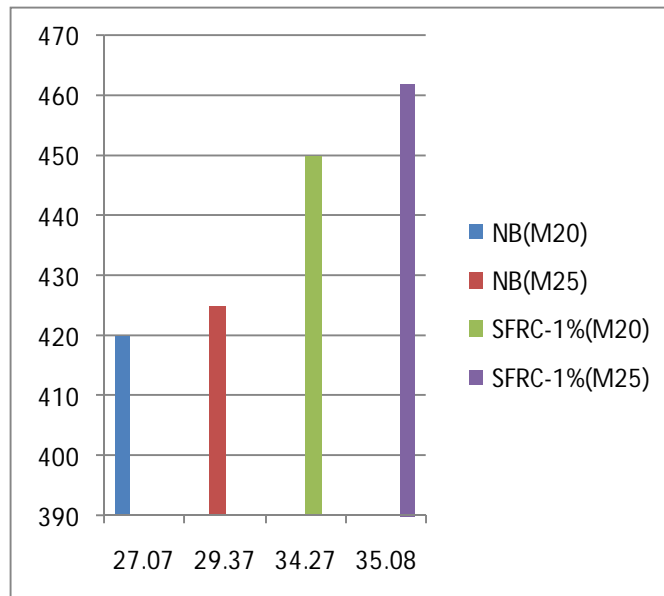


chart:1 static load applied to the beam

5.2 Impact resistance

This section discusses general behaviors such as the variation of forces, displacements, and support rotations exhibited by the specimens under sequential impact. Moreover, the impact capacity of each specimen is provided in terms of total imparted energy until final failure. The results of the impact test are summarized in Table 8. The impact force was measured by a load cell installed in the drop hammer, and the reaction force was calculated by adding the measured support reactions. The variation of the maximum reaction force was used as the failure criteria. This implies that when the force was abruptly decreased, the specimen could be considered to fail, which is similar to previous test results for RC beam. In the case of SFRC-1%, the control specimen, shear failure was observed in the first impact. Whereas, the other specimens with the stirrups exhibited flexural and shear failure, respectively, in the fourth impact. The specimen SFRC-1% exhibited ductile behavior and dissipated 30.37 kJ of imparted energy until the eighth impact. On the other hand, the specimen SFRC-0%-S exhibited ductile behavior with flexural-failure and dissipated 23.15 kJ of imparted energy. Therefore, it was verified that impact resistance can be enhanced by adding steel fibers and using shear reinforcement, as compared with conventional RC beams with stirrups (SFRC-0%). The final crack profiles of impact test specimens are presented in Fig. 9. The specimens with stirrups exhibited shear failure with severe diagonal cracks, and those reinforced with stirrups exhibited vertical flexural cracks. The number of cracks increased with increase in the steel fiber content. In all the specimens, local damages occurred at the surface where the large impact load was imparted rapidly owing to the load concentration.

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Fig 7 impact load test

Table no: 4 Result of Impact test.

Sl.no	Fibre content %	Flexural Failure Load (KN)	Impact properties			Max –Midspan Displacement F_i (KN)
			H(mm)	F_i (KN)	E_i (KJ)	
1	NB(M20)	430	600	483	2.06	20.56
			600	490	1.98	20.60
			900	478	1.90	20.78
2	NB(M25)	438	600	444	2.10	21.09
			900	365	2.06	21.37
			900	376	2.09	21.56
3	SFRCbeam-1%(M20)	462	600	469	3.02	23.36
			600	456	6.11	23.67
			600	470	6.23	23.70
			900	379	12.26	23.88
			900	460	12.46	23.90
4	SFRCbeam-1%(M25)	470	600	490	3.12	24.24
			600	476	6.23	24.44
			900	-	13.03	24.54
			900	453	13.74	24.67
			1200	498	13.98	24.78

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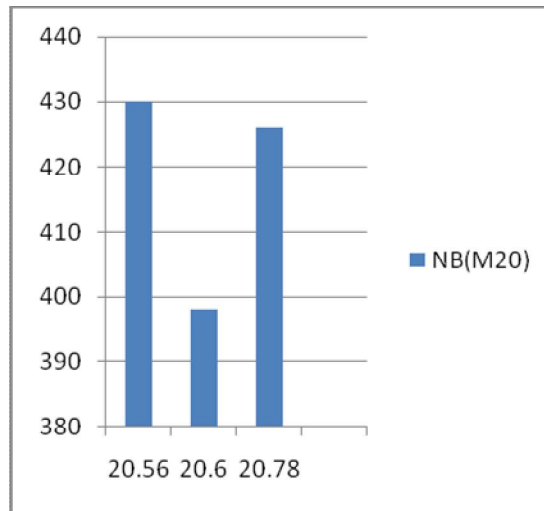


chart 2 :The impact load test from NB(M20)

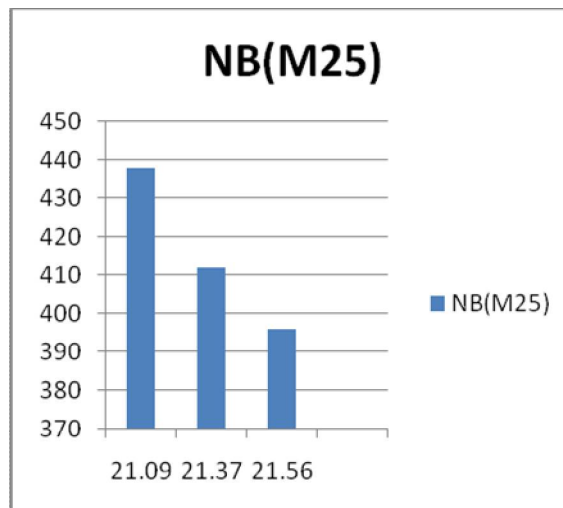


chart 3: The impact load test from (M25)

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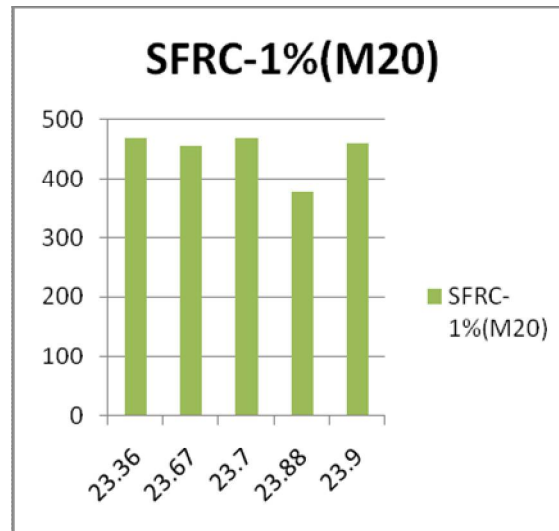


chart 4: The impact load applied to the SFRC beam

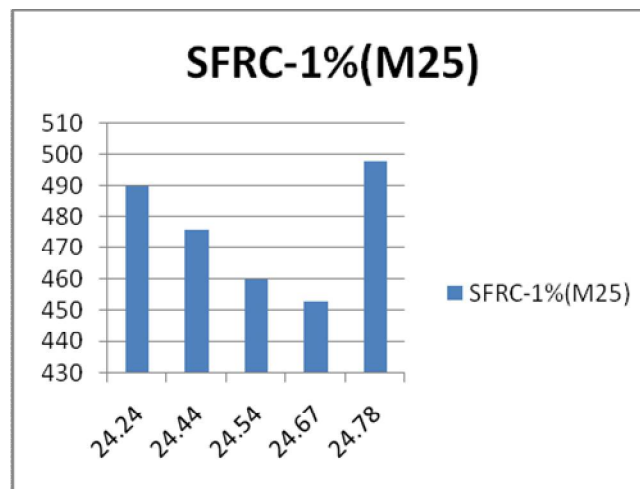


chart 5: The impact load applied to the SFRC beam.

5.3 Comparative effectiveness of steel fibers on static and impact resistances of RC beams As mentioned previously, adding fibers enhances the displacement control, ductility, and shear resistance of the RC beams under the static and impact loads. Moreover, the specimens exhibited the capability to resist larger impact force and impulse as the fiber content was increased. Therefore, it was verified through the experimental tests that the addition of steel fibers can be an effective method to enhance impact and static resistances. However, considering the strain rate and loading type, the increase-ratio of fiber contribution varied dissimilarly. For example, the maximum reaction force of SFRC-1.0% in the static test increased by 72% when compared with the control specimen, while the maximum reaction force of SFRC-1.0% in the impact tests increased by 36% respectively. Thus, it can be concluded that the addition of steel fibers is most effective under impact condition than under static conditions. Because much more fiber fractures were occurred in impact tests, in contrast, the fibers were pulled out in static test. The reason of fiber fracture is due to increasing bond strength between fiber and concrete as the dynamic increase factor (DIF) is increased. Therefore, fibers to be used in SFRC subjected to dynamic load should be designed differently in order to avoid fiber fracture failure. The fiber

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contribution increased continuously as the fiber content increased in the static test, an inflection point appeared at 1.0 % of fiber content in the impact tests. Moreover, the fiber contributions of the impact test specimens at 1.0 vol % were measured to be smaller than that of the static test results. This can be attributed to the fiber fractures that occurred under the impact and blast loadings].The figure illustrates that the prediction model provided reasonable estimation in the static condition. However, no prediction models are available to predict the shear resistance of reinforced SFRC beams under impact and blast loads. Thus, further research is required to study the effects of fibers on shear resistances under the dynamic loading condition.

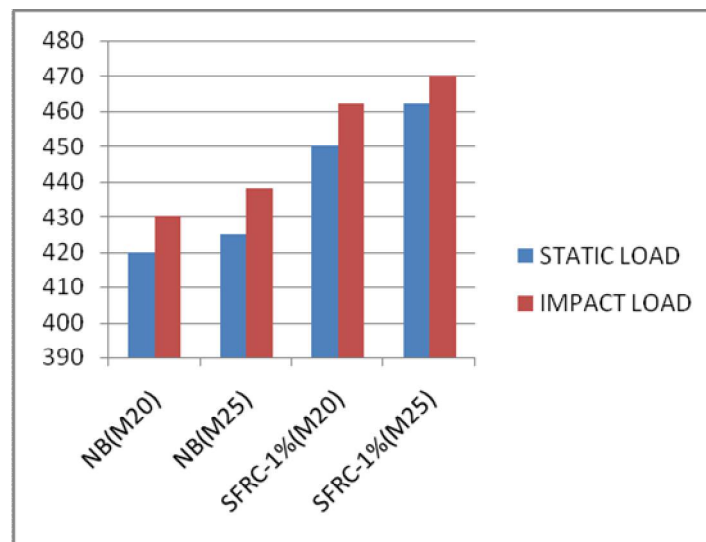


chart 6: The combined beam from static and impact load.

VI. CONCLUSION

Concrete mix design was prepared by Indian Standard and mix design for M20 and M25 grade concrete for trial mixes were done. Five types of concrete mixes were prepared using water cement ratio of 0.5. The Hybrid fibres are combination of 75% Steel fibres. Compressive strength tests for both cube and cylinder, Flexural strength test were carried out to study the properties of hardened concrete. Results showed that, as the fibre content in concrete increases, the strength also increases up to a certain extent. Mix containing 1% Hybrid fibre showed maximum performance.

- M20 and M25 grade concrete mix is designed based on IS: 10262-2009 guide lines and the mix proportion obtained as 1: 1.5: 3.03 and 1:1.7:3 with w/c ratio of 0.5 to obtain 75 mm slump.
- The compressive strength of M25 grade concrete for 28 days is 33.23 and 32.01 N/mm² and Compressive strength of optimum dosage of HYFRC 1% is 37.23 and 37.68 N/mm² will be increased.
- Eight identical beams are cast in control beam as well as HYFRC beams. The first static crack load observed in control beams are 420 and 425 KN and the same observed in HYFRC beams are 450 and 462 kN. The HYFRC beam shows 30% increase in first crack load.
- Eight identical beams are cast in control beam as well as HYFRC beams. The first impact crack load observed in control beams are 430 and 438 KN and the same observed in HYFRC beams are 462 and 470 kN. The HYFRC beam shows 30% increase in first crack load.
- The flexural strength of conventional beam of M20 and M25 grade of concrete for 28 days is 420 and 425 KN and hybrid reinforced concrete beams 450 and 462 KN.

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