Replacement of Reinforcement in Slabs Using Steel Fibres

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Abstract – To determine the compression, split tensile, & flexure strength of conventional concrete (M25) & steel FRC. To find the behaviour of RCC slab, SFRC slab, Mattock plastic hinge length (50mm at centre) slab and Priestley and Park plastic hinge length (100mm at centre) slab under one point loading test Strength characteristics are compared. Twelve numbers of cubes, cylinders and beams of size (0.15x0.15 m), (0.3 m length & 0.15 m ᶲ) and (0.5x0.1x0.1 m) respectively were casted to carry out load test. Eight slabs of span .810X.400m and the depth of slab as 0.60 m (according to IS 456:2000 cl.23.2.1) were casted to conduct point loading. The compressive strength, tensile strength, & flexural strength of concrete can be determined. The better performance of slabs with minimum reinforcement and various combinations of steel fibers under point loading can be arrived. The steel fiber will reduce the usage of steel rods in concrete slab. ii. Steel fibers are used for reduction of cost when compare to the usage of steel rods in the slab. iii. When steel fiber as reinforcement used, is easy to precast instead of steel rods as reinforcement.

Index Terms – Fibres, Reinforcement, Compression.

1. INTRODUCTION

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily moulded into shape. It is most widely used construction material in the world due to its ability to get cast in any form and shape. It also replaces old construction materials such as brick and stone masonry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cemetitious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suitable for a wide range of applications. In general usage, concrete plants come in two main types, ready mix plants and central mix plants. A ready mix plant mixes all the ingredients except water, while a central mix plant mixes all the ingredients including water. A central mix plant offers more accurate control of the concrete Quality through better measurements of the amount of water added, but must be placed closer to the work site where the concrete will be used, since hydration begins at the plant. With the advancement of technology and increased field application of concrete and mortars the strength, workability, durability and other characteristics of the ordinary concrete is continually undergoing modifications to make it stronger.

1.1. Reinforced Cement Concrete

Reinforced cement concrete is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength and/or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars (rebar) and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure. Small changes in the design of a floor system can have significant impact on material costs, construction schedule, and ultimate strength, operating costs, occupancy levels and end use of a building. structural response of reinforced concrete when subjected to different types of forces (such as axial, compression, flexure, shear and torsion), depends on structure. In order to properly understand the structural behaviour of reinforced concrete members, an appreciation of the mechanical behaviour of concrete and the reinforcement necessary.

1.2. Steel Fiber Reinforced Concrete

Fibre-reinforced concrete is concrete containing fibrous material which increases its structural integrity. The fibres help to transfer loads at the internal micro cracks. Such a concrete is called fibre-reinforced concrete (FRC), the FRC in which Steel fibres are used is called Steel fibre-reinforced concrete (SFRC). The one of the important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fibre composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibres are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fibre composite pronounced post – cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied, shock or impact loading.

1.3. Plastic hinge

In the structural engineering beam theory term, plastic hinge is used to describe the deformation of a section of a beam where plastic bending occurs. In earthquake engineering plastic hinge is also a type of energy damping device allowing plastic rotation [deformation] of an otherwise rigid column connection. A plastic hinge is a zone of yielding due to flexure in a structural member. Member behaviour between Myp and Mp is considered to be elastic. When Mp is reached, a plastic hinge is formed in the member. In contrast to hinge permitting free rotation, it is postulated that the plastic hinge allows large rotations to occur at constant plastic moment Mp. By inserting a plastic hinge at a plastic limit load into a statically determinate beam, a kinematic mechanism permitting an unbounded displacement of the system can be formed. It is known as the collapse mechanism. For each degree of static indeterminacy of the beam, an additional plastic hinge must be added to form a collapse mechanism.

2. RELATED WORK

Bernardo Moraes Neto (2013), states that the aim of contributing for the development of design guidelines capable of predicting with high accuracy the punching resistance of steel fibre reinforced concrete (SFRC) flat slabs, a proposal is presented in the present paper and its predictive performance is assessed by using a database that collects the experimental results from 154 punching tests. The theoretical fundaments of this proposal are based on the critical shear crack theory proposed by Muttoni and his co-authors. The proposal is capable of predicting the load versus rotation of the slab, and attends to the punching failure criterion of the slab. The proposal takes into account the recommendations of the most recent CEB-FIP Model Code for modelling the post-cracking behaviour of SFRC. In recent years the use of steel fibres to increase of the punching resistance, and mainly, to convert brittle punching failure mode into ductile flexural failure mode of reinforced concrete (RC) flat slabs has been explored. In fact, available research showed that, if proper mix compositions of steel fibre reinforced concrete (SFRC) are used, steel fibres can be suitable shear reinforcement for RC flat slabs, by improving the load carrying capacity and the energy absorption performance of the column–slab connection. These benefits are derived from the fibre reinforcement mechanisms provided by fibres bridging the micro-cracks that arrest the crack propagation, favouring the occurrence of large number of cracks of small width.

Nguyen-Minh, et al (2013), states that the behavior and capacity of steel fiber reinforced concrete (SFRC) flat slabs under punching shear force. A total of twelve small-scale flat slabs of different dimensions that consisted of nine SFRC and three control steel reinforced concrete (SRC) ones were tested. Effect of steel fibers amount on punching shear cracking behavior and resistance of the slabs was investigated. The results show a significant increase of the punching shear capacity and considerable improvement of cracking behavior as well as good integrity of column-slab connection of the slabs with fibers. The slabs without fibers failed suddenly in very brittle manner, while, the fiber reinforced ones collapsed in more ductile type. The paper presents an experimental study of effect of steel fibers on the punching shear resistance and cracking behavior of SFRC slabs, in which, a total of twelve small-scale flat slabs of different dimensions was tested. Moreover, the paper provides evaluation of accuracy of existing formulas used to predict the punching shear capacity of SFCR flat slabs based on data of the authors and other researchers.

Julien Michels (2012), investigated that the bearing behaviour of concrete flat slabs with steel fibres as only reinforcement. In a first step, experimental investigation on large-scale plates with symmetrical loading around the column is presented. The results show an absence of punching shear failure and give information on fibre distribution and orientation in steel fibre reinforced concrete (SFRC) elements with growing thickness. In general, a decreasing fibre orientation with an increasing plate height can be noticed. Adding steel fibers transforms the quasi-brittle concrete into a ductile material. Whereas in this case the maximal tensile strength is hardly enhanced , the fiber-knitting through the crack allows stress transfer even at large crack openings. It is shown that for one specific fiber type, higher fiber dosage involves higher residual flexural strength. The presence of a fiber reinforcement involved a lower ultimate compressive strength compared to the unreinforced specimens. However, ultimate strain increased with growing fiber content. In general, workability of the conglomerate represents an upper limit for fiber dosages.

Anant Pande, et al (2012), presents the Critical investigation for M-40 grade of concrete having mix proportion 1:1.43:3.04 with water cement ratio 0.35 to study the compressive strength, flexural strength, and Split tensile strength of steel fibre reinforced concrete (SFRC) containing fibres of 0%, 1%, 2% and 3% volume fraction of hook tain. Steel fibres of 50, 60 and 67 aspect ratio were used. A result data obtained has been analysed and compared with a control specimen (0% fibre). A relationship between aspect ratio vs. Compressive strength, aspect ratio vs. flexural strength, aspect ratio vs. Split tensile strength represented graphically. Result data clearly shows percentage increase in 28 days Compressive strength, Flexural strength and Split Tensile strength for M-40 Grade of Concrete. The compressive strength, Flexural Strength and split tensile strength of steel fibre reinforced concrete is probably increases with the increase in the percentage of the steel fibre about aspect ratio (l/d) of 50.

Vikrant, et al (2012) investigated the Fibre reinforced concrete has been successfully used in slabs on grade, shotcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. The usefulness of fibre reinforced concrete in various Civil Engineering applications is thus indisputable. This review study is a trial of giving some highlights for inclusion of steel fibres especially in terms of using them with new types of concrete. The study on the introduction of effect of steel fibres can be still promising as steel fibre reinforced concrete is used for sustainable and long-lasting concrete structures. Steel fibres are widely used as a fibre reinforced concrete all over the world. The results shown the increase in strength of 6% to 17% compressive strength, 18% to 47% split tensile strength, 22% to 63% flexural strength and 8% to 25% modulus of elasticity respectively.

Volkan Tabak, et al (2012), investigated that the, effects of aspect ratio (l/d) and volume fraction (V) of steel fibre on the compressive strength, split tensile strength, flexural strength and ultrasonic pulse velocity of steel fibre reinforced concrete (SFRC) were investigated. For this purpose, hooked-end bundled steel fibres with three different l/d ratios of 45, 65 and 80 were used. Three different fiber volumes were added to concrete mixes at 0.5%, 1.0% and 1.5% by volume of concrete. Ten different concrete mixes were prepared. After 28 days of curing, compressive, split and flexural strength as well as ultrasonic pulse velocity were determined. It was found that, inclusion of steel fibers significantly affect the split tensile and flexural strength of concrete accordance with l/d ratio and Vf. Besides, mathematical expressions were developed to estimate the compressive, flexural and split tensile strength of SFRCs regarding l/d ratio and Vf of steel fibers.

3. METHODOLOGY

The flow chart for methodology is shown in Fig. 1

3.1. Materials

i. Cement

The cement used should confirm to IS specifications. There are several types of cements are available commercially in the market of which Portland cement is the most known and available everywhere. PPC 53 grade was used for this study. The physical properties of cement are listed below in Table 1.

S.No.	**Characteristics**	**Experimental Value**
1	Standard consistency	33%
2	Initial setting time	30min
3	Specific gravity	3.04
4	Fineness modulus	3

Table 1 Physical properties of cement

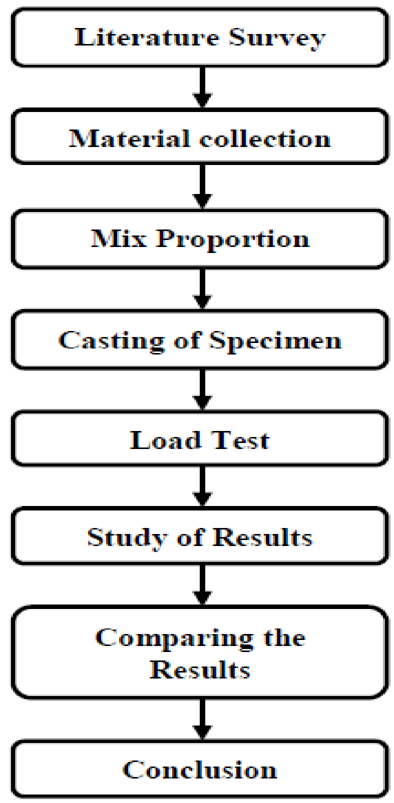

Fig. 1 Methodology Flow Chart

ii. Fine aggregate

Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS383-1970 is used. The sieve analysis results are shown in Table 2 Weight of aggregate taken = 1000 grams.

S.No	Characteristics	Experimental value
1	Fineness modulus	2.83
2	Specific gravity	2.51
3	Zone of fine aggregate	Zone II

Table 2 Physical properties of fine aggregate

iii. Coarse Aggregate

Coarse aggregates to be used for production of concrete must be strong, impermeable, durable & capable of producing a sufficient workable mix with minimum water cement ratio to achieve proper strength. Locally available coarse aggregate (basalt commonly known as blue metal) retaining on 4.75mm sieve is used. The physical properties of coarse aggregate are listed below in Table 3.

S.No	Characteristics	Value of obtained experimentally
1	Specific gravity	2.78
2	Nominal size of aggregate	20mm

Table 3 Physical properties of coarse aggregate

iv. Steel Fibre

Steel fiber with hooked ends is made using high-quality low-carbon steel wire. A kind of high-performance steel fiber, with the characteristics of the high tensile strength, good toughness, low prices, etc. The product is widely used in concrete strengthening.

S. No	DD Characteristics	Properties
1	Sp.gravity	7.8
2	Type	Hooked end
3	Length	50 mm
4	Diameter	1 mm
5	Aspect ratio	50

Table 4 Physical properties of steel fiber

v. Water

The quality of mixing water for concrete has a visual effect on the resulting hardened concrete. Impurities in water may interfere with setting of cement & will adversely affect the strength and durability of concrete with steel slag. Fresh and clean water which is free from organic matter, silt, oil, and acid material as per standards is used for casting and curing the specimen. Usually water that is piped from the public supplies is regarded as satisfactory.

4. EXPERIMENTAL WORK

The mechanical properties of cubes, cylinders and beams such as compression test, split tensile test and flexure test respectively was carried out for conventional concrete and steel fibre reinforced concrete. The test results are then compared.

4.1. Compression test

1. Concrete is primarily meant to withstand compressive stresses.
2. Cubes, cylinders and prisms are the three types of compression test specimens used to determine the compressive strength.
3. Cubes of size 150 × 150 × 150 mm are used in the present work.
4. The specimens are casted as follows
5. The mould is applied with oil for lubrication.
6. Concrete is laid in the mould in a layer up to some height and compacted with tamping rod for conventional concrete.
7. For every one layer, 25 tamping was done.
8. In this way, the concrete is laid in three layers and the procedure is repeated..
9. The next step is vibration on a vibrating machine.
10. The above procedure is the same for all the mixes with different percentage of admixture replacement and without vibration.
11. The cubes are cured for 7, 14 and 28 days.

4.2. Split Tensile Test

1. This is to determine the tensile strength of concrete.
2. Cylinders are the test specimens used to determine the tensile strength.
3. Cylinders of size 150 mm diameters and length 300 mm are used in the present work.
4. The specimens are casted as follows
5. The mould is applied with oil for lubrication.
6. Concrete is laid in the mould in a 3 layer up to some height and compacted with tamping rod.
7. In this way, the concrete is laid in layers and the procedure is repeated.
8. The next step is vibration on a vibrating machine.
9. The cylinders are cured for 7, 14 and 28 days.

4.3. Flexure Test

1. This is mainly to determine the flexure strength of the concrete.
2. Prisms are the test specimens used to determine the flexure strength.
3. Prisms of size 500 × 100 × 100 mm are used in the present work.
4. The specimens are casted as follows
5. The mould is applied with oil for lubrication.
6. Concrete is laid in the mould in a layer up to some height and compacted with tamping rod for both conventional concrete and SFRC concrete.

7. In this way, the concrete is laid in three layers and the procedure is repeated.
8. The next step is vibration on a vibrating machine.
9. The beams are cured for 7, 14 and 28 days.
10. After 7, 14 and 28 days of curing, the beams are tested in a Compression Testing Machine (CTM).

4.4. One Point Load on Slabs

1. This is mainly to determine the ultimate load and deflection of the slab.
2. Slabs of size 810 × 400 mm are used in the present work. The specimens are casted as follows
3. The wooden mould is applied with oil for lubrication.
4. Concrete is laid in the mould in a layer up to some height and compacted with tamping rod.
5. In this way, the concrete is laid in three layers and the procedure is repeated.
6. The next step is vibration on a vibrating machine.
7. The slabs are cured for 28 days.
8. After 28 days of curing, the slabs are tested in a loading frame.

5. RESULTS AND DISCUSSION

The test was carried out and the results are obtained with the help of mechanical properties. The discussion was carried out about compressive strength, split tensile strength, flexure strength and load vs deflection of slabs.

5.1. Compressive Strength

Concrete Type	7 days Compressive strength (N/mm^2)	14 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
Conventional Concrete	18	24	27
Steel fibre	21	30.17	33.64
% Increase	16	25	26

Table 5 Compression Strength of concrete for 7, 14 and 28 days

The compressive strength of the concrete is shown in fig 1.In normal conventional concrete, the compressive strength is attain up to 18,24,27 N/mm^2 for 7,1. and 28 days respectively and in steel fibre reinforced concrete , the compressive strength attains up to 21,31.17,33.64N/mm^2 for 7,14 and 28 days respectively.

In 7, 14 and 28 days, the compressive strength of steel fibre reinforced concrete is increase up to 16, 25 and 26% respectively when compared to conventional concrete is shown in Table 5. The Fig. 5 shows comparitive difference between the compressive strength of CC and SFRC for 7, 14 and 28 days.

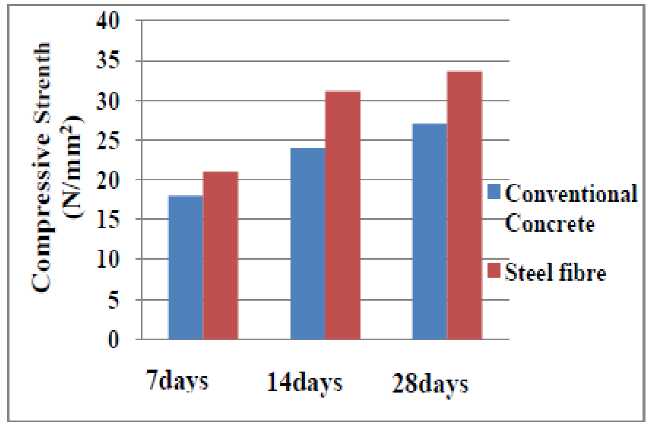

Fig. 2 Comparison between compressive strength of CC and SFRC for 7, 14 and 28 days

5.2. Split Tensile Strength

Concrete Type	7 days Tensile Strength N/mm^2	14 days Tensile strength (N/mm^2)	28 days Tensile strength (N/mm^2)
CC	2.24	2.42	3.08
Steel fibres	2.75	2.92	3.72
% Increase	21.66	22.75	22.77

Table 6 Split Tensile Strength of concrete for 7, 14 and 28 days

In normal conventional concrete, the split tensile strength is attain up to 2.24,2.62,3.08 N/mm^2 for 7,14 and 28 days respectively and in steel fibre reinforced concrete , the split tensile strength attains up to 2.75,2.92,3.22N/mm^2 for 7,14 and 28 days respectively.

In 7, 14 and 28 days, the compressive strength of steel fibre reinforced concrete increase up to 21.66, 22.75 and 22.77 % respectively when compared to conventional concrete shown in Table 6.

5.3. Flexure Strength

The Flexure strength of concrete for 7, 14 and 28 days are conducted and test results are shown in Table 7.

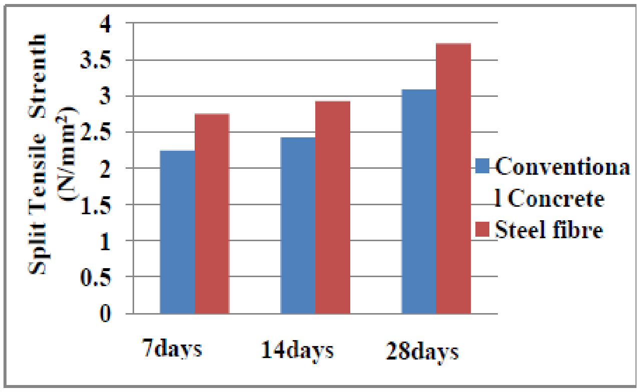

Fig. 3 comparison of split tensile strength of conventional concrete and steel fibre reinforced concrete for 7, 14 and 28 days

Concrete Type	7 days Flexure strength (N/mm^2)	14 days Flexure strength (N/mm^2)	28 days Flexure strength (N/mm^2)
CC	2.15	2.65	3.52
SFRC	3.15	4.15	5.25
% Increases	46.51	56.60	58.15

Table 7 Flexure strength of concrete for 7, 14 and 28 days

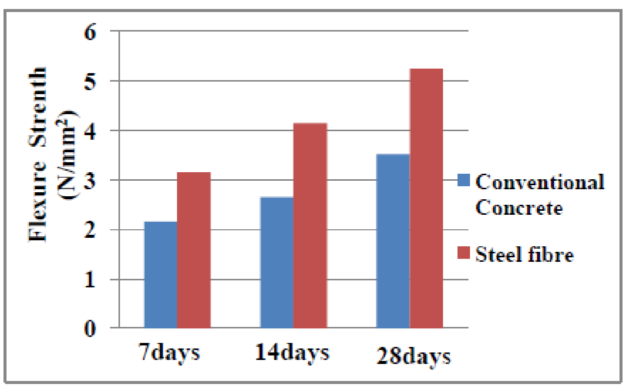

Fig. 4 comparison of flexure strength of conventional concrete and steel fibre reinforced concrete for 7, 14 and 28 days

In normal conventional concrete, the flexure strength is attain up to 2.15,2.65,3.52 N/mm^2 for 7,14 and 28 days respectively and in steel fibre reinforced concrete , the flexure strength attains up to 3.15,4.15,5.25N/mm^2 for 7,14 and 28 days respectively. In 7, 14 and 28 days, the compressive strength of steel fibre reinforced concrete increase up to 46.51, 56.60 and 58.15 % respectively when compared to conventional concrete shown in Table 7.

5.3. Ultimate Load and Deflection of Slab

	RCC Slab	SFRC Slab	Plastic Hinge Length (100mm)	Plastic Hinge Length (50mm)
Deflection (mm)	7.6	11	10.9	9.6
Load (kN)	44.14	53.95	51.50	46.59

Table 8 Ultimate load and deflection of slabs for 28 days

In RCC slabs, SFRC slabs, Mattock plastic hinge length (50mm) slabs, priestely and park plastic hinge length(100mm) slabs attains the ultimate load up to 44.14kN ,53.95kN, 51.50kN and 46.59kN respectively as shown in Table 8.

In RCC slab, SFRC slab, Mattock plastic hinge length (50mm) slab, Priestely and Park plastic hinge length (100mm) slab attains the deflection up to 7.6, 11, 10.9 and 9.6 respectively on one point loading as shown in Table 8.

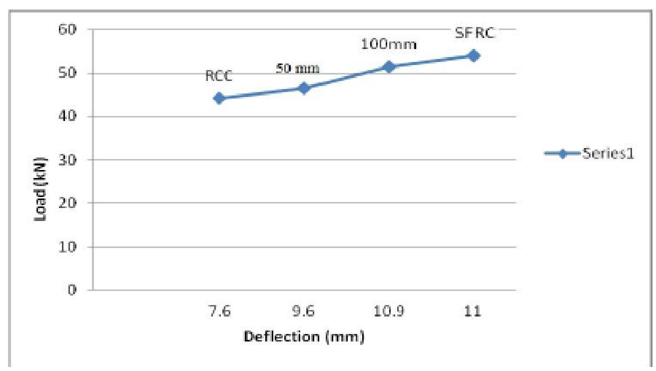

Fig. 5 Load vs. Deflection of slabs

6. CONCLUSION

As per IS 10262: 2009 and IS 456:2000, the concrete mix design was carried out for concrete grade M25. The Compressive strength of concrete increases up to 16, 25 and 26% for steel fiber reinforced concrete when compared to conventional concrete of 7, 14 and 28 days of curing in the ratio of 1.5% of the volume of M25 concrete. The split tensile strength of concrete increases up to 21.66, 22.75 and 22.77% for steel fiber reinforced concrete when compared to conventional concrete of 7, 14 and 28 days of curing in the ratio of 1.5% of the volume of M25 concrete. The flexure strength of concrete increases up to 46.51, 56.60 and 58.15% for steel fiber reinforced concrete when compared to conventional concrete of 7, 14 and 28 days of curing in the ratio of 1.5% of the volume of M25 concrete. In RCC slab, SFRC slabs, Mattock plastic hinge length (50mm)slab, priestly and park plastic hinge length(100mm) slab attains the ultimate load up to 44.14kN ,53.95kN, 51.50kN and 46.59kN respectively. In RCC slab, SFRC slab, Mattock plastic hinge length(100mm) slab, Priestely and Park plastic hinge length (50mm) slab attains the deflection up to 7.6, 11, 10.9 and 9.6 respectively on one point loading. From the comparison of results, the ultimate load and deflection of priestly and park plastic hinge length (100mm) is equal when compared to SFRC slab.

6.1. Future work

The different types of fibres can use in this project. The steel fibres can be use in beam plastic hinge length instead of slab plastic hinge length. This experiment can be analysis in Ansys.

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