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STUDY ON STRENGTH CHARACTERISTICS OF STEEL FIBRE REINFORCED CONCRETE

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Abstract: *Punching shear is undesirable in structural concrete slab systems owing to its brittle nature, which may lead to progressive collapse of a building. Methods to enhance the punching shear resistance of slabs and these include traditional shear reinforcing method using stirrups but this method is inapplicable to slabs with shallow depth less than 150mm (ACI 318-2002), new method using headed-studs but this one need much time for construction, helix reinforcement and lattice reinforcement, apart from the provision of drop panels. The use of steel fibers to improve the punching shear resistance and cracking control of slab-column connections has been proven to give good results. Fiber bridging over the cracks leads to increased shear, punching and moment resistance, reduced crack spacing and crack widths, increased flexural stiffness and increased ductility in compression. The experimental study was carried on twelve reinforced concrete slabs using crimped steel fibers. Three specimens were casted without steel fiber. The other twelve specimens considered the variation of steel fiber volume fraction which was 15kg/m³, 30kg/m³ and 45kg/m³. Nano Silica and GGBS was also used which was kept constant at 2% and 20% to increase the compressive strength and also to reduce the cement content and decrease in the emission of CO_2. The optimum dosage of fiber was found to be 30Kg/m³ where the percentage increase in stress was found to higher that is 21.1%. Similarly the optimum dosages for Compressive strength and Split tensile strength 30Kg/m³ where the strengths were found to higher when compared to conventional concrete.*

Index Terms*: *Punching shear, Crimped fibers, Nano Silica, GGBS.

I. INTRODUCTION

For Flat plates may fail in shear in two different mechanisms: (1) one-way shear and (2) two-way shear or punching shear. However, the punching shear capacity of a slab is usually far less than its one-way shear capacity; thus, punching shear governs the design (Park and Gamble 2000). In a typical slab-column connection, not only concentric loads are transferred from the slab to the column, but also bending moments are transferred due to uneven loading schemes or unequal adjacent span lengths. The moment transfer is magnified in the case of slab-column edge connections and if the structure is to resist lateral loads. In any case, if the applied punching shear stresses are higher than the capacity of the connection, shear reinforcement is to be used to increase the punching shear capacity. Stud shear reinforcement, in particular, has been used to increase the capacity and ductility of steel-RC connections. It is easy to install inside thin slabs as it does not interrupt the flexural reinforcement; moreover, it has sufficient anchorages on both upper and lower ends to prevent bond slip prior to yielding.

For the slab-column connection, the punching shear strength is defined as the net ultimate reaction at the column's contra flexural points and the failure can be generally classified as either flexural or shear, depending on whether the failure is initiated by yielding of reinforcement, crushing of concrete and formed internal diagonal cracking.
When a reinforced normal strength concrete (NSC) flat slab structure is subject to heavy gravity load, punching shear cracks occur at slab tension surface in column vicinity, they
Propagate at 20 -50 angles through the slab thickness to form a truncated conical or pyramid failure surface around the column. In addition to vertical loads, the slab-column connections may be subject to unbalanced moments, which may be caused for example by unequal spans on both sides of the column or by lateral loading such as wind or earthquakes. The unbalanced moment is resisted by a combination of stresses in slab flexural reinforcements, shear strength of concrete, and shear reinforcement in the vicinity of the column.
The punching shear failure mechanism of the NSC slab under punching shear usually starts with flexural cracking in the tension area directly under the support column. These cracks are distributed in radial and tangential directions with load increasing till the critical shear cracks open and then are distributed to form the failure cone diameter at the tension area. Shear cracks move towards the compression area through the thickness of the slab to form the whole punching shear cone.
Punching shear phenomenon emerges in concrete slab structures exposed to high bending moment and concentrated shear stress loads that are either supported on a column or subjected to a point load. As an example that can be mentioned is column-supported slabs or bridge deck flat slabs, also foundation slabs under columns are common. The benefit with flat slabs is the exclusion of haunches, capitals, beams and girders, which reduces overall floor depth, thereby creating additional

floor space for a given building height.

Punching shear failure is a three-dimensional issue of brittle mode due to the high shear stress. Since punching phenomenon is considered as a combination of shearing and splitting that occurs without crushing, failure is assumed to arise in the compression zone near the bottom surface of the slab close to the column, due to the column reaction reaching a critical level.

When only shear forces are applied and no bending moment exists, the cracks will propagate in 30° angle alignment, while pure flexural cracks created by a bending moment with no shear force have 90° angel alignment (Hermansson& Johansson, 2009). Consequently, once punching appears the column and the slab disconnect and the resistance capacity of the structure is radically decreased, hence the failure occurs suddenly and causes hazardous damages. This type of failures must absolutely be avoided since it does not allow any overall development of yielding mechanism.

1.1 PUNCHING SHEAR REINFORCEMENT

If the shear capacity provided by concrete in a slab-column connection is not adequate to resist the applied shear stress, the punching shear capacity of the connection has to be increased to insure a ductile/deformable flexural failure rather than a brittle punching shear failure. This can be achieved by many methods such as: (1) increasing the area of concrete resisting shear stresses, i.e., increasing the thickness of the slab, providing a drop panel or a column head and/or increasing the column dimensions, (2) using concrete with higher compressive strength and (3) providing additional shear strength by placing shear reinforcement at the column vicinity. Although all these methods provide an increase in the punching shear capacity of the connections, only properly anchored shear reinforcement increased the ductility/deformability of the failure mode allowing for large slab-column deformations (Megally and Ghali 2000).

Although shear Reinforcement in the shape of shearheads were introduced in the 1930s (Wheeler 1936), it was not until the 1960s and the 1970s when design provisions for shear reinforcement were implemented in the ACI code for slabs thicker than 250 mm (ACI Committee 318 1963) and for thin slabs (ACI Committee 318 1971), respectively.

In a slab-column connection without shear reinforcement, the major inclined crack forms at an angle of approximately 30-35^o with the plane of the slab. When shear reinforcement is present, it controls the inclined cracks propagation and provides additional confinement to the concrete. The crack inside the shear reinforced zone forms at a steeper angle of about 45^o (Polak et al. 2005). Three main conditions have to be satisfied in order for the shear reinforcement to be effective:

(1) the radial spacing of the reinforcement should be limited to insure that inclined cracks do not form between two adjacent reinforcing bars,

(2) effective anchorage in both tension and compression zones must be provided for the shear reinforcement especially in thin slabs and (3) the shear reinforcement should be placed without obstructing the placement of the flexural reinforcement.

1.2 BUILDING CODES PROVISIONS FOR PUNCHING SHEAR

IS 456:2000, Clause 31.6.1 The critical section for shear shall be at a distance *D/2* from the periphery of the column/capital/drop panel, perpendicular to the plane of the slab where *D* is the effective depth of the section. The shape in plan is geometrically similar to the support immediately below the slab (see Fig. 13A and 13B).

NOTE- For column sections with re-entrant angles. The critical section shall be taken as indicated in Fig. 13C and 13D.

IS 456:2000 Clause 31.6.1.1 In the case of columns near the free edge of a slab, the critical section shall be taken as shown in Fig. 1.

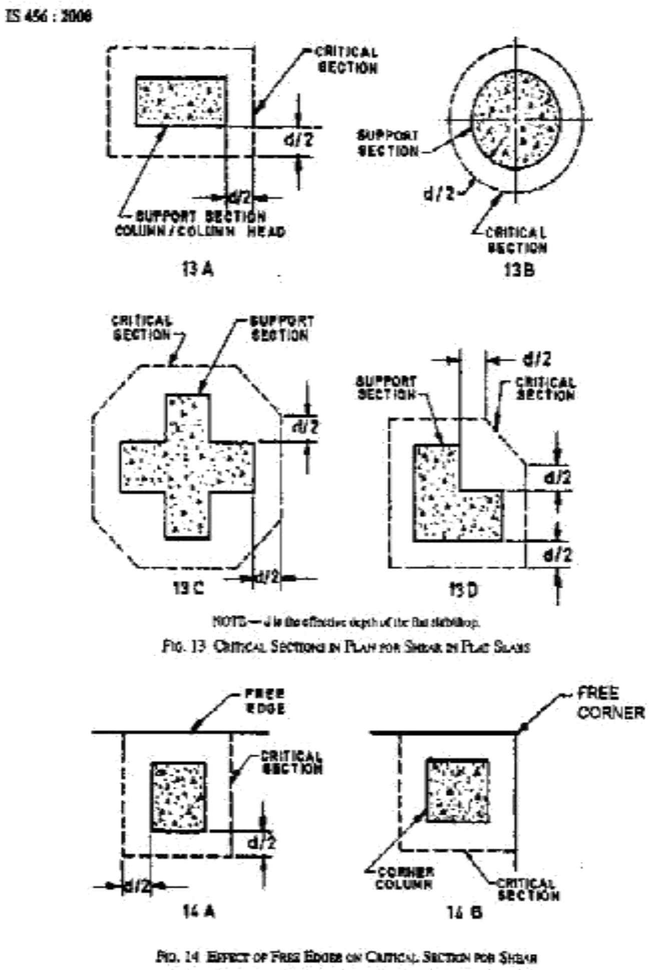

Figure 1.: Critical sections for Shear as per IS 456:2000

1.3 Scope of the study

- The proposed study is planned for M30 grade of concrete.
- In the proposed study crimped steel fibers are used.
- Steel re-bars of 8mm□ @ 140mm c/c is used.
- This is also studied with the addition of constant Nano Silica & GGBS.

1.4 Need of the study

- Punching force increases with increase in the Punching Stress. So, therefore it is intended to increase the Punching stress for the given sample.
- Not much work has been done on the crimped steel fibres. Crimped steel fibres are being used to determine it’s effect on Punching shear capacity of the slabs.

1.5 Objectives of present study

The main objectives of this present study are:

- To investigate the effect of addition of crimped steel fibers on the punching shear capacity of slabs.
- To propose a mathematical formulation to predict the punching shear strength of Fiber Reinforced Concrete.

II. LITERATURE REVIEW

K H Tan and A Venkateshwaran (2020) studied the punching shear capacity of steel fibre reinforced concrete (SFRC) slabs without traditional steel bar reinforcement was investigated by conducting central point-load tests. They concluded that the yield line theory provides accurate predictions of the load carrying capacity of the SFRC slabs while the punching shear prediction models fail to predict the observed values accurately. They also concluded that the slabs experienced a flexural mode of failure rather than a punching shear failure.

Sumanth Doodala and Ch. Kusuma Keerthi (2019) studied the Partial replacement of cement with GGBS and Coarse aggregate with steel slag and concluded that by replacing 20% GGBS with cement and 20% steel slag with coarse aggregate the compressive strength and split tensile strength increases and deformation in the cylinders was also less compared with conventional concrete.

Abibasheer Basheerudeen, S.K. Sekar (2019) studied the behaviour and capability of SFRSCC in flexure and punching shear by conducting experimental investigation on prism and slab- column specimen. They concluded performance of flexural and punching shear properties is significantly increased with the addition of steel fibers, and the increase was more prominent with 0.75% volume fraction of steel fibers.

Vijay M. Mhaske, Rahul D. Pandit, A. P. Wadekar (2019) carried out to assessment of mechanical properties of high strength fiber reinforced concrete (HSFRC) using crimped steel fiber. They concluded that compressive strength is increased continuously with increase in fiber content up to 3.5% of fiber volume content in HSC. Similarly they also concluded that the tensile strength increases with increase in the percentage of fiber content in HSC.

Karthika P (2016) studied the Strength & Durability of Concrete by Partial Replacement of Cement with Nano Silica with 0%, 1%, 2%, 3%, 4% and found out that the optimum percentage was 2%. He concluded that the compressive strength, split tensile strength and flexural strength was increased by 40%, 15%, and 35% by replacing 2% of cement with Nano Silica. He also concluded that durability of concrete containing 2% Nano silica exhibits better resistance against sulphate attack, chloride attack and acid attack.

Khalid. S. Ragab, Ahmed S. Eisa and Saaid. I. Zaki (2012) studied the behavior and capacity of steel fiber reinforced high strength self compacting concrete (SFRHSCC) slabs under punching shear force. They used hooked-ends type steel fibers with varying fiber dosage, ordinary concrete, self-compacting concrete and high strength self compacting concrete. They concluded that steel fibers with volume fraction equal to 0.75% with self compacted concrete is the ideal percentage to increase the punching shear resistance.

L.NGUYEN-MINH, M. ROVNAK, T. TRAN-QUOC, and K. NGUYENKIM (2011) studied small-scale flat slabs of different dimensions that consisted of nine SFRC and three control steel reinforced concrete (SRC). They concluded that the punching shear increases with the addition of fibers. For an addition of 30 to 60 kg/m³ there is an increase of punching shear resistance of slabs from 9 to 39.8%. They further concluded that the average crack width of slabs reduced up to 70.8% approx.

From the literature studied it has been found that most of the investigators had done work towards the enhancement of punching shear capacity of slabs but scantily work is there in the direction of other types of fibers like crimped fiber where as crimped fiber is very good fiber in resisting flexure. Crimped fibers have better deformation resistance, ductility, and energy absorption capability. Not much work has been done using crimped fiber. So, therefore it is intended to use crimped fiber to determine its effect on the Punching shear capacity of slabs.

III. METHODOLOGY

3.1 Material Properties

Mix design was done to calculate the amount of materials used in M30 grade concrete. The Mix design obtained was 1:1.71:1.85 with 0.45 as water content.

MATERIAL PROPERTY	Cement	Fine Aggregate	Coarse Aggregate
Specific Gravity	3.12	2.6	2.7

Table 3.1.1: Specific Gravity of materials

MATERIALS	**QUANTITY (Kg)**	**PROPORTION**

Cement	476.09	1
Fine Aggregate	812.16	1.71
Coarse Aggregate	881.92	1.85
Water Content	214.24	0.45

Table 3.1.2: Mix Proportion

MATERIALS	**WEIGHT (Kg)**
Cement	1.0948
Fine Aggregate	2.98
Coarse Aggregate	2.74
GGBS	0.322
Nano Silica	0.0322
Water	0.72Kg/^{3}

Table 3.1.3: Mix proportion in slab with 0kg/m^3 of fibre content

3.2 Preparation of Test Specimen:

The preparation of test specimen can be broadly be executed in three stages. They are mixing, casting and curing.

3.2.1 Mixing:

Mixing was done as follows:

- Firstly, the ground was sprayed with water to remove any residual materials and for the absorption water. Then the remaining water was thrown away.
- Then the dry materials i.e. coarse aggregate, graded fine aggregate, cement, nano silica and GGBS were added and mixed for 2-3 minutes.
- Then crimped fibers are added. (Only for the specimen with fibers).
- Then our required water for sufficient workability is added and is mixed well for 4-5 minutes to see if there will be a loss in workability.

3.2.2 Casting of Specimen:

A total of 12 square reinforced concrete slab specimens with same dimensions were casted. All slabs have same 75 mm depth. The concrete used in the specimens consisted of ordinary Portland cement, natural sand and crushed stone aggregate with maximum size 10 mm. The water cement ratio for concrete was 0.45. Fiber volume of individual slabs was varied. From the literature[6,11], Nano silica(6) is kept constant at 2% which is used to increase its strength and permeability and GGBS(11) is kept constant at 20% not only to increase its compressive strength but also it reduces the cement content which eventually leads to the decrease in emission of CO_2.The slabs in each group were cast at the same time from the same batch of concrete. Adequate compaction was achieved. All slabs were cast and cured under similar conditions and tested after 28 days. Details of the slab samples are given in Table.

Casting is done in wooden moulds for slabs and in iron moulds for 150mm cubes and cylinders. In this stage proper compaction is very important. To attain proper compaction, fill about one third of the mould with concrete then compact using tamping rod, then fill the rest of the mould and re compact to remove air voids.

Slabs	Fibers	Steel	Nano Silic	GGBS

							a	
Dimensions (mm)	Fibers (kg/m³)	Type	L (mm)	ϕ (mm)	Diameter (mm)	Spacing (mm)	(%)	(%)
500*500*75	0	Crimped	35	0.5	8	140	2	20
500*500*75	15	Crimped	35	0.5	8	140	2	20
500*500*75	30	Crimped	35	0.5	8	140	2	20
500*500*75	45	Crimped	35	0.5	8	140	2	20

Table 3.2.2: Details of Reinforced Concrete Slab Specimen

Figure 3.2.1Reinforcement detailing of the slabs

Figure 3.2.2: Casted specimen

3.7.3 Curing of Specimen:

The specimens has been cured in curing tank for about 28 days and tested. All slabs were cast and cured under similar conditions and tested after 28 days.

3.7.4 Testing of Specimen:

Testing was done for initial setting time, final setting time, slump cone and compaction factor test on fresh concrete and for compressive strength and tensile strength on hardened concrete.

Table 3.7: Sample Specimens

Fiber Content (Kg/m³)	Sample No
0	i
	ii
15	iii
	iv
30	v
	vi
45	vii
	viii

3.8 Testing of slabs for punching shear:

The tests were designed to simulate conditions in actual structures. Each slab was subjected to concentrated loading at the geometric center using a universal testing machine. Square steel support was placed at the bottom of the slab during testing in the form simple support. Loading was applied to specimen at an approximately constant rate up to the peak load; at the same time deflections were measured. Failure occurred abruptly in all specimens and loading was stopped after failure.

Figure 3.8.1: Slab test on the universal testing machine

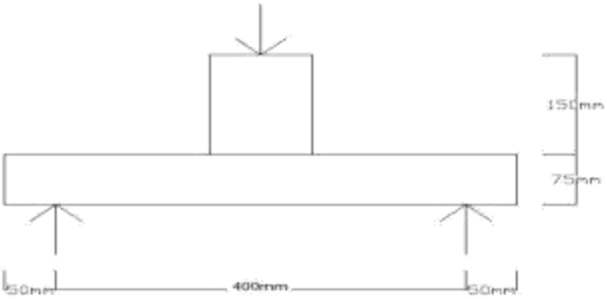

Figure 3.8.2: Front view of the Experimental setup

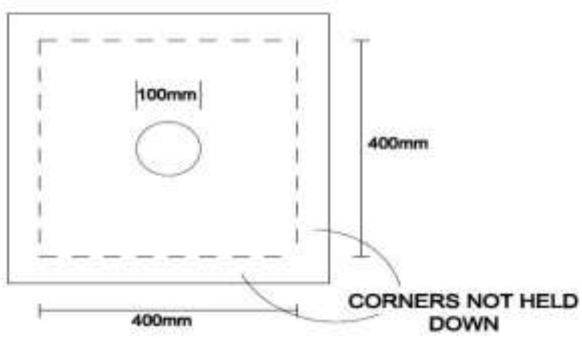

Figure 3.8.3: Top view of the Experimental setup

IV. RESULTS AND DISCUSSIONS

4.1 General:

This section can be classified into two categories:

i. The first section is about the Compressive test which is done to study the compressive strength i.e; f_{ck} and Split tensile test to study the tensile behavior due to presence of fibre.
ii. In the second section, the study is observed on the experimental behavior of the slab-column connection specimen.

4.2 Compressive Strength:

Compressive Strength of concrete mixes made with crimped fibers was determined at 28 days age. Two samples were tested for each percentage. It’s mean value is taken and compressive strength was found out. The test results are given table 4.2. The maximum compressive strength of cube was found when the crimped fibers were replaced at 30kg/m³.

Table 4.2: Compressive test for 28 days

Crimped fibers replaced	Compressive Strength of cubes N/mm² for 28 days			
	TRIAL I	TRIAL II	MEAN	COMPRESSIVE STRENGTH (N/mm²)
0 kg/m³	760	900	1660	37
15 kg/m³	960	920	940	41.8
30 kg/m³	980	1040	1010	44.89
45 kg/m³	960	1000	980	43.5

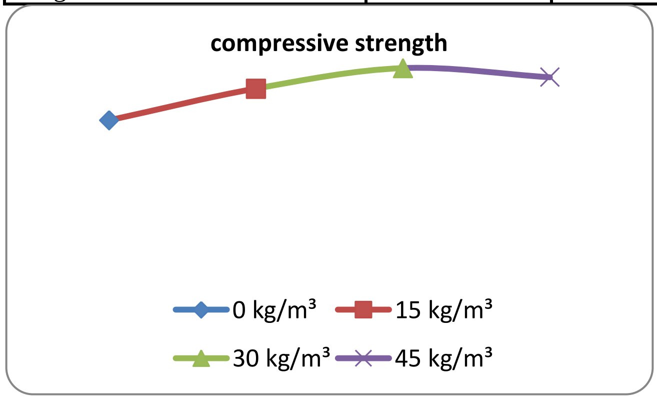

Figure 4.1: Compressive strength

From the graph it can be seen that the compressive strength of the cubes increases from 15 Kg/m³ to 30 Kg/³ there after it deceases on addition of more fibers i.e; 45 Kg/m³ due to honeycombing and presence of fibres. The Percentage increase from

0 Kg/m³ to 15 Kg/m³ is found to be 12.97%. Similarly 30Kg/m³ and 45 Kg/m³ the percentage increase was found to be 21.32% and 17.7%.

4.3 Split Tensile Strength:

Split Tensile Strength of concrete mixes made with crimped fibers was determined at 28 days age. The test results are given table 4.3. The maximum tensile strength of cylinder was found when the crimped fibers were replaced at 30kg/m³

Table 4.3: Split Tensile test for 28 days

SL No	Crimped fibers replaced	Split Tensile Strength of cylinders N/mm² for 28 days		
		TRIAL I	TRIAL II	MEAN
1	0 kg/m³	2.0	2.2	2.1
2	15 kg/m³	2.3	2.7	2.5
3	30 kg/m³	3.0	2.8	2.9
4	45 kg/m³	2.8	2.5	2.65

From the graph it can be seen that the split tensile strength of the cylinders increases from 15 Kg/m³ to 30 Kg/³ there after it deceases on addition of more fibers i.e; 45 Kg/m³. The Percentage increase from 0 Kg/m³ to 15 Kg/m³ is found to be 19%. Similarly 30Kg/m³ and 45 Kg/m³ the percentage increase was found to be 38.1% and 26.2%.

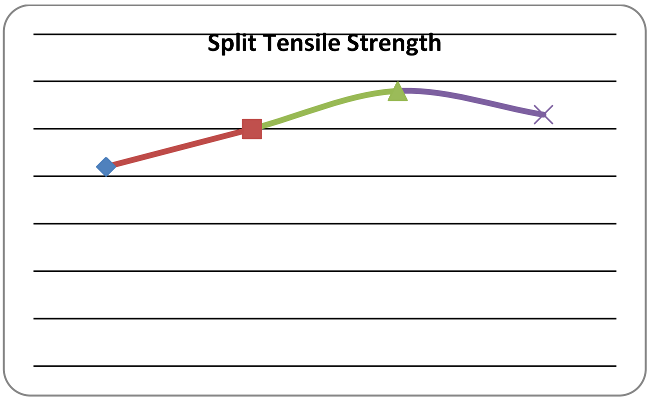

Figure 4.3: Split Tensile strength

4.4 Punching Shear:

All the models underwent punching type of failure with their inherent brittle characteristics and failed in a punching shear mode. The cracking pattern of the top surface of all the slabs were very much localized as shown in Figure 4.4.1. The cracking patterns at the bottom surface of slabs were more. A typical crack pattern after failure on the bottom surface of slab model is shown in Figure 4.4.1.

Figure 4.4.1: Typical cracking pattern on the BOTTOM surface of the model slab, cracking pattern on the top Surface of the slab

(a) Bottom surface (b) Bottom surface (b) Bottom surface

(c) Top surface (d) Bottom surface

Figure 4.4.2: Typical cracking pattern on the top and bottom Surface of slab samples of different fiber ratios.

4.4.1 Deflection:

The slab when tested on a universal testing machine Loads in Kg's and Deflection in mm were noted. Graph was plotted between load and deflection and following graphs were obtained as shown below.

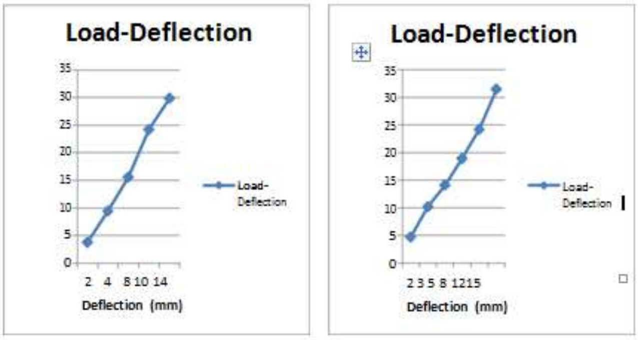

Figure 4.4.1(a): Load-Deflection curve with 0 Kg/m³ crimped fiber of sample i and ii.

The above graph represents a load-deflection curve having 0kg/m³ of fiber content. This graph shows the increase in the deflection due to increase in load. The maximum deflection was found upto 14mm at a failure load of 30kN.

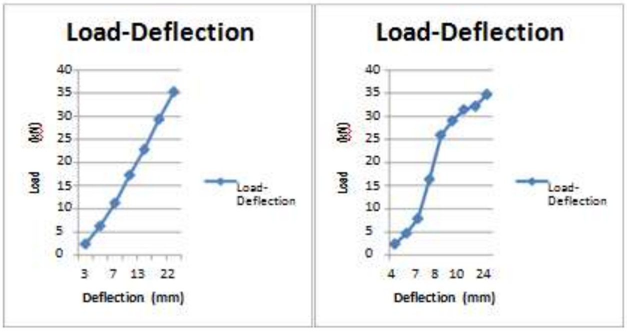

Figure 4.4.1(b): Load-Deflection curve with 15 Kg/m³ crimped fiber of sample iii and iv.

The above graph represents a load-deflection curve having 15kg/m³ of fiber content. This graph shows the increase in the deflection due to increase in load. The maximum deflection was found upto 24mm at a failure load of 34.85kN. .

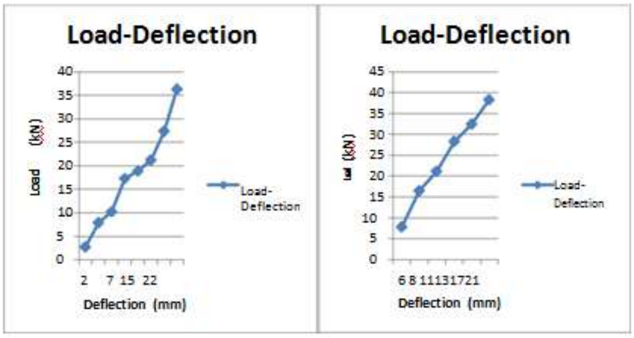

Figure 4.4.1(c): Load-Deflection curve with 30 Kg/m³ crimped fiber of sample v and vi.

The above graph represents a load-deflection curve having 30kg/m³ of fiber content. This graph shows the increase in the deflection due to increase in load. The maximum deflection was found upto 24mm at a failure load of 35.86kN.

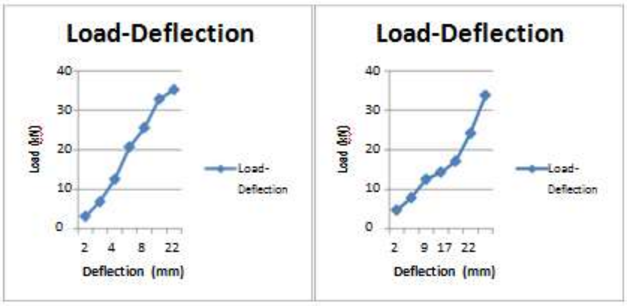

Figure 4.4.1(d): Load-Deflection curve with 45 Kg/m³ crimped fiber of sample vii and viii.

The above graph represents a load-deflection curve having 45kg/m³ of fiber content. This graph shows the increase in the deflection due to increase in load. The maximum deflection was found upto 22mm at a failure load of 33.94 kN.

From Fig. 4.4.1(a) to 4.4.1(d) it can be found that the specimen shows more deflection with increase in the fiber content. This is evident from the deflection of slab.

4.4.2 Shear Stress:

Specimens are tested for punching shear till failure and the Punching force causing failure is noted down.

Table 4.4.2.1: Punching Force causing failure.

Fibre content (Kg/m³)	Sample	Punching Force causing failure (kN)
0	i	29.74
	ii	30.88
15	iii	33.72
	iv	34.85
30	v	37.22
	vi	35.86

45	vii	33.84
	viii	33.94

The Percentage Increase in the Punching Stress by comparing it with avg. experimental value of 0% crimped fibre. Punching stress increases from 0kg/m³ to 30 kg/m³ and then decreases on 45 kg/m³ compared to 30 kg/m³ due to honeycombing and due to presence of fibres it decreases in workability.

Table 4.4.2.2: Percentage increase in Punching stress

Punching Stress	Experimental values (N/mm^2)	Percentage Increase in Exp values (%)
τ0	**70.7*4*75** = 1.42	13.4 -
τ15	**70.7*4*75** = 1.61	
τ30	**70.7*4*75** = 1.72	21.1
τ45	**70.7*4*75** = 1.60	12.7

Test were conducted on slab to study the Punching shear strength of slabs. IS code 456:**0.25**√ 2000recommends from Clause 31.6.3.1 that theoretical value of shear stress shall be τ_c = in limit state method of design.

Table 4.4.2.3: Comparison of Experimental and Theoretical values of Punching stress.

Punching Stress	Experimental values (N/mm^2)	Theoretical values as per IS code (N/mm^2)
τ_0	**70.7*4*75** = 1.42	1.37
τ15	**70.7*4*75** = 1.61	1.37
τ30	**70.7*4*75** = 1.72	1.37
τ45	**70.7*4*75** = 1.60	1.37

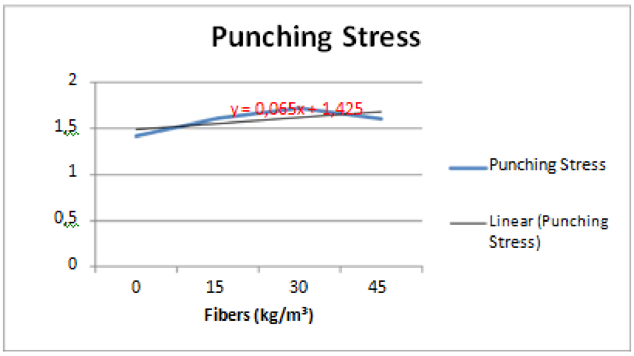

Figure 4.2.2: Punching stress

Punching stress was plotted against fiber content. Fig.4.4.2 shows the variation of Punching stress with increase in the fiber content. Punching stress of 0Kg/m^3 of fibers was found to be 1.42 N/mm^2. Similarly Punching stress of 15 Kg/m^3, 30 Kg/m^3 and 45 Kg/m^3 of fibers was found to be 1.61 N/mm^2, 1.72 N/mm^2 and 1.60 N/mm^2.

The Percentage increase in the Punching stress by adding 15 Kg/m^3 of fiber content and comparing it with conventional mix i.e; 0 Kg/m^3 was found to be 13.4%. Similarly for 30 Kg/m^3 of fiber content the increase was found to be21.1% and for adding fiber content to 45 Kg/m^3 there was a increase in Punching stress but the increase was not much and was found to be 12.7%.

V. SUMMARY AND CONCLUSIONS

5.1 Summary

There is a need for alternative construction material to give strength to the concrete and increase it's punching shear capacity. Hence, we are adding crimped steel fibers in the concrete mix to increase impact, shatter and abrasion resistance of concrete and reduces segregation, plastic settlement, and shrinkage cracking of concrete. One of the main drawbacks of concrete is the lack of tension. Here, we have seen the effect of crimped steel fibers in concrete and have seen how fibers enhance the strength at various dosages. Moreover we are adding GGBS which not only increases the compressive strength but also reduces the cement content which eventually leads to the decrease in emission of CO_2. and Nano silica improves the strength and permeability of concrete by filling up the minute voids and pores in the microstructure.

5.2 Conclusions

- The addition of crimped steel fiber has enhanced the Punching shear carrying capacity of concrete. This enhancement in Punching shear capacity was found to increase with increase in percentage of fiber. For fiber content 15kg/m^3 this increase is 13.4%, for 30kg/m^3 of fiber content, percentage increase was found to be 21.1% and for fiber content of 45kg/m^3 the increase was found to be 12.7%.

- The maximum percentage of increase was 21.1% at 30kg/m^3 of fiber content.

- From the limited study, based upon the experimental work done a linear equation was fitted by carrying out regression analysis to determine the strength at any percentage replacement of cement by crimped fiber for the following 4 mix cases carried out in the thesis work.

"$f_p = 0.065x + 1.425$"

Here the x terms represent variation in fiber content and the constant term 1.425 represents the inherent concrete strength.

5.3 Limitations of present study

- The study is carried out on four fibre percentage variations because after that the Punching stress as well as strength decreases due to honeycombing due to addition of more fibres.
- The work is carried with fibres of 35mm length and 0.5mm ø with an aspect ratio of 70.
- The study is carried by keeping Nano silica and GGBS constant at 2 % and 20% studied from previous literature.

5.4 Scope for further work

There is a scope to continue with similar work to increase the Punching behavior of slabs. Hence further, more diverse work to reduce the tendency of tensile cracks and to enhance the Punching shear strength using different types of fibers, their aspect ratios needs to be done and it should be compared to ordinary concrete.

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