A Comparative study of SFRC as a Structural element with Conventional concrete

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MASTER OF TECHNOLOGY

In

Structural Engineering

By

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LUCKNOW

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CERTIFICATE

Certified that Kaushal Kishor Rawat (1180444004) has carried out the research work presented in this Thesis entitled **"A Comparative study of SFRC as a Structural element with Conventional concrete"** for the award of **MASTER OF TECHNOLOGY** (Structural Engineering) from BABU BANARASI DAS UNIVERSITY, LUCKNOW under my supervision. The Thesis embodies results of original work, and studies are carried out by the student himself and the contents of the Thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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DECLARATION

I hereby declare that the Thesis entitled **"A Comparative study of SFRC as a Structural element with Conventional concrete"** in the partial fulfillment of the requirements for the award of the degree of Master of Technology (Structural Engineering) of **BABU BANARASI DAS UNIVERSITY**, is the record of the own work carried under the supervision and guidance of **Mr. SHUBHRANSHU JAISWAL** to the best of my knowledge this Thesis has not been submitted to **BABU BANARASI DAS UNIVERSITY** or any other University or Institute for the award of any degree.

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ABSTRACT

The purpose of this research work is to introduce the application of Steel Fibre Reinforced Concrete (SFRC) as a structural material in building structural load bearing elements like Columns and beams, for this purpose first the previous research work was referred that have been done to obtain various important mechanical properties of SFRC which helps us to understand its behavior as a structural element. After getting most appropriate properties obtained by experimental material testing on SFRC, the material was simulated using software approach. The software used in this analysis was ETABS 17.0.0. After modifying this SFRC material with Conventional M40 grade concrete, seismic analysis of G + 8 story RC frame building was performed and the results have definitely shown that SFRC building Model have performed better under seismic loading.

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Finally, I would like to dedicate this research work to my family and friends whose continuous love and support guided me through difficult times.

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CHAPTER 1

1. INTRODUCTION

Use of Fibre reinforced concrete as a Structural material is something not new, its use to some extent has been seen several times as an old technique, but as the time changes, its importance and applications have evolved. Studies have proved that the use of Fibre Reinforced Concrete changes the properties of concrete that make it more useful material to be used as a structural component in Structures. Use of Steel Fibre Reinforced Concrete(SFRC) is very prominent in the modern age as it is much cheaper, easier to use and experimental studies has shown it increases the strength of concrete to some extent.. Nowadays Steel Fibre Reinforced Concrete (SFRC) is widely used in the construction of many complex structures like industrial slabs, airfields, tunnels, elevated slabs, pedestrian bridges, roadways and many modular prefabricated buildings. The SFRC has many benefits in the modern construction practices but the only disadvantage is that it decreases the workability and increases the stiffness of fresh concrete. SFRC sometimes also used with certain admixtures like Fly Ash and silica fume, and shown a marginal increase in its workability as well with increasing the percentage of such admixtures. The performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete. It can be said that the addition of steel Fibres has an influence on the stressstrain relati onship in compression,and the level of critical stresses increases in conjunction with t he amount of steel Fibres added to the concrete mixture.

As the market for high-resistance concrete has risen, reinforced concrete's structural nature has become more brittle. To mitigate this side effect, steel fibre-reinforced concrete (SFRC) has emerged as a viable method for obtaining ductility not only during tensioned post-cracking behaviour, but also during compressed post-peak softening behaviour. Use of SFRC as a structural member has also found to increase its ductility to some extent that may be proved to be a better material under seismic loading as well. Steel fibre reinforced concrete (SFRC) has a distinctive tensile strength, impact resistance, resistance to fatigue, flexural resistance ductility and crack arrest capability. They also diminish concrete permeability and thus decrease water bleeding. It is, such building material is studied for over 40 years as well as for pavement construction. Many experimental research in past have been performed that aims to collect data on the effect of steel fibre and its combination on workability, compressive strength , flexural strength and non-destructive testing (NDT) such as Rebound Hammer, in order to assess SFRC efficiency relative to traditional concrete. There are many types of steel Fibre available in the market but majorly used types are: traditionally straight, hooked, crimped, coned, etc. In the present framework various mechanical properties of hooked end steel fibre is used for the modeling of SFRC.

Some previous research in this area has shown that the rise in the proportion of steel fibres in concrete subjected to the moment of hogging increases their compressive power. Also addition of Steel Fibres in concrete improves the resilience, ductility and durability of standard RC members under earthquake and blast loads (dynamic loads). In terms of minimizing the development of cracks in concrete by Adding SFs one can prevent crack growth and crack widening; this may allow the use of high-strength steel bars without undue crack width or duty load deformation. Spalling of concrete is seen many times due to excessive loading and low confinement, use of SRFC may reduce this problem to some extent by providing enhanced impact resistance to traditional RC members, enhancing local damage and spreading resistance.

One of the unwelcoming features of concrete as a porous material is its low tensile strength and pressure capacity. Hence, reinforcement is needed to be used as the most widely used building material. Conventionally, this reinforcement takes the form of continuous steel bars placed in the concrete framework at the required places to withstand the tensile and shear stresses applied. At the other hand, fibers are typically small, discontinuous and uniformly scattered around the concrete portion to produce a composite building material known as fibre-reinforced concrete (FRC).

Fibers used in cement-based composites are mainly constructed of or derived from natural steel, glass, and synthetic materials. Fibers can monitor splitting more effectively than conventional reinforced steel bars because of their ability to be spaced tightly. It should be noted that fiber is not a substitute for traditional steel plates used as concrete reinforcement. Fibers and steel bars have different roles to play in advanced concrete technology and there are a lot of applications where both fibers and continuous steel reinforcing bars should be used.

Steel fiber (SF) is the most popular type of fibre used as concrete reinforcement. Initially SFs are used to avoid / monitor plastics shrinking and concrete drying. Further research and development has revealed that adding SFs to concrete significantly increases its flexural toughness, capacity for energy absorption, ductile behavior before ultimate failure, reduces cracking and improves durability.

1.1 Different Types of Fiberes

There are two pathways by which fibers can be graded according to their modulus or origins of elasticity. From the point of view of the elasticity module, fibers can be classified into two basic classes, namely those with a higher elastic module than concrete mixes (called harsh intrusion) and those with lower elastic modules than concrete mixtures (called gentle intrusion). Stone, carbon, and glass have higher elastic modules than cement mortar matrix and are known as polypropylene and vegetable fibers. Around the same time , high elastic modulus fibers can improve flexural and impact resistance; while low elastic modulus fibers can enhance concrete impact resistance but do not contribute substantially to flexural resistance.

These are classified into three types: metallic fibers (such as steel , carbon steel, and stainless steel), mineral fibers (such as asbestos and glass fibers), and synthetic fibers, depending on the source: fibres. Organic fibers can be further broken down into natural and man-made fibres. Organic fibers may be categorized as plants or sisals (e.g. wood fibers and leaf fibers) and animals (e.g. hair fibers and silk); man-made fibers can also be graded as organic polymers (e.g. cellulose and protein fibers) and synthetic fibers (e.g. nylon and polypropylene) into two categories. Figure 1.1 shows the detailed description.

1.2 Types of Steel Fibres:

Steel fibre is a commodity of industrial application. Steel fiber for reinforced concrete is classified as thin, distinct lengths of steel fibers with an aspect ratio (length to diameter ratio) of about 20 to 100, with different cross-sections and small enough to disperse freely in an unhardened concrete mixture using the normal mixing methods. There are two methods by which Fibres can be classified according to their elasticity modulus or roots. From the point of view of the elasticity module, fibers can be classified into two basic categories, namely those with a higher elastic module than concrete mixes (called hard intrusion) and those with lower elastic modules than concrete mixtures (called soft intrusion). On the basis of formation Steel Fibres can be categorized as a cold drawn wire Fibre with corrugated and flatted shape.

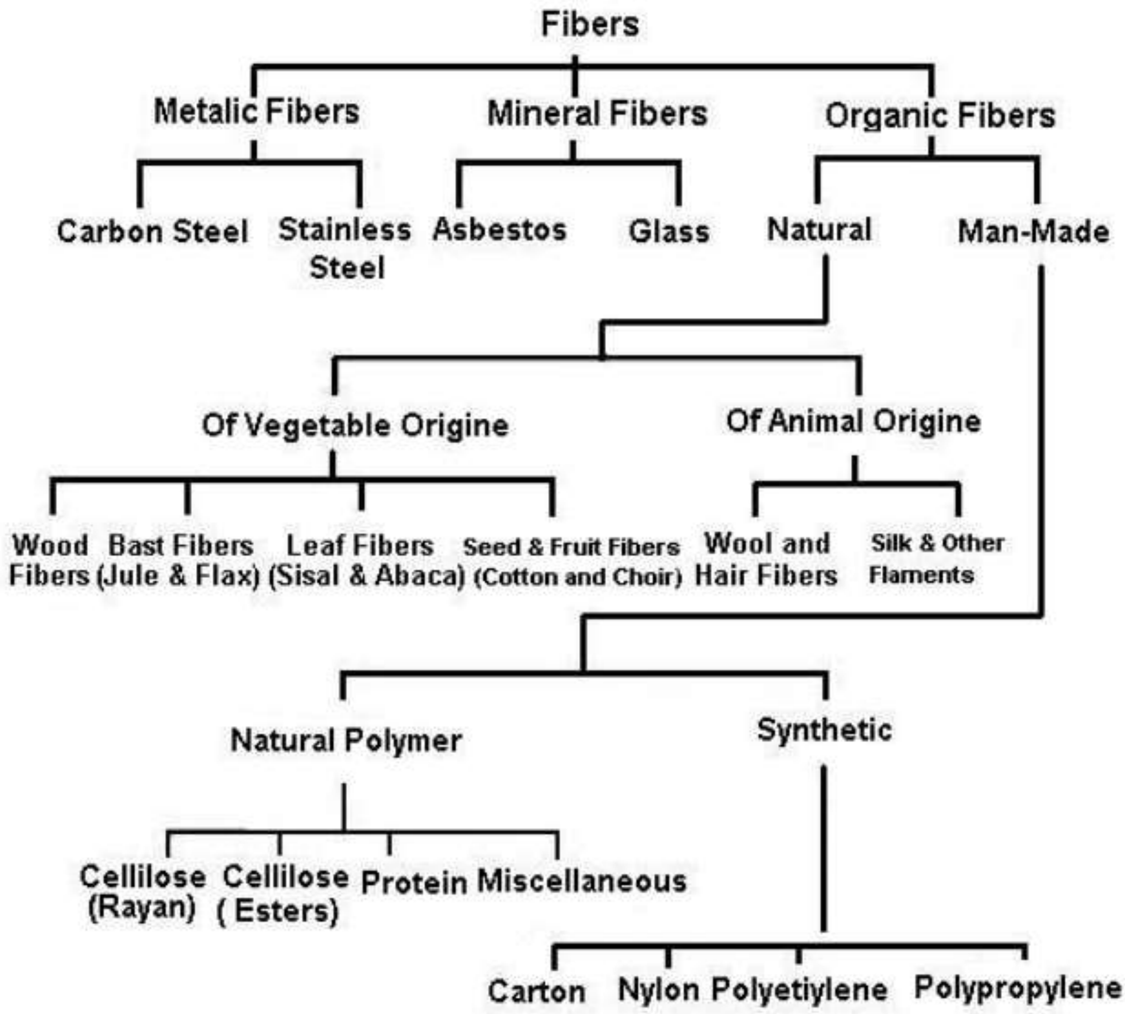


Figure 1.1- Classification of Fibres

The five most popular steel Fibre types are: traditionally straight, hooked, crimped, coned, and deformed mechanically. The geometries of the described non-straight fibres is shown in Figure 1.2.1, 1.2.2 and 1.2.3.

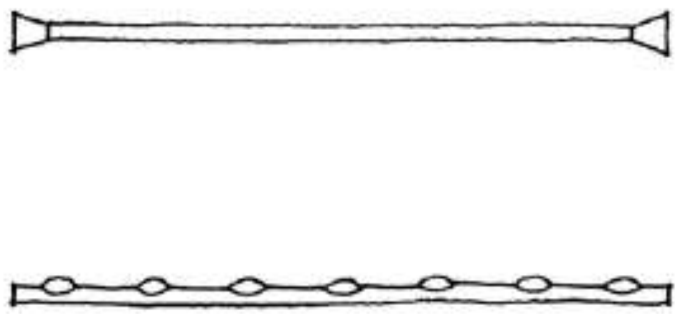


Figure 1.2.1- Coned and Mechanically Deformed Steel Fibres

Figure 1.2.2- Flatted shape Steel Fibre with Hook

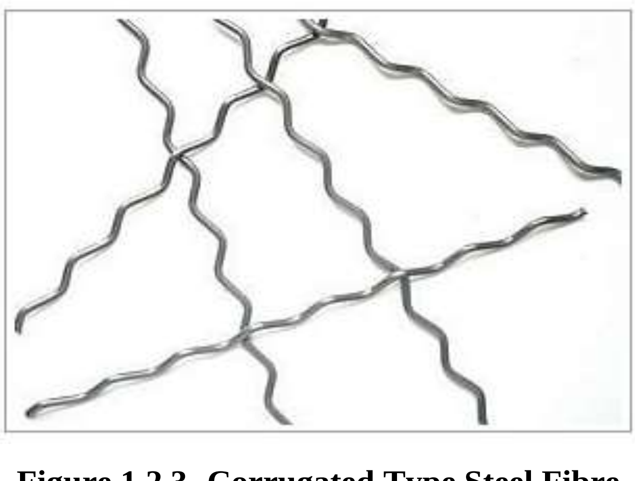


Figure 1.2.3- Corrugated Type Steel Fibre

Figure 1.2.3- Concrete with Steel Fibres

Action of SFRC 's can be categorized into three categories depending on its fiber volume percentage, use, and fiber effectiveness; for example, SFRC is graded as follows on the basis of its fiber volume percentage:

1- Really low quantity fraction of SF (less than 1 percent per concrete ton), used for several years to control plastic shrinkage and to stabilize the pavement.
2- Moderate volume fraction of SFs (1% to 2% per concrete volume) capable of enhancing rupture module (MOR), flexural strength, impact tolerance and other appealing mechanical properties of concrete.
3- High volume percentage of SFs (more than 2 per cent of the concrete volume) used in special applications such as impact and blast resistant structures.

1.3 Properties of Steel Fibre Reinforced Concrete:

SFRCs crack-arrest and crack-control function has three significant effects on SFRC structure behavior.

1. Using SFs delays the onset of flexural cracking. The tensile strain can be raised as much as 100 per cent at the first crack and the final strain can be as high as 20 to 50 times that of standard concrete.
2. Adding SFs imparts the system a well-defined post-cracking behavior.
3. The crack-arrest property and the consequent increase in ductility give the

system a greater capacity to withstand energy (higher toughness) before collapse.

Elasticity module and Poisson 's ratio are the concrete 's main mechanical properties for assessing the flexural and shear stiffness of concrete elements. While steel fibers are beginning to be recognized in modern building codes, in these building codes, calculations for estimating the elasticity modulus and Poisson's Fiber Reinforced Concrete (FRC) ratio are not given. While the direct calculation of the elasticity modulus and the Poisson ratio is sufficiently defined, the use of non-destructive methods such as the Ultrasonic Pulse Velocity (UPV) test provides a cost-effective and simple alternative to explore.

1.3.1. Compressive Strength of SFRC

Ultra high strength concrete (UHSC) brittleness with poor tensile strength and strain capacities can be solved with the application of steel fibres. UHSC's compressive strength increased with steel Fibres applied at different volumes Faults. The strength showed a maximum fraction at 0.75% but a slight decrease at 1.0% and 1.5% fraction compared to 0.75 percent, which is still 10.6 percent higher than before the addition of Fibre.

In an experimental research performed by (Avinash Joshi , Pradeep reddy ,Punith kumar and Pramod hatker) in 2016 on SFRC, the variation of compressive strength for different grade of concretes for SFRC(0%, 0.5%, 1%, 1.5% steel Fibre reinforced concrete) is shown by the Tabular representation in table 1.3.1

Days of Curing	**Volume of Steel Fibres(%)**	**COMPRESSIVE STRENGTH(N/mm2)**			
		M20	**M25**	**M30**	**M40**
3days	0%	13.2	15.69	19.41	27.17
	0.50%	15.2	18.34	22.87	32.91
	1%	17.11	20.63	25.6	36.4

	1.50%	18.69	22.12	27.89	39.39
7days	0%	18.9	24.6	32.21	41.45
	0.50%	21.11	28.78	37.37	47.67
	1%	24.38	33.1	42.81	54.37
	1.50%	27.73	35.71	46.03	59.93
28days	0%	28.7	33.4	41.37	52.76
	0.50%	32.98	37.83	46.79	60.8
	1%	37.93	43.74	53.76	68.79
	1.50%	41.02	48.03	59.86	75.84

Table 1.3.1- Compressive strength of SFRC

By Johnston (1974), and Dixon and Mayfield (1971) It has been observed that adding up to 1.5% of SFs by volume raises the compressive power from 0 to 15%. A steady slope in the downward portion of the stress-strain curves shows SFRC's enhanced spreading tolerance, ductility and resilience as shown in Figure 1.3.1 (Padmarajaiah and Ramaswamy, 2002).

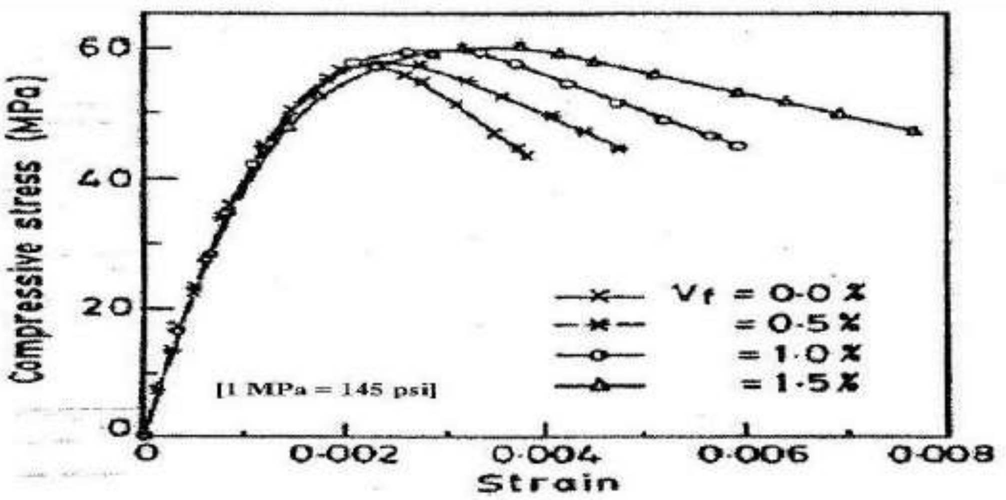


Figure 1.3.1- Stress-strain curves for SRFC

1.3.2 Tensile Strength of SFRC:

As per experimental study done by(ZHANG Ju, YAN Changwang, and JIA Jinqing) in 2010, the strength enhancing ultra high reinforced steel Fibre capacity Concrete strength (SFRC) containing 0.5%, 0.75%, 1.0% and 1.5% volume of hooked-end steel Fibres. Compared with the counterpart for plain ultra high-strength concrete (UHSC). Increase of SFRC compressive resistance. Compared to UHSC, 0.5 percent volume fractions, 0.75 percent, 1.0 percent, and 1.5 percent steel Fibre.

$$\text{Strength-effectiveness} = \frac{\text{SFRC strength - UHSC strength}}{\text{UHSC strength}} \times 100\%$$

Specimen	Fiber volume fraction V_f [%]	Compressive strength f_{cf}		Splitting tensile strength f_{tf}	
		Measured [MPa]	Strength-effectiveness* [%]	Measured [MPa]	Strength-effectiveness* [%]
UHSC	0.00	103.6	—	5.05	—
SFRC-0.50	0.50	115.4	11.4	6.98	38.2
SFRC-0.75	0.75	119.7	15.5	9.38	85.7
SFRC-1.00	1.00	116.3	12.3	9.49	87.9
SFRC-1.50	1.50	114.6	10.6	9.69	91.9

Table 1.3.2- Compressive strength and Split tensile strength of SFRC

In an experimental work performed by (Merve AÇIKGENÇ, Kürşat Esat ALYAMAÇ, Zülfü Çınar ULUCAN) in 2015 three hardened properties of SFRC were discussed. Table 2 gives these mechanical properties below. Each given properties are average values of at least three specimens. As seen in the table, mixtures are expressed with codes which consist of mix code and Vf. The mixture codes with R letter means reference mixtures which do not have any steel fibers. Table 1.3.3 also gives the toughness values of SFRC specimens. Since the toughness of SFRC is significantly higher than normal concrete without fibers.

V_f	Mix Code	Strength (MPa)			Toughness, T (Joule)
		Compressive, f_c	Splitting Tensile, f_{st}	Flexural, f_{ft}	
0%	R-M1	56.5	5.46	6.64	-
	R-M2	42.7	4.75	5.79	-
	R-M3	32.8	3.92	5.25	-
0.1%	M1-0.1	56.5	5.48	6.75	151
	M2-0.1	43.2	4.78	6.08	130
	M3-0.1	33.0	3.95	5.52	115
0.3%	M1-0.3	56.9	5.52	6.98	154
	M2-0.3	43.5	4.83	6.16	132
	M3-0.3	33.3	3.97	5.66	118
0.5%	M1-0.5	57.3	5.73	7.71	177
	M2-0.5	44.0	4.92	6.67	158
	M3-0.5	34.0	4.00	5.88	139
1%	M1-1	58.4	6.33	9.13	227
	M2-1	44.6	5.51	8.42	204
	M3-1	35.7	4.44	7.39	167

Table 1.3.3- Mechanical Properties of Specimens and Toughness of SFRC Specimens

1.3.3 Shear Strength:

Previous work has shown that addition of Steel Fibres significantly increases concrete's shear strength. In a research work done by Noghabai, K. (2000) The ultimate shear strength of SFRC which contains 1% by volume of Steel Fibres increases by up to 170% compared to RC without Steel Fibres. SFRC 's overall shear power comprising SFs improves by up to 170 per cent as opposed to RC without SFs.

1.4 Testing on SFRC:

The main objective of testing SFRC members is to investigate various important properties for the consumptive use of it. Various mechanical properties of SFRCs helps to understand its behavior as a structural element and limitations as well. Some of the important Tests performed for SFRC are as follows:

1.4.1 Ultrasonic pulse velocity test of SFRC:

This test is performed to evaluate the quality of concrete by method of ultrasonic pulse velocity as per IS: 13311 (Part 1)-1992.

The method consists of measuring the travel time of an ultrasonic pulse that goes through the concrete being tested. Comparatively higher velocity is obtained when the concrete consistency is strong in density, uniformity, homogeneity etc.

Figure: 1.4.1- Ultrasonic pulse velocity test

Ultrasonic pulse velocity test is a kind of non-destructive test method carried out, involving ultrasonic pulse velocity test applied to different SFRC mixtures. The theory of this test is that sound velocity in a solid material (V) is a function of the square root ratio of its Young's Modulus (E) to its density (ρ). The equation is as follows according to Polish standards:

$$E = V^2 . \rho$$

This relationship can be used to evaluate the elasticity modulus and thus as a means of testing the concrete consistency. The test is also useful for detecting voids, corrosion caused by frost or fire and uniformity of concrete in similar elements. The ordinary concrete's pulse velocity depends on the aggregate elasticity modulus and the aggregate content of the mix. Steel reinforcement is also well known to contribute to increased ultrasonic pulse velocity. Both of these drawbacks have led the ultrasonic pulse velocity test to be rarely used to determine the characteristics of reinforced concrete made from steel Fibre (SFRC).

1.4.2 Tri-axial loading Tests on SFRC:

The stress-strain relationships were obtained for the direct tension and flexure control tests and the typical stress-strain curves for the tri-axially tested specimens and shown in figure 1.4.1

1.4.3 Uniaxial Tension Test for SFRC:

Uniaxial strain research for SFRC was conducted and an experimental study (ALI AMIN, TOMISLAV MARKIN, AND WALTER KAUFMANN) was carried out to examine the pre- and post-cracking activity of a single SFRC blend through uniaxial stress experiments with differing boundary conditions (fixed-fixed (FF), rotating (RR), and fixed-rotating (FR) conditions). For through test setup four specimens were made. The steel fibers were 35 mm in length, 0.55 mm in diameter and 1340 MPa in absolute notional tensile force. The dose of Fiber used in this study was 60 kg / m3.

The concrete was supplied from a nearby mixing plant and shipped without the fibers used in this mixture to the laboratory. The defined concrete compressive strength was 40 MPa (the compressive resistance of the calculated cylinder concrete was 63 MPa at the time of the test), and the coarse aggregate used was basalt with a maximum particle size of 10 mm. The fibers were placed in the Stirrer at the location and blended to cast instances 10 minutes in advance. To assess the operability of the New SFRC, a standard decrease in Test was used, and the recession checked Find 200 mm in length. The test result shows that Concrete Elastic Deformations across the crack are low in contrast to the ripple opening; also the amounts of form-induced tensile stress are poor and may be heterogeneous, and the specimen 's ability to redistribute tension in the experiment.

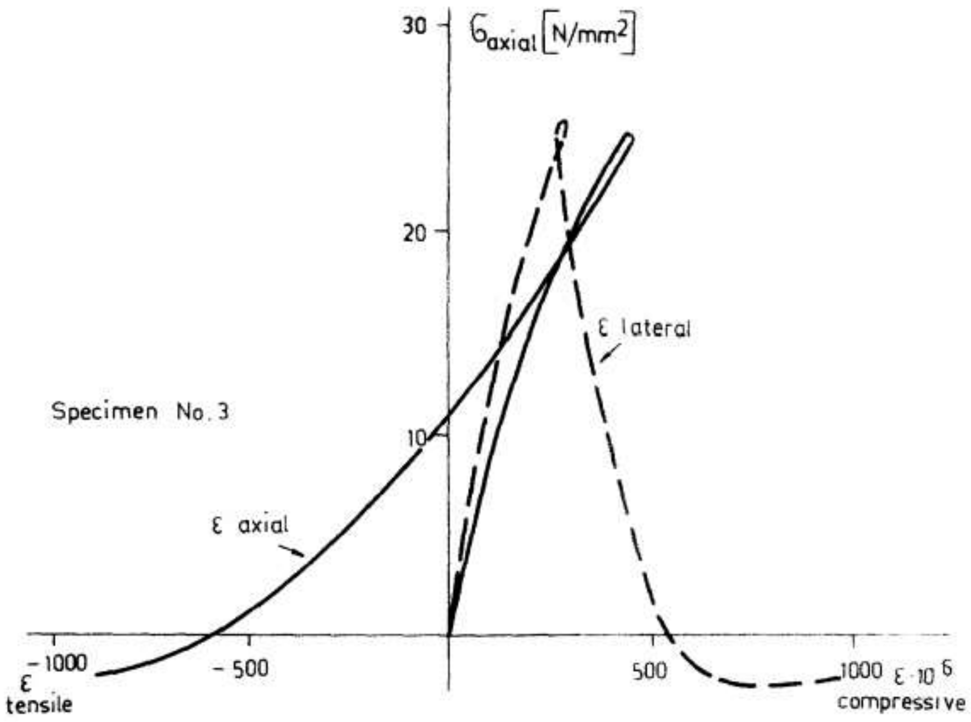


Figure 1.4.2- Stress-strain curves for the specimen in tri axial loading

1.4.4 Split Tensile Test:

One of the basic and essential properties is the tensile strength of concrete, which significantly influences the degree and size of cracking in structures. Nevertheless, because of its porous composition the concrete is very fragile under stress. Accordingly. Clear strain is not supposed to resist. Therefore, as tensile forces exceed its tensile strength, concrete develops cracks. Therefore, the tensile strength of concrete must be measured to determine the load at which the concrete members can crack.

Splitting tensile strength test on concrete cylinder is a technique for evaluating concrete tensile strength. The process is based on ASTM C496 (Standard Cylindrical Concrete Specimen Test Method) which is identical to other codes such as IS 5816 1999.

Figure: 1.4.3- Split Tensile Test

Figure: 1.4.4- Split Tensile Test for cylindrical concrete specimen

The addition of Fibres to concrete significantly improves its tensile strength and a good correlation exists between the strength of the splitting tensile and the volume fraction of the fibre, as well as between the strength of the splitting tensile and the index of Fibre strengthening. Splitting tensile strength and flexural resistance testing are preferred to evaluate SFRC tensile efficiency. The splitting test of tensile strength needs a standard cube or cylinder specimen while the flexural strength test requires a heavy beam specimen with larger dimensions provided by most norms. Hardened concrete experiments were carried out in water on 28 days of cured concrete specimens. According to the TS EN 12390-3 (2010) and the TS EN 12390-6 (2010) specifications, compressive and splitting tensile strength tests were evaluated for the investigation of mechanical properties. Additionally, in accordance with the TS 10515 (1992) standard, a 4-point flexural strength test was performed using 150 environ1505500 mm of beam specimens. Load-deflection data of the SFRC specimens were collected during flexural strength tests. The maximum flexural resistance of SFRC specimens was determined using peak load. Toughness values for maximum 5 mm midpoint displacement value of the beam specimens were taken into account as the area under the load-deflection curves. Figure 1.4.2 shows typical load-deflection curves of SFRC specimens. The toughness of SFRC is significantly higher than normal concrete without Fibres.

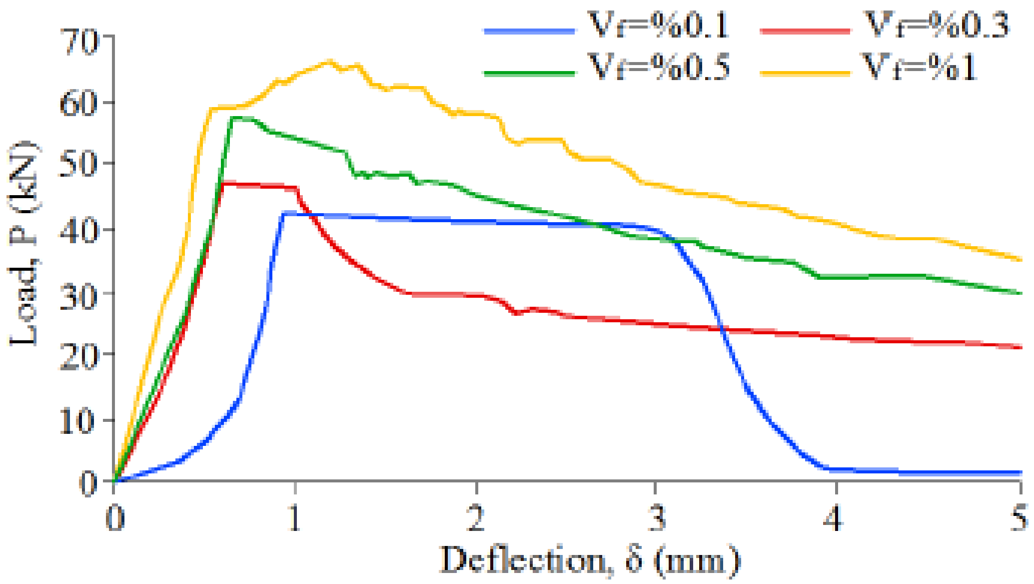


Figure 1.4.5- Load-deflection curves of SFRC specimens.

1.4.5 Workability Test:

Workability is a feature of a mixture of raw or fresh concrete. Workability requires, in plain terms, the simplicity of positioning, because workable concrete is the concrete that can be placed because quickly compacted without separation.

Workability is both a essential feature of concrete and synonymous with compaction and energy. For all concrete types the desired workability isn't the same. With a small, unstable portion or highly reinforced part, more workability is required, rather than a body of mass concrete. Therefore, we can not set a minimum operability on all casting works.

Compaction and workability are closely related. Workability can also be characterized as the amount of useful internal work needed to bring about complete compaction.

1.4.5.1. Different Types of Workability of Concrete:

1. **Unworkable Concrete**:

Also called rough concrete, the impracticable concrete is a concrete with very little water. This is challenging to mix the concrete by hand. This particular type has a strong segregation of the aggregates. And it is really hard to preserve the homogeneity of a concrete mix.

2. Medium Workable concrete:

In most building works medium workable concrete is used. Too much division and lack of homogeneity this concrete is fairly easy to mix, transport, position and compact.

3. Highly Workable Concrete:

Such concrete is very simple to mix, to express, to put and to compact. It is applied in situations where effective concrete compaction can not be achieved. The problem is that there are strong chances of discrimination and a lack of homogeneity in the highly workable concrete.

For us concrete strength is the most important commodity. It depends on the ratio of density or compaction, and depends on adequate workability. New concrete must be workable, because compaction to optimum density with a fair amount of work is possible.

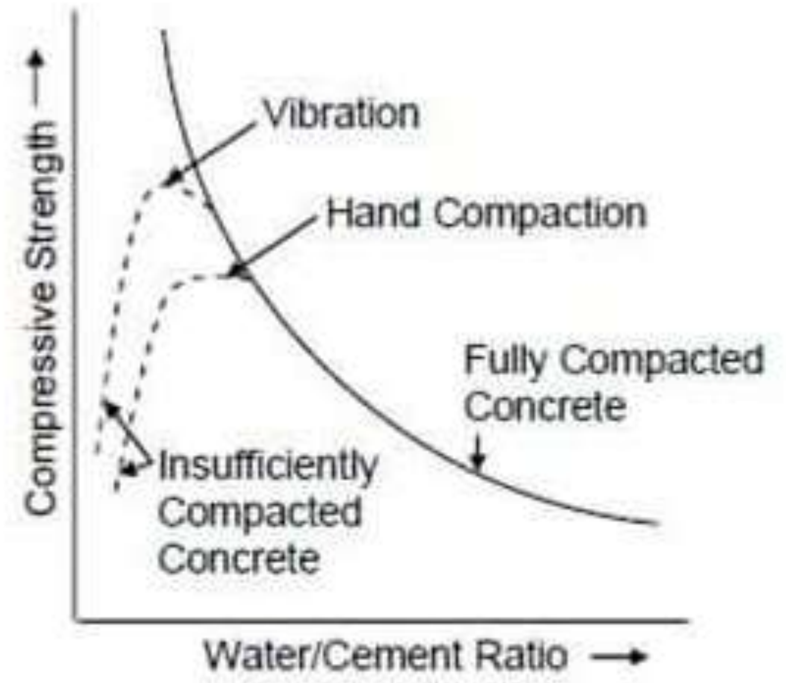


Figure 1.4.6- **Compressive strength vs w/c ratio of concrete.**

Workability is carried out by conducting the slump test and compaction factor test as per IS 1199-1959 on ordinary concrete and Fibre reinforced concrete. The properties of fresh concrete can be evaluated by slump cone test & compaction factor test with W/C ratio 0.4. In a test performed by (Avinash Joshi , Pradeep reddy ,Punith kumar and Pramod hatker) in 2016. The result of properties is given in table 1.4.1.

That said there are a number of physical fiber properties that will affect both slump and workability:

1. Type of Fiber/ Configuration of the Fiber
2. Quantity of Fiber
3. Length of Fiber
4. Proportions of the Plain Mix
5. Admixtures or Additives Incorporated in the Mix

S.No.	Mix type (SF %, SF&FA %)	Slump value(mm)	compaction factor
01	MS0(0.0%, 0.0%&0.0%)	78	0.952
02	MS1 (0.5%, 5%&5%)	23	0.820
03	MS2 (0.5%, 10%&10%)	38	0.810
04	MS3 (0.5%, 15%&15%)	49	0.902
05	MS4 (1.0%, 5%&5%)	18	0.801
06	MS5 (1.0%, 10%&10%)	21	0.786
07	MS6 (1.0%, 15%&15%)	31	0.802
08	MS7 (1.5%, 5%&5%)	12	0.740
09	MS8 (1.5%, 10%&10%)	15	0.792
10	MS9 (1.5%, 15%&15%)	19	0.810

Table 1.4.1- Slump and compaction factor of SFRC

1.5 Benefits of SFRC:

SFs' beneficial impact on concrete depends on several factors such as form , shape, length, cross section, thickness, fiber quality, bond strength of SFs, matrix strength, mix size, and concrete mix. Some of the major benefits of using Steel Fibres in concrete are as follows:

1. Steel Fibres' beneficial influence in concrete depends on many factors, such as type , shape, length, cross section, strength, Fibre content, bond strength of steel Fibres, matrix strength, mixing design and concrete mixing.
2. Steel Fibres also improves the Brittle Nature of the Concrete.
3. Steel Fibres increase the tensile strength of the matrix, thereby improving the flexural strength of the concrete.
4. Increase ductility of the concrete
5. SFRC is more durable and serviceable than conventional Reinforced Concrete.
6. In SFRC structures, corrosion in concrete structures due to cracks is less severe than in conventional RC structures.

The only downside of SFRC would be its reduced workability and accelerated fresh concrete stiffening due to the introduction of SFs, thus increasing the construction work and time due to the additional friction needed to make the SFRC workable. This problem could be partially overcome with the use of newly developed high-range super plasticizers which not only improve SFRC’s workability but also maintain the mix's plasticity for a longer period of time.

Using bonded or unbounded overlays to the under slab, SFRC may be used in the building of new pavements or for repair of existing pavements. It leads to a higher flexural strength which causes the necessary thickness of the pavement to decrease. Furthermore, the Resistance Increase to effect and frequent loading. SFRC 's increased tensile strain capacity leads to a drop in the maximum crack widths as compared to plain concrete.

1.6 Applications of SFRC:

1 **Highway and air-field pavements:** There are numerous applications of steel Fibre reinforced concrete (SFRC) for large blocks such as heaw vibrating equipment foundations, dolos armor units, spillways, road overlays, etc.

2 **Hydraulic Structures:** The most important advantage of using SFRC in hydraulic structures is the resistance of SFRC to cavitations or erosion as compared to conventional RC due to the high speed of water flow.

3 **Fibre shotcrete:** Fibre shotcrete is used for stabilization of the rock slope, tunnel lining and repair of bridges. A thin simple shotcrete coating placed monolithically on top of the shotcrete material, possibly used to avoid surface staining due to SFs rusting. The fiber shotcrete may be used for steel framework safety.

4 **Precast Application:** SFRC may be found in prefabricated items such as manhole coverings, concrete pipes, and computer bases and frames. Improved SFRC flexural strength and impact resistance can allow these products to be used in situations of rough handling.

5 **Refractory Concrete:** Steel-fiber reinforced refractory concretes have been reported to be more durable than their unreinforced counterpart when exposed to high thermal stress, thermal cyclic, thermal shock or mechanical abuse. The extended service period is possibly attributed to the SFs' combination of crack regulation, improved durability, spalling, and abrasion resistance.

6 Using steel fibers improves the durability, ductility, and dignity of traditional RC members under earthquake and blast loads.Increases the strength of RC members to shear. As a result, the shear strength of the slabs will increase and sudden punching failure can be transformed into a slow ductile failure.

7 SFRC may be found in prefabricated items such as manhole coverings, concrete tubing, and machine bases and frames.

8 Can provide enhanced impact resistance to traditional RC members, enhancing local damage and spreading resistance (spalling)

9 Adding SFs can prevent crack growth and crack widening; this may allow the use of high-strength steel bars without undue crack width or duty load deformation.

1.7 Seismic analysis of SFRC as a Structural element:

Seismic structural analysis plays a very important function in every structure's load study, since structures are usually built primarily for vertical loading due to self weight, live load, impact load, etc. However dynamic loads affect the structure during earthquake especially via dynamic lateral or horizontal loading, which is a major concern from the point of structural protection.

Two different methods used to make Earthquake resistant structures are:

- Equivalent Static Seismic Analysis
- Dynamic Seismic Analysis.
- Response Spectrum Method (Considers dynamic Response of structure).
- Time History Method (uses time history data).

Application of above-mentioned methods may vary as per the site conditions, type of structure, height and seismic zone etc.

1.7.1. Equivalent Static Seismic Analysis:

Both seismic system projects have to take account of the complex complexity of the system. Nevertheless, for basic regular systems, study by analogous linear static approaches is always enough. In regular, low- to medium-rise buildings which are allowed by most practice codes. It starts with an estimation of the base shear load and its on-plot distribution, calculated using formulae provided in the document. For low- to medium-rise buildings, however, comparable static research should operate well without significant lateral-torsional coupling modes, in which only the first mode is regarded in each direction. Tall buildings (over, say, 75 m), where second and higher modes might be appropriate, or buildings with torsional impact, are much less ideal for the solution and need more complex methods to be used in these circumstances.

1.7.2. Dynamic Seismic Analysis:

Dynamic research may be carried out either by way of reaction continuum, or by way of time history.

1.7.3. Time History Method:

This is an study of the structure's complex reaction at-time interval, as the foundation is exposed to a particular time background of ground motion. Alternatively, documented ground motions archive from historical natural disasters can be a credible source for period records but it is not collected at any particular location to contain all seismological features appropriate for that location. Documented ground motions are randomly chosen from equivalent category (bin) of magnitude, distance and state of the soil; three key parameters in the generation of time history. Adding further restrictions to the characteristics of each bin allows it more definitive and comparable to the characteristics of the location, but it may place severe limits on the availability of actual documents in bin. Selected ground motion response spectrum may differ from target response spectral accelerations that are met with target spectrum around the structure's fundamental period. Never the less similar correlation between the range of record and target reaction can be done by clearly the one particular aspect of the record.

1.7.4. Response Spectrum Method:

The representation of the maximum response of an idealized single degree of freedom method for a certain duration of damping during earthquake ground movement is the maximum response plotted against undamped natural time and for specific damping value, and can therefore be expressed in the maximum absolute maximum relative velocity or maximum relative displacement for this reason.

1.8 Seismic Analysis using ETABS 17.0.0:

ETABS is a software which analyzes and designs a building. ETABS is the major software for design on the market today. Many designers use this software company for design purposes of their projects. This research paper thus deals primarily with the comparative study of the results obtained from the analysis of a multi-storey building structure when analyzing comparative analysis separately using ETABS software.

Some of the useful features of ETABS 17.0.0 are as follows:

- One Portal, Several Views:-ETABS has a simple user interface: Simulation, Research, Architecture, Description and Reporting.
- Models:-ETABS has a broad range of models for launching a new model quickly. The appropriator has the ability to define grid and grid spacing, the number of stories and the default sections of the structural system.
- Automated loading code:-ETABS will automatically generate and apply seismic and wind loads based on different domestic and international codes.
- Loading Cases and Combinations:-ETABS makes unrestricted load cases and combos. Forms of mixture loads.
- Mixed units:-ETABS provides direct power to the appropriator of the units used for all configuration details and shows the effects of the appropriate units. Both architectural units or outcomes units for study, you may have some mixture of units all over your plan.
- Deformed Geometry:-Appropriator can show deformed geometry centered on any load or module combination, as well as mode animations.
- Reaction Diagrams:-Help reactions for chosen reaction components may be represented graphically on the model either as vectors or as tabulated charts.

- Report generation features:-The report generator features include an indexed table of contents, model description information, and tabulated format review and design tests. Reports can be viewed within ETABS with live document navigation connected to the Model Explorer, and can be exported directly to Microsoft Word.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

[1] Merve AÇIKGENÇ, Kürşat Esat ALYAMAÇ, Zülfü Çınar ULUCAN, 2015, The relationship between the splitting tensile strength and the flexural strength of SFRC with different cement dosages and water / cement ratios was explored in his research, first. In addition, it has found that there is a connection between these strength values, and the flexural tensile strength of SFRC can be measured using the splitting tensile strength.

[2] YAN Changwang, ZHANG Ju, and Jinqing, investigates the compressive strength and splitting tensile strength of ultra high strength concrete containing steel fiber. The steel fibers were added at the volume fractions of 0%, 0.5%, 0.75%, 1.0% and 1.5%. The compressive strength of the steel fiber reinforced ultra high strength concrete (SFRC) reached a maximum at 0.75% volume fraction, being a 15.5% improvement over the UHSC. The splitting tensile strength of the SFRC improved with increasing the volume fraction, achieving 91.9% improvements at 1.5% volume fraction. Strength models were established to predict the compressive and splitting tensile strengths of the SFRC. The models give predictions matching the measurements. Conclusions can be drawn that the marked brittleness with low tensile strength and strain capacities of ultra high strength concrete (UHSC) can be overcome by the addition of steel fibers.

[3] Joshi Avinash , reddy Pradeep , kumar Punith and Pramod hatker, The various aspects covered are the materials, mix proportioning for M20, M25, M30, M40 grades of concrete. As the concrete is weak in tension, a work has been carried out to investigate the improvement in tensile, shear, flexure, and even compressive strength of concrete and also to investigate the cracking strength and reserve strength of concrete & FRC.M20, M25, M30, M40 grades of concrete have been added to investigate the compressive strength, tensile strength & shear strength of concrete. Steel fibers acts as a bridge to retard their cracks propagation, and improve several characteristics and properties of the concrete. Fibers are known to significantly affect the workability of concrete. The aspect ratio (50) and variable in this study were percentage of volume fraction (0, 0.5, 1.0 and 1.5) of steel fibers. Compressive strength, splitting tensile strength and flexural strength of the concrete were determined for the hardened properties. Their main purpose is to increase the energy absorption capacity and toughness of the material. But also the increase in tensile and flexural strength is often the primary objective. A marginal improvement in the ultimate strength was observed. The addition of fiber enhanced the ductility significantly.

[4] Anurag Mishra, Prof. Kirti Chandraul, Prof. Manindra Kumar Singh, From the research is it has found that using different type of fibers in concrete improves the mechanical properties, durability and serviceability of the structure. Here the concrete of M 20 grade have been studied by varying the percentage of fibers such as 0%, 0.5%, 0.1%, 1.5%, 2%, 2.5% and 3% by weight of cement with Aspect Ratio 60(30mm length and 0.5mm diameter). The Cubes and Cylinders were prepared for Compressive and Split Tensile Strength at 7th day, 14th day and 28th day of curing. With varied percentage of fiber reinforced concrete were studied and it has been found that there is significant strength improvement in steel fiber reinforced concrete. The Slump cone test results reveale

[5] Shende.A.M., Pande.A.M. Fibre reinforced concrete, a composition of concrete and fibres is being prominently used for various important applications. The hook tain steel fibres assist in controlling the propagation of micro-cracks present in the matrix, first by improving the overall cracking resistance the matrix and later by bridging across even smaller cracks formed after the application of load on to the member thereby preventing there widening into major cracks. In the present paper, the effect of steel fibre reinforcement with different percentage of fibre 0, 1%, 2% and 3% by volume for M-40 grade of concrete with aspect ratio 50, 60 and 67 are studied. The beam is tested for flexural strength. The percentage increase through utilization of steel fibers is reported. A relationship between aspect ratio vs. flexural strength represented graphically.

CHAPTER 3

3. METHODOLOGY AND MATERIALS USED

Based on previous research and experimental works performed by many researches on determination of various mechanical properties and behavior of SFRC under Flexural, Compression as well as Tension further seismic analysis for this research was done. Research has shown that behavior of SFRC is much similar to that of normal concrete with minor exception. In an experimental work on M20 concrete by (Anurag Mishra, Prof. Kirti Chandraul, Prof. Manindra Kumar Singh) in 2017, observed that its superior resistance to cracking and crack propagation is one of the important properties of Steel Fibre Reinforced Concrete (SFRC). And the concrete is reinforced in various amounts with the steel fibre such as 0 percent, 0.5 percent, 1.0 percent, 1.5 percent, 2 percent, 2.5 percent and 3 percent by cement weight. Aspect Ratio 60 (30 mm long and 0.5 mm diameter) has been tested for all volume proportions. On the 7th , 14th and 28th day of curing the Compressive and Tensile Strength were analyzed as per IS standards. The results obtained were as follows:

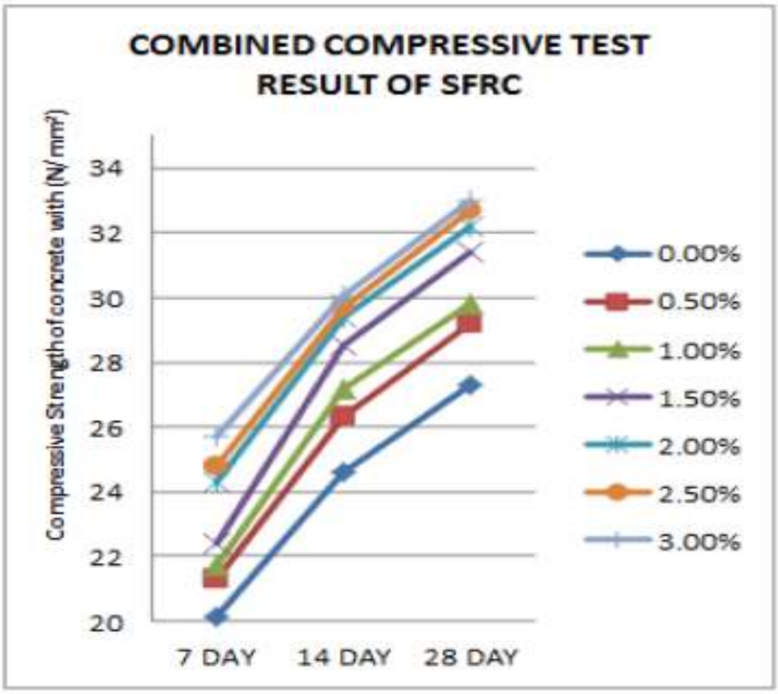


Figure: 3.1.1- Comparison of Compressive strengths of different % of SF in Concrete

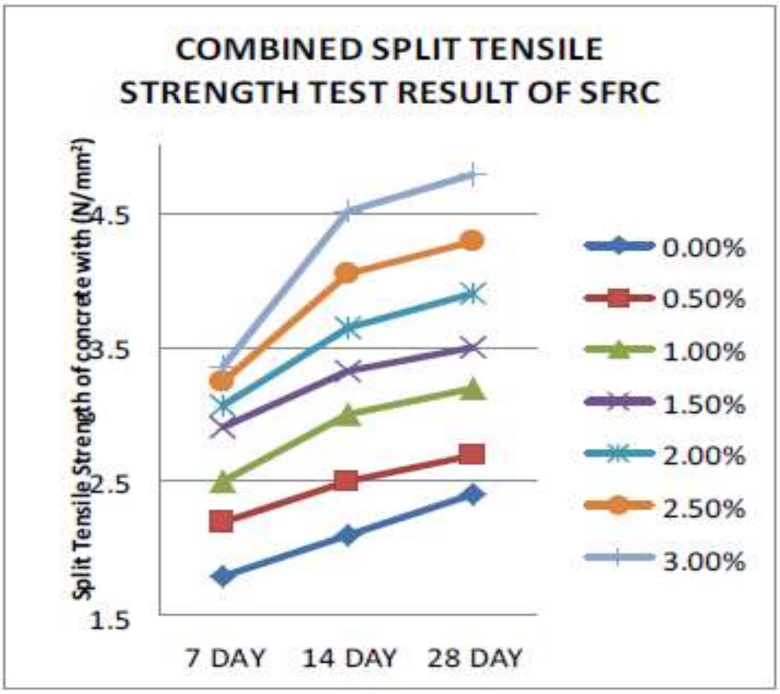


Figure: 3.1.2- Comparison of Split Tensile strengths of different % of SF in Concrete

It can be observed that the Compressive strength for M20 concrete is in increasing order from 0.0 % to 3 % of steel fibre use concrete and the maximum strength is gained at 3.0% that is 33 MPa. Also for the same samples the Split Tensile strength is in increasing order and the maximum strength is gained at 3.0 % that is 4.8MPa.

In an another experiment performed by (Shende.A.M., Pande.A.M).in 2011 in which Hook end steel fibre with different aspect ratio of 50, 60 and 67 were used in M40 grade concrete with with 0%, 1%, 2% and 3% Steel Fibre. For the same samples with different aspect ratios maximum increase in percentage flexural strength was found with Hook end steel Fibre Reinforced M40 concrete with aspect ratio 50. The results for the percentage increase in flexural strength and compressive strengths of different % of steel fibre containing SFRC for Aspect ratio 50 is represented by the graph shown in

FLEXURAL STRENGTH OF SFRC WITH 0%, 1%, 2% and 3% FIBRES				
Different aspect ratios of fibres	**For Normal M40**	**For SFRC**	**For SFRC**	**For SFRC**
	with 0% fibres	**with 1% fibres**	**with 2% fibres**	**with 3% fibres**
	Flexural strength (MPa)			
	Avg.	**Avg.**	**Avg.**	**Avg.**
	7.47	8.8	9.47	10.4
		8.4	9.2	10
		8.27	9	9.73

Table: 3.1- Flexural Strength of SFRC with 0% of steel fibre in M40 grade concrete

COMPRESSIVE STRENGTH OF SFRC WITH 0%, 1%, 2% and 3% FIBRES				
Different aspect ratios of fibres	**For Normal M40**	**For SFRC**	**For SFRC**	**For SFRC**
	with 0% fibres	**with 1% fibres**	**with 2% fibres**	**with 3% fibres**
	Comp. strength (MPa)			
	Avg.	**Avg.**	**Avg.**	**Avg.**
50	45.19	52	53.33	56.3
60		50.37	52.59	54.07
67		50.22	51.41	53.04

Table: 3.2- Compressive Strength of SFRC with 0% of steel fibre in M40 grade concrete

Hence from the experimental work based on different types, aspect ratio and % of steel fibres used in SFRCs we can say that SFRC with 3% of steel fibres is showing maimum flexural, tensile and compressive strength as compared to the normal conventional concrete (Shende.A.M., Pande.A.M).in 2011 & (Anurag Mishra, Prof. Kirti Chandraul, Prof. Manindra Kumar Singh) in 2017.

It can be observed from the results that the flexural strength is maximum in the case of Hook end SFRC with 3% steel fibre and aspect ratio 50 i.e. 10.40 MPa. Also the compressive strength of the same sample was found to be maximum i.e. 56.30 MPa.

3.1. Modeling:

In the present research work, SFRC with Hooked shaped steel fibre(Aspect ratio= 50 and 3% steel fibre) is used as a Structural material in Beam and Column. Also the same was simulated and modelled in ETABS 17.0.0 sofware in which the a comparitive seismic analysis was performed to study the behaviour of M 40 grade SFRC based G+8 storey model in which only Beam and Column material was replaced with 3% SFRC, where as slab was same as conventional M40 grade. The same model was compared with conventional M40 grade concrete Reinforced Concrete model in which all structural elements such as Beam, Column and slab were of standard M 40 Grade (0% SFRC). Based on various Results Outcomes after seismic analysis of both the Models various Comparisons were done.

The other relevant data for modifying the material properties of M 40 grade concrete to M 40 SFCR- 3% (Molel-2) Model was referred to previous research work and literature available and mentioned in this paper. Some of the comparison of various Material properties of Conventional M40 Model (Model-1) is shown in the table 3.1:

MODEL-1: Conventional M40 Model

MODEL-2: M 40 SFCR- 3% Model in which M40 grade concrete with 3 % steel fibre was used in Beam and Columns only, Slab remains same as M 40 grade Conventional concrete)

Propeties	Specific Weight Density (kN/m^3)	Mass per unit volume (kg/ m^3)	Modulus of elasticity (Mpa)	Poisson's ratio	Coefficient of thermal expansion	Shear Modulus (Mpa)
MODEL- 1	24.9926	2548.538	31622.78	0.2	0.0000055	13176.16
MODEL - 2	26.59	2711.424	37516.661	0.2	0.0000055	15631.94

Table: 3.1- Material Properties of used for simulation: MODEL- 1 and MODEL- 2

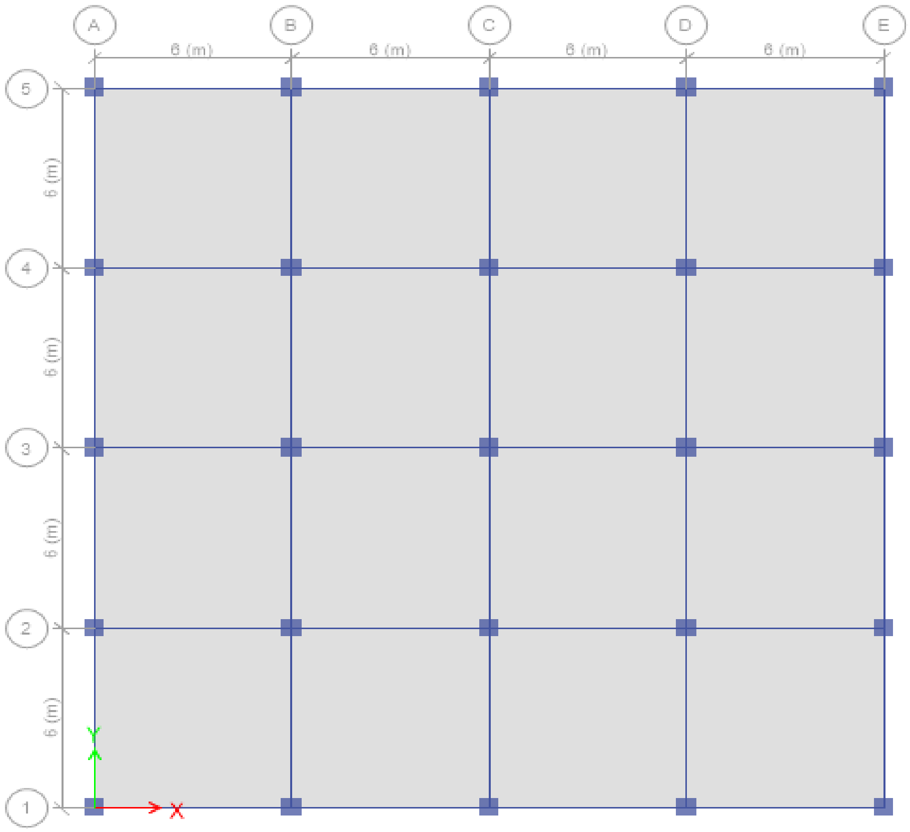


Figure: 3.1- Plan view of G+8 multi - story building Model

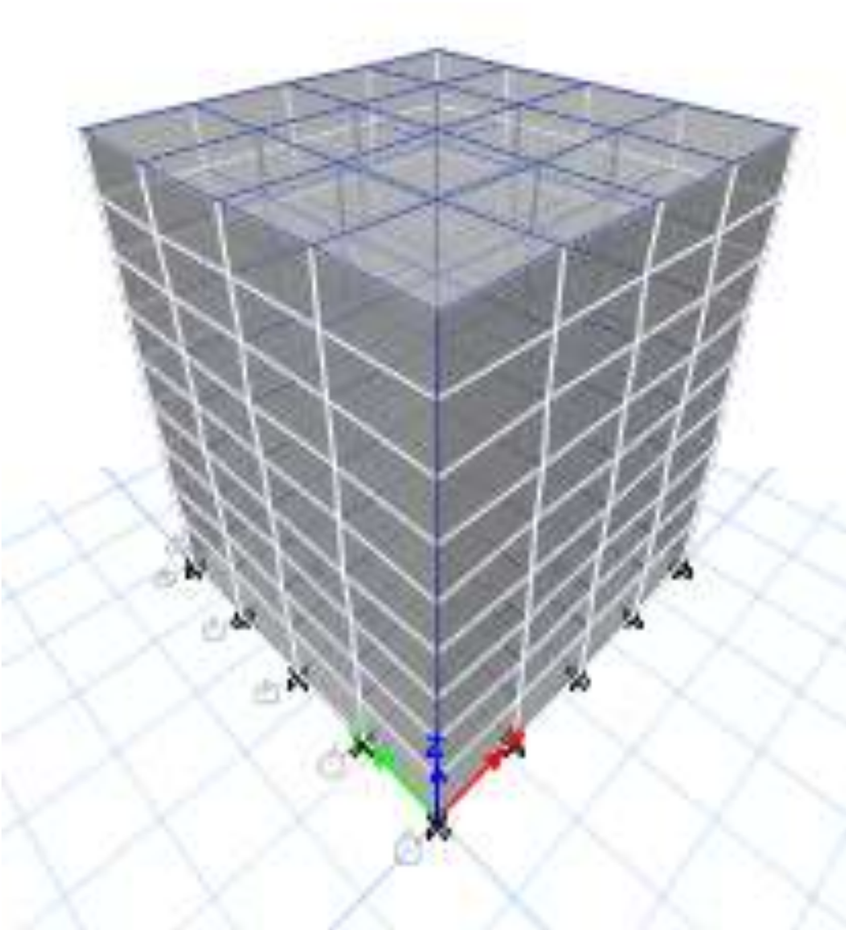


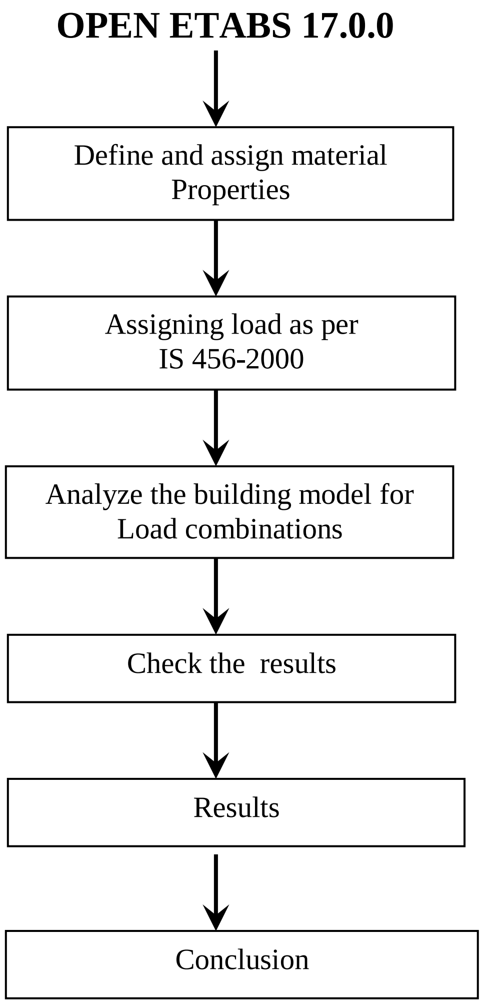
Figure: 3.2- 3-D view G+14 multi-story building Model

Case	Type	Status	Action
Modal	Modal - Eigen	Finished	Run
Dead	Linear Static	Finished	Run
Live	Linear Static	Finished	Run
EQ	Linear Static	Finished	Run

Figure: 3.3- Load cases to Run on Model

The ETABS software is used in the present investigation to develop and conduct the analysis of the RC Frame Model. Linear static analysis of the building structures is done on ETABS. For both models, line element was used in the present investigation for beams (600 mm x 600 mm) and columns (600 mm x 600 mm) and concrete element for slabs (150 mm thickness) for the modeling of the G+8 story RC building with first soft height as 4 m and rest story height as 3.15 mm. The fundamental structure was established entirely by constraining all degrees of independence. An RC building code contrast of Indian seismic coad IS 1893:2016 on medium soil was studied, and the style shapes across the framework were obtained due to various load combinations, displacement, story drifts and base shear.

3.1.1. Analysis Procedure Flow Chart:



3.1.2. Loads:

The data here is showing the loading information as applied to the models.

The Following Loads were applied to both the Models:

1. Dead Load = 3 kN/m on slab
2. Live Load Load = 6 kN/m on slab
3. Cladding Load on exterior beams = 0.2 kN/m
4. Earthquake Load in X direction = As per IS 1893:2016
5. Earthquake Load in X direction = As per IS 1893:2016
6. Seismic Zone: V
7. Response reduction factor = 3
8. Soil Type = 2 (medium)
9. Importance Factor = 1

3.1.2.1. Load Patterns:

Name	Type	Self Weight Multiplier	Reference
Dead	Dead	1	Auto Load
Live	Live	0	
EQ	Seismic	0	IS 1893:2016

Table 3.2 - Load Patterns

3.1.2.2. Load Combination as per IS 1983: 2016:

- 1.2 [LL + DL + (ELx+ 0.3 Ely + 0.3 ELz)]
- 1.2 [LL + DL - (ELx+ 0.3 Ely + 0.3 ELz)]
- 1.2 [LL+ DL + (ELy+ 0.3 Elx + 0.3 ELz)]
- 1.2 [LL + DL - (Ely + 0.3 Elx + 0.3 ELz)]
- 1.5 [DL + (0.3 Ely + ELx + 0.3 ELz)]
- 1.5 [DL - (0.3 Ely + ELx + 0.3 ELz)
- 1.5 [DL + (0.3 ELx + Ely + 0.3 ELz)]

- 1.5 [DL - (Ely + 0.3 ELx + 0.3 ELz)] 0.9 DL + 1.5 (ELx + 0.3ELy + 0.3ELz)
- 0.9 DL - 1.5 (0.3Ely + ELx + 0.3 ELz) 0.9 DL + 1.5 (0.3ELx+ Ely + 0.3ELz)
- 0.9 DL - 1.5 (0.3ELx + Ely + 0.3 ELz)

Name	**Type**
Dead	Linear Static
Live	Linear Static
EQ	Linear Static

Table 3.3 - Load Cases - Summary

3.1.3. Model Sectional and Material Parameters:

Parameter	**Rebar in all members (Main)**	**Rebar in all members (Confinement)**	**Beam Material (Concrete)**	**Beam Size**	**Column Material (Concrete)**	**Column Size**	**Slab material (Concrete)**	**Slab Thickness**	**Height of Building**
Model-1	FE 500	FE 250	M40	600 x 600 mm	M40	600 x 600 mm	M40	150 mm	29.2 m (9 Storey)
Model-2			SFRC M40 3%		SFRC M40 3%				

Table 3.4 Material parameters of MODEL-1 & MODEL-2

3.1.3.1. Material properties

- **<u>For MODEL-1</u>**

Concrete

Concrete with following properties is considered for study.

- Characteristic compressive strength (fck) M = 40 MPa
- Density = 24KN/m^3
- Modulus of Elasticity (E) = 5000 x √ fck = 25000 MPa
- Poisons Ratio = 0.2

Steel

Steel with following properties is considered for study.

- Yield Stress (fy) = 500 MPa
- Poisons Ratio = 0.15
- Modulus of Elasticity (E) = 2x105 MPa

- **<u>For MODEL-2</u>**

Concrete

Concrete with following properties is considered for study.

- Modulus of Elasticity (E) = 5000 x √ fck = 25000 MPa
- Poisons Ratio = 0.2
- Characteristic compressive strength (fck) M = More than 40 MPa
- Density = 26.59 KN/m3

Steel

Steel with following properties is considered for study.

- Yield Stress (f_y) = 500 MPa
- Poisons Ratio = 0.1
- Modulus of Elasticity (E) = $2x10^5$ MPa

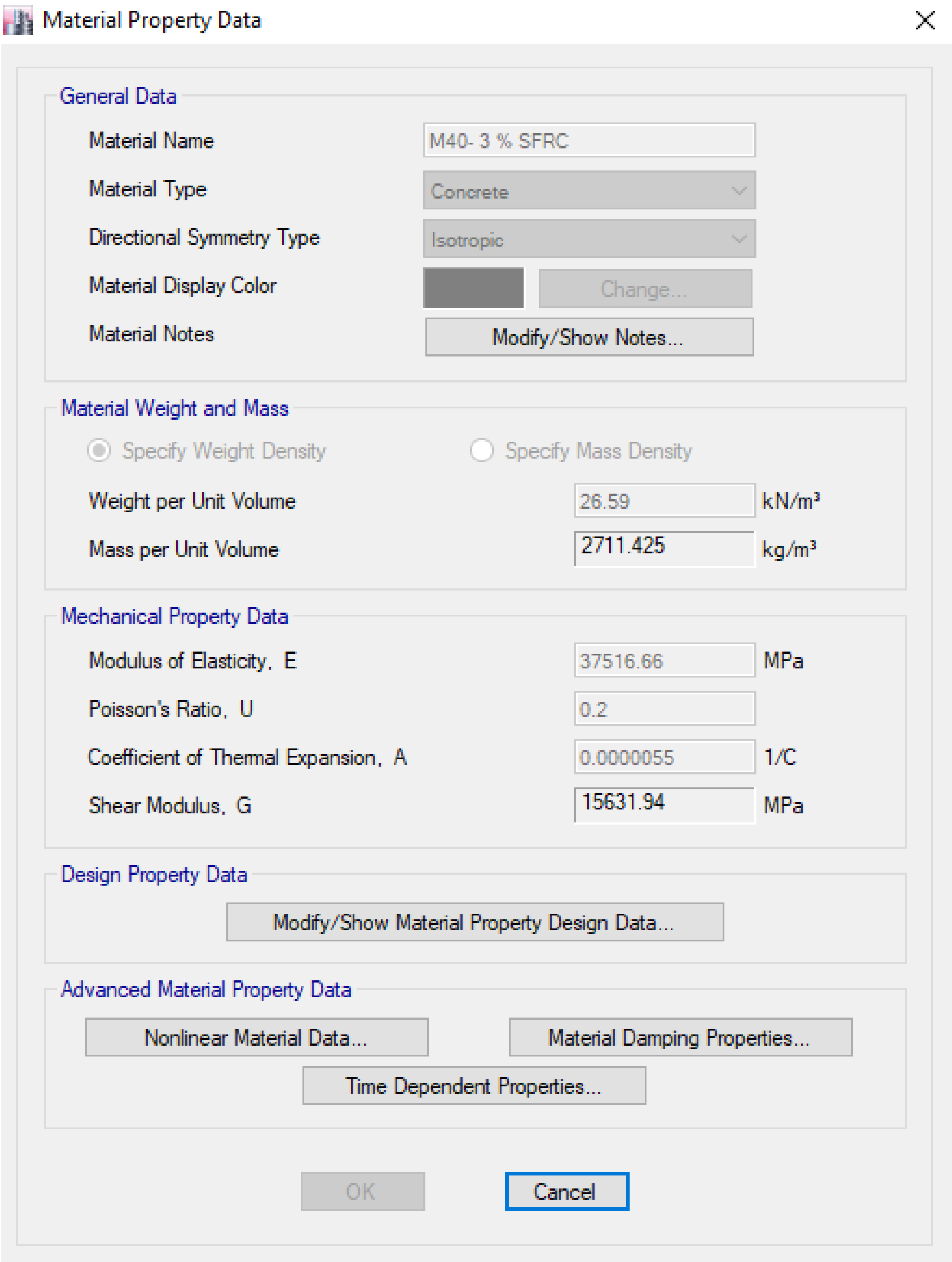


Figure: 3.4- Modified Material (M40 concrete + 3% steel fibre) in ETABS

3.1.3.2. Design horizontal seismic coefficient (Ah):

Seismic coefficient is calculated as per IS: 1893 (1) -2002, cl. 6.4.2, pg. 14.

Ah = (Z I Sa / 2 R g)

For any structure with T < 0.1 S, Ah 's value will not be taken less than Z/2 whatever is the I / R value.

Where,

Z = zone factor

I = importance factor

R = response reduction factor

Sa/g = average response acceleration coefficient

3.1.3.3. Zone factor (Z):

For the maximum called earthquake, the value of the zone factor (Z) given in table is. The factor 2 in the Z denominator is used to reduce the factor of the MCE zone to the earthquake-based design factor (DBE).

Table No. 3.5- Zone Factor (Z) (IS 1893 (Part-1):2002, Cl. 6.4.2)

Seismic zone	**II**	**III**	**IV**	**V**
Seismic Intensity	low	Moderate	severe	Very severe
Z	0.10	0.16	0.24	0.36

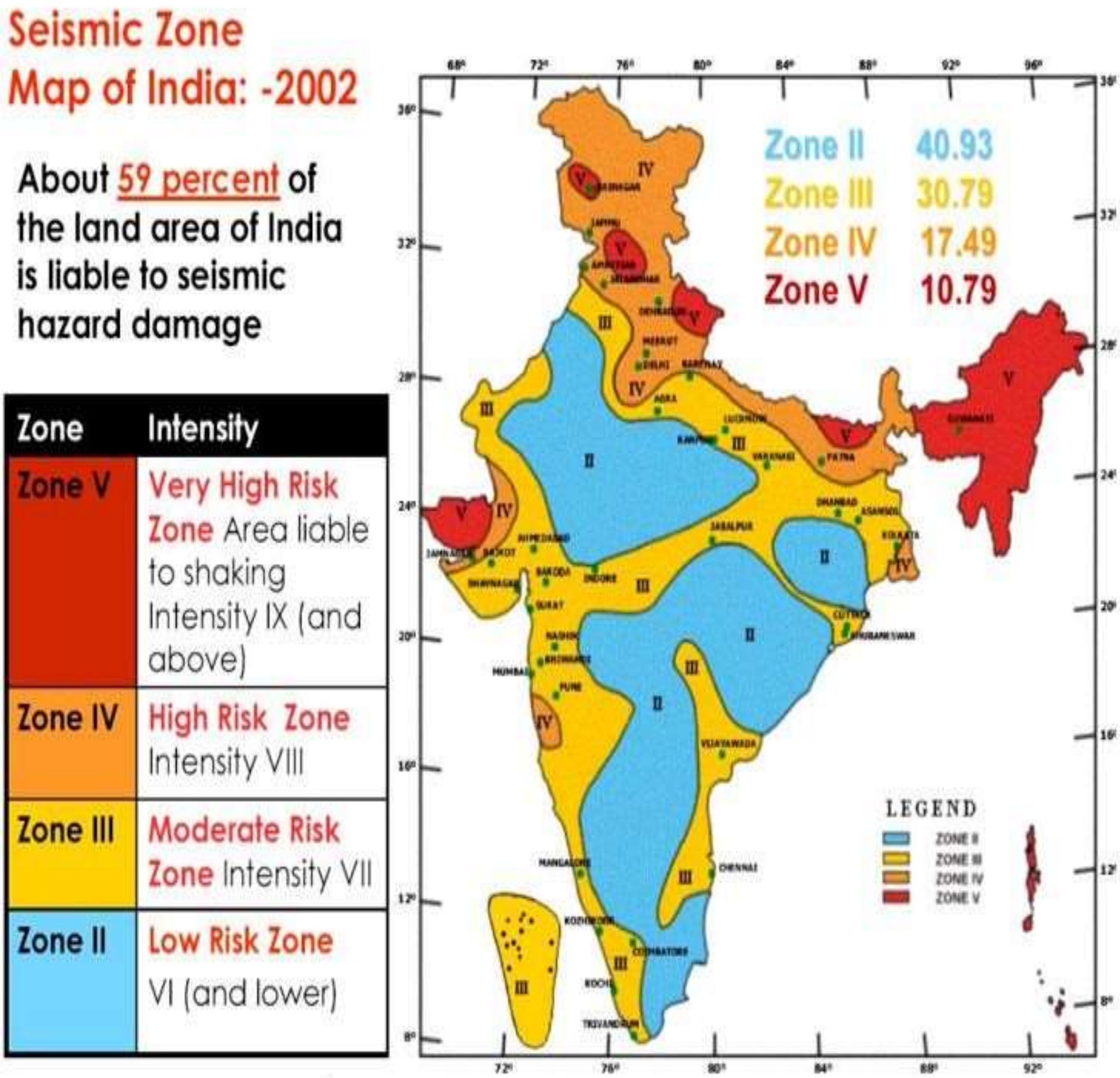


Fig.:3.5 Seismic Zones of INDIA

3.1.3.4. Importance factor (I):

Importance factor depends on the structures' functional use, characterized by hazardous consequences of their failure, need for post-earthquake function, historical value, or economic significance. Table 3.6 provides the values of factor of interest (I).

SI. NO. (1)	STRUCTURE (2)	Importance Factor (3)
(I)	Importance infrastructure and community building, such as hospitals; schools; historic structures; emergency building such as telephone exchange, TV stations, community radio halls such as cinemas, assembly halls and subway station, power station.	1.5
(ii)	All other building	1.0

Table No. 3.6- Importance Factor, I (IS 1893 (Part-1):2002, Cl. 6.4.2)

3.1.3.5. Response reduction factor (R):

It depends on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio I/R shall not be greater than I.

Sr. no. (1)	Lateral load resisting system (2)	R (3)
(I)	Ordinary RC moment – resisting frame(OMRF)[2]	3.0
(ii)	Special RC moment – resisting frame (SMRF)[3]	5.0

Table No. 3.7- Response Reduction Factor, R For Building Systems (IS 1893 (Part-1):2002, Cl 6.4.2)

CHAPTER 4

RESULTS

4.1. IS 1893:2016 Auto Seismic Load Calculation

This analysis presents, as determined by ETABS, the automatically generated lateral seismic charges for the load pattern EQ x according to IS 1893:2016.

Direction and Eccentricity

Direction = X

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 3] $Z = 0.36$

Response Reduction Factor, R [IS Table 9] $R = 3$

Importance Factor, I [IS Table 8] $I = 1.0$

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.2] $\frac{S_a}{g} = 0.34$ $\frac{S_a}{g} = 0.34$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]

$$A_h = \frac{ZI\frac{S_a}{g}}{2R}$$

The following Results were obtained after the Seismic analysis of both the Models (MODEL-1 and MODEL-2). Also the results compared here are only for Earthquake Load case.

4.2. Maximum storey Displacement

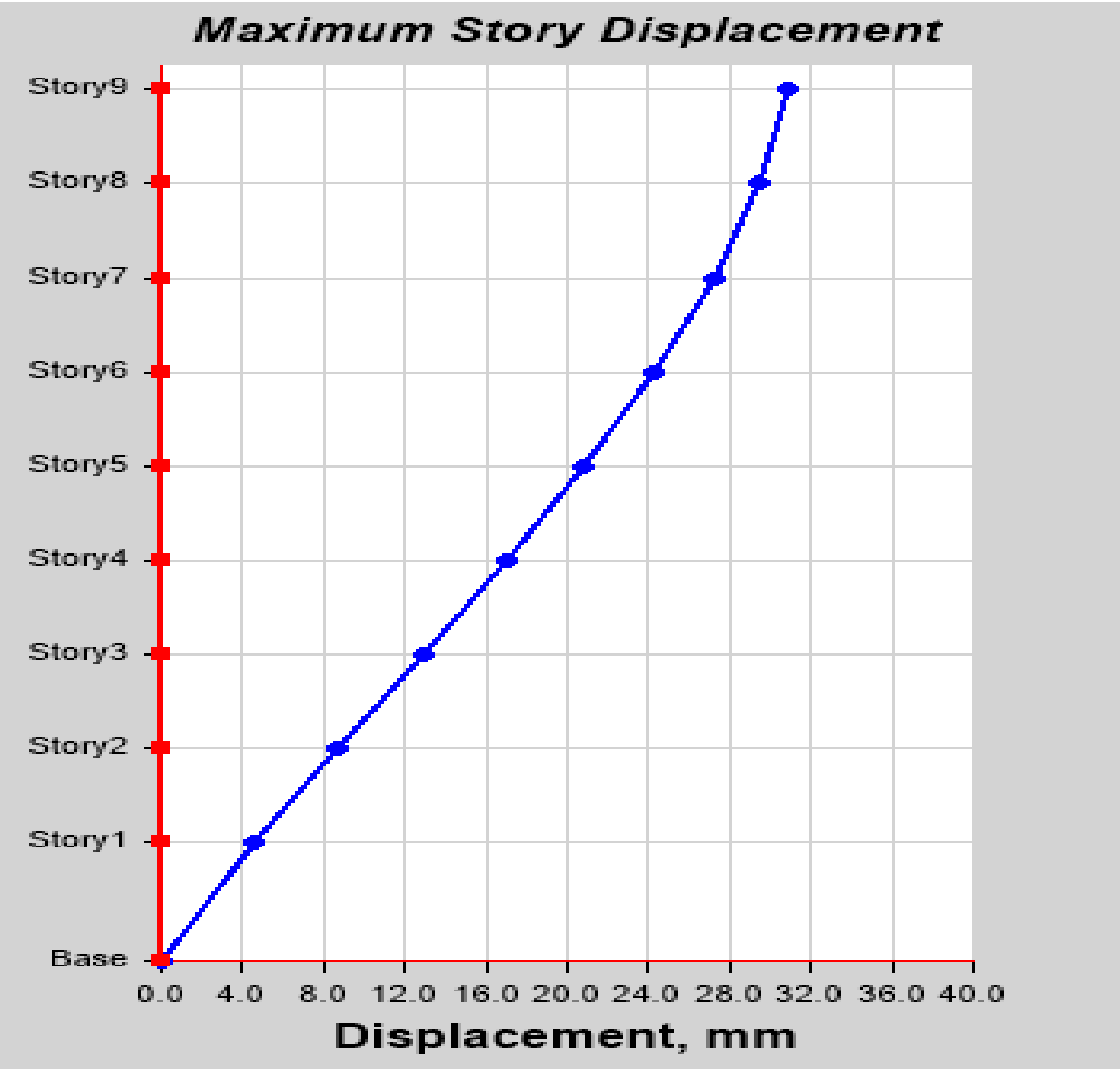


Figure: 4.1- Maximum storey Displacement for MODEL-1

TABLE: Max Story Displacement				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m	mm	mm
Story9	Top	29.2	30.812	0.004
Story8	Top	26.05	29.455	0.005
Story7	Top	22.9	27.243	0.003
Story6	Top	19.75	24.312	0.002
Story5	Top	16.6	20.846	0.001
Story4	Top	13.45	17.006	0.001
Story3	Top	10.3	12.933	0.00081
Story2	Top	7.15	8.738	0.00023
Story1	Top	4	4.517	0.0044
Base	Top	0	0	0

Table 4.1- Maximum storey Displacement for MODEL-1

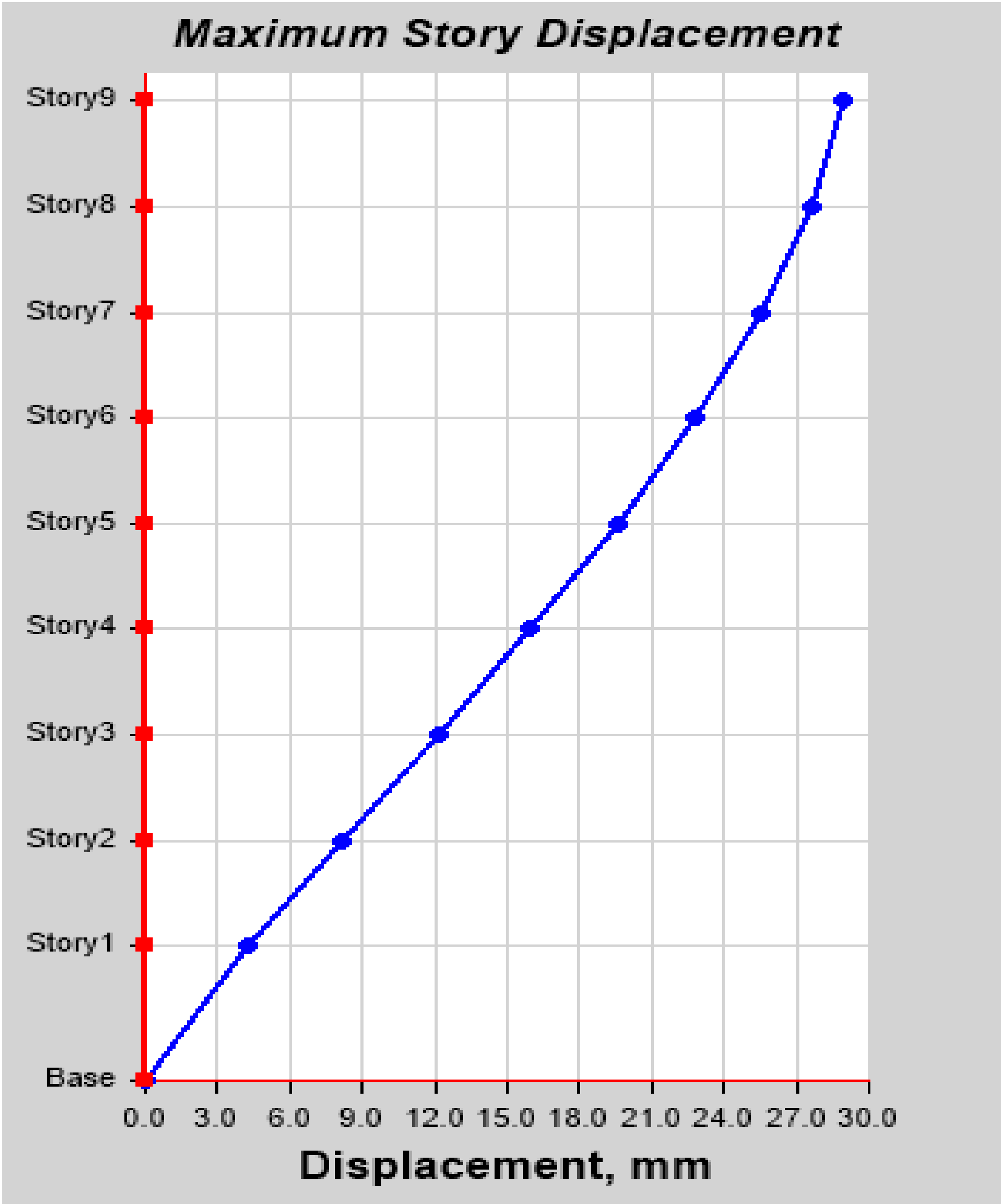


Figure: 4.2- Maximum storey Displacement for MODEL-2

TABLE: Max Story Displacement				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m	mm	mm
Story9	Top	29.2	28.9006	0.00508
Story8	Top	26.05	27.628	0.00532
Story7	Top	22.9	25.553	0.003
Story6	Top	19.75	22.804	0.0027
Story5	Top	16.6	19.551	0.0019
Story4	Top	13.45	15.947	0.0013
Story3	Top	10.3	12.123	0.0008
Story2	Top	7.15	8.185	0.0002
Story1	Top	4	4.224	0.004
Base	Top	0	0.00000	0.00000

Table 4.2- Maximum storey Displacement for MODEL-2

- In Model- 2 the Maximum storey Displacement is decreased in X direction by 3.201529 % and increased in Y Direction by a very low margin of 1.2 % from Model-1 in the top storey

4.3. Maximum Storey Drift:

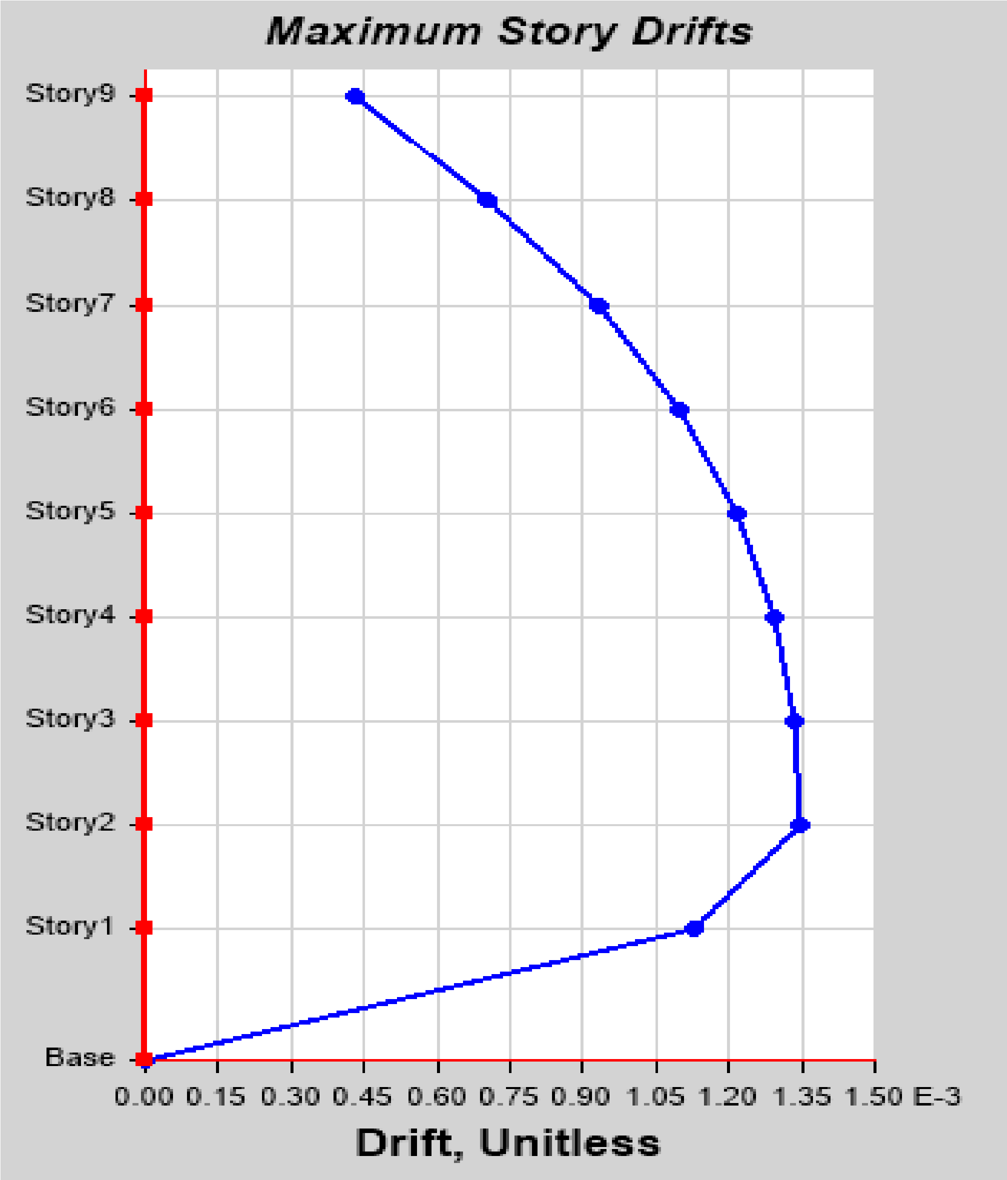


Figure: 4.3- Maximum Storey Drift for MODEL-1

TABLE: Max Story Drift				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m		
Story9	Top	29.2	0.0004	1.29E-07
Story8	Top	26.05	0.0007	5.3E-07
Story7	Top	22.9	0.0009	2.97E-07
Story6	Top	19.75	0.0011	2.49E-07
Story5	Top	16.6	0.001219	2.03E-07
Story4	Top	13.45	0.001293	1.66E-07
Story3	Top	10.3	0.001332	1.86E-07
Story2	Top	7.15	0.001346	1.35E-06
Story1	Top	4	0.001129	1.12E-06
Base	Top	0	0	0

Table 4.3- Maximum storey Drift for MODEL-1

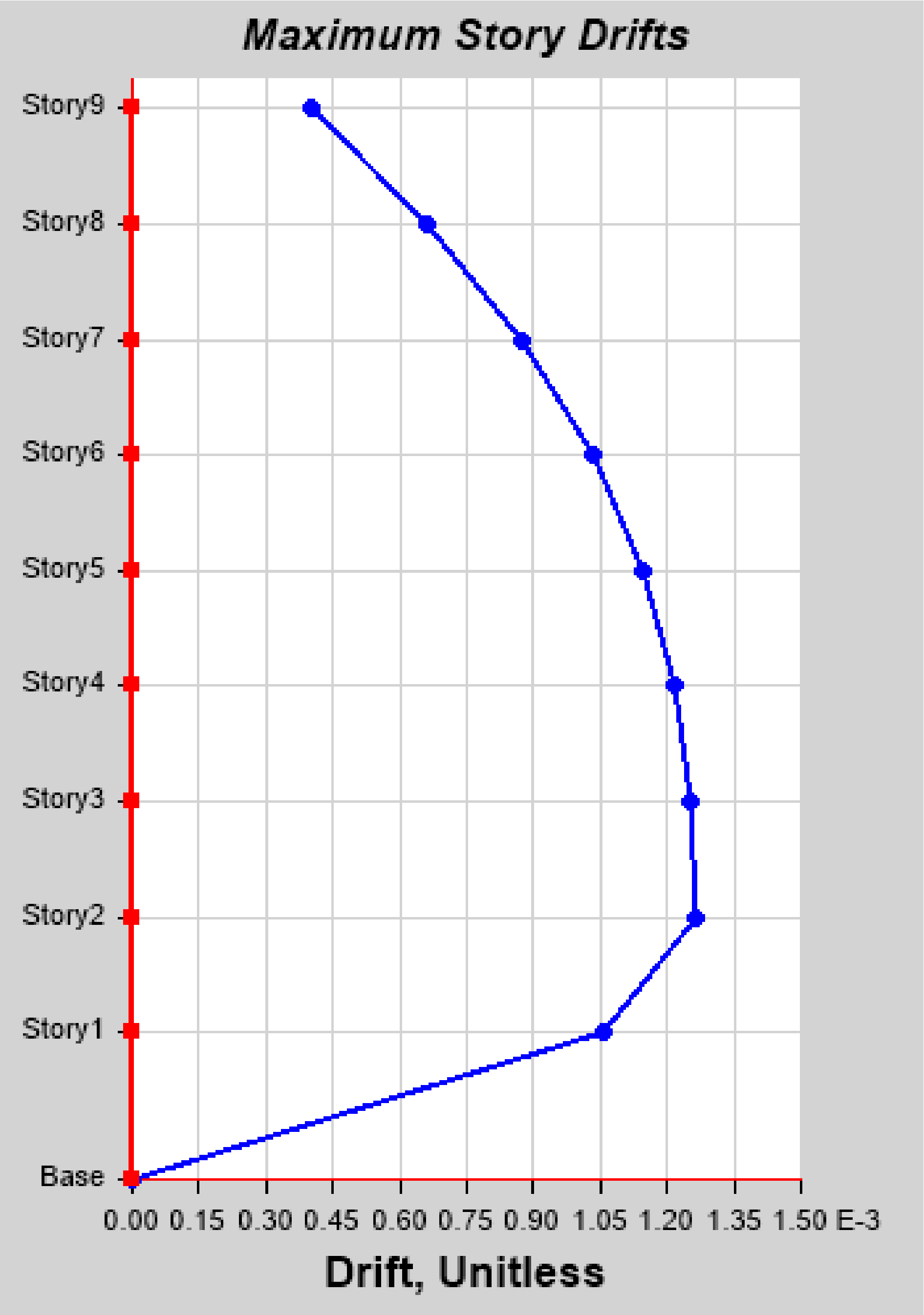


Figure: 4.4- Maximum Storey Drift for MODEL-2

TABLE: Max Story Drift				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m		
Story9	Top	29.2	0.000404	7.64164E-08
Story8	Top	26.05	0.000659	5.09847E-07
Story7	Top	22.9	0.000873	3.00192E-07
Story6	Top	19.75	0.001033	2.50911E-07
Story5	Top	16.6	0.001144	2.04611E-07
Story4	Top	13.45	0.001214	1.68502E-07
Story3	Top	10.3	0.00125	1.67331E-07
Story2	Top	7.15	0.001263	1.17989E-06
Story1	Top	4	0.001056	9.99177E-07
Base	Top	0	0	0

Table 4.4- Maximum storey Drift for MODEL-2

- In Model- 2 the Maximum storey Drift is decreased in X direction by a average 3.22% throughout the height and decreased in Y Direction by 5.857194 % at story 1 and 25.50189 % at top story from Model-1

4.4. Storey Shear:

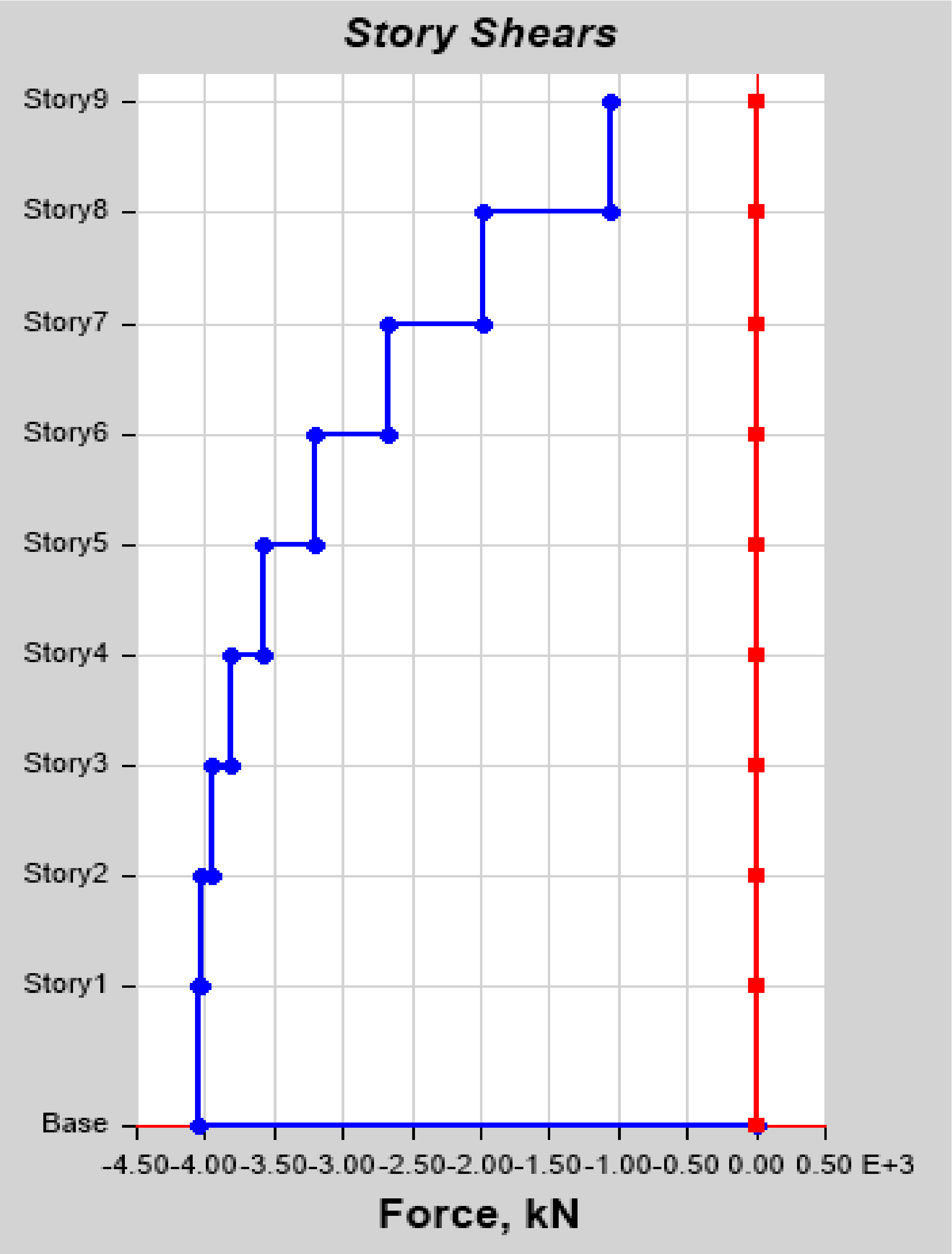


Figure: 4.5- Storey Shear for MODEL-1

TABLE: Story Shear				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		kN	kN
Story9	29.2	Top	-1061.24	1.82E-09
		Bottom	-1061.24	1.82E-09
Story8	26.05	Top	-1973	3.5E-09
		Bottom	-1973	3.5E-09
Story7	22.9	Top	-2677.59	5.01E-09
		Bottom	-2677.59	5.01E-09
Story6	19.75	Top	-3201.68	6.37E-09
		Bottom	-3201.68	6.37E-09
Story5	16.6	Top	-3571.92	7.6E-09
		Bottom	-3571.92	7.6E-09
Story4	13.45	Top	-3814.97	8.57E-09
		Bottom	-3814.97	8.57E-09
Story3	10.3	Top	-3957.51	9.3E-09
		Bottom	-3957.51	9.3E-09
Story2	7.15	Top	-4026.2	9.8E-09
		Bottom	-4026.2	9.8E-09
Story1	4	Top	-4048.13	1.01E-08
		Bottom	-4048.13	1.01E-08
Base	0	Top	0	0
		Bottom	0	0

Table 4.5- Maximum storey Drift for MODEL-1

Figure: 4.6- Storey Shear for MODEL-2

- In Model- 2 the storey Shear is increased in X direction by a average 4.24% throughout from Story 1 to the top story Y Direction it was increased by 2.822787 % at story 1 and 0.803174 % at top story as compared to Model-1

TABLE: Story Shear				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		kN	kN
Story9	29.2	Top	-1169.63	1.79E-09
		Bottom	-1169.63	1.79E-09
Story8	26.05	Top	-2176.73	3.39E-09
		Bottom	-2176.73	3.39E-09
Story7	22.9	Top	-2954.99	4.84E-09
		Bottom	-2954.99	4.84E-09
Story6	19.75	Top	-3533.88	6.12E-09
		Bottom	-3533.88	6.12E-09
Story5	16.6	Top	-3942.83	7.2E-09
		Bottom	-3942.83	7.2E-09
Story4	13.45	Top	-4211.3	8.11E-09
		Bottom	-4211.3	8.11E-09
Story3	10.3	Top	-4368.75	8.8E-09
		Bottom	-4368.75	8.8E-09
Story2	7.15	Top	-4444.62	9.27E-09
		Bottom	-4444.62	9.27E-09
Story1	4	Top	-4468.85	9.51E-09
		Bottom	-4468.85	9.51E-09
Base	0	Top	0	0
		Bottom	0	0

Table 4.6- Maximum storey Drift for MODEL-2

4.5. Story Stiffness:

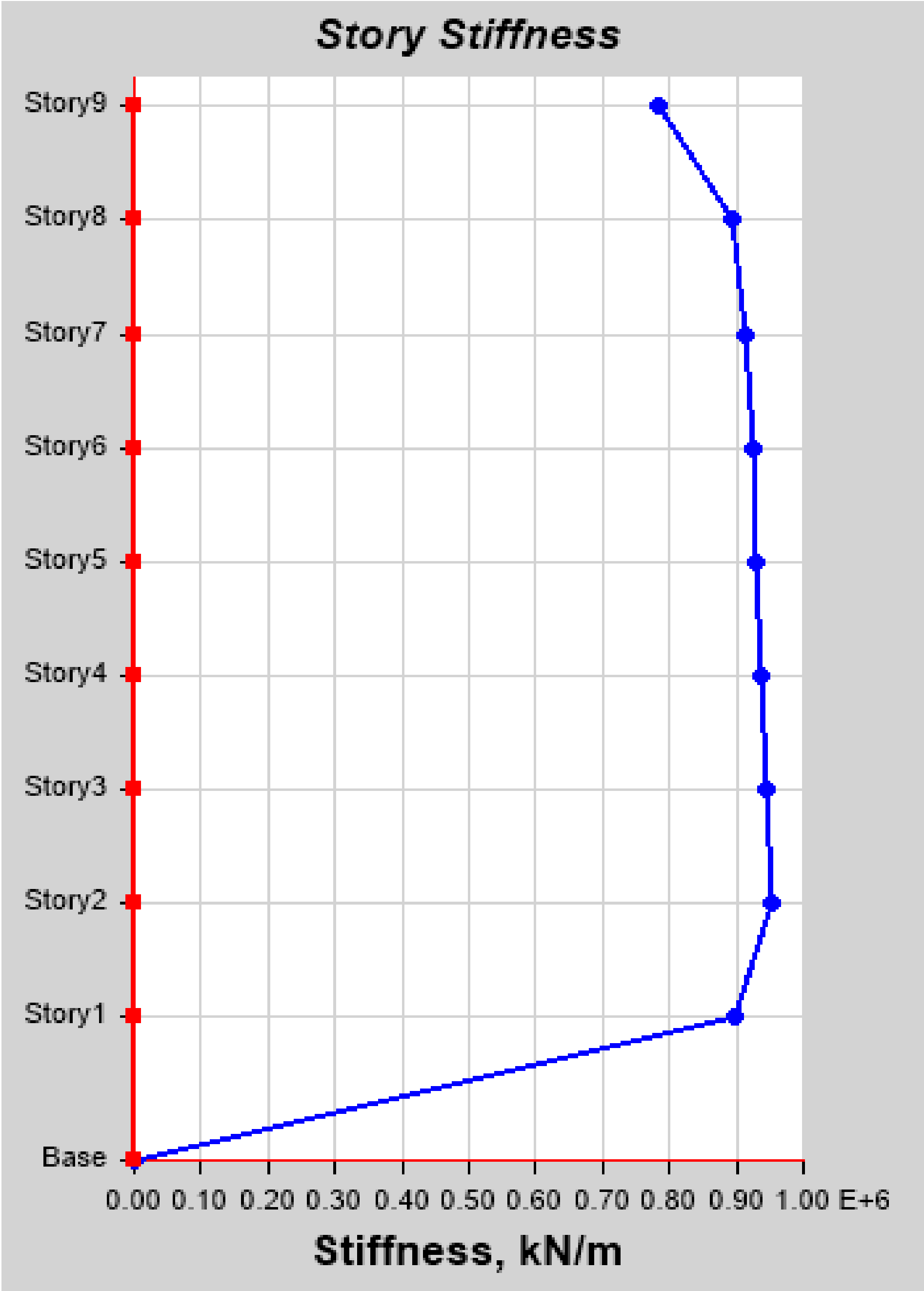


Figure: 4.7- Storey Stiffness for MODEL-1

TABLE: Story Stiffness				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m	kN/m	kN/m
Story9	Top	29.2	783624.5	0
Story8	Top	26.05	892646.3	0
Story7	Top	22.9	914121.7	0
Story6	Top	19.75	923796.6	0
Story5	Top	16.6	930495.4	0
Story4	Top	13.45	936584.8	0
Story3	Top	10.3	943667.5	0
Story2	Top	7.15	951902	0
Story1	Top	4	897860.3	0
Base	Top	0	0	0

Table 4.7- Story Stiffness for MODEL-1

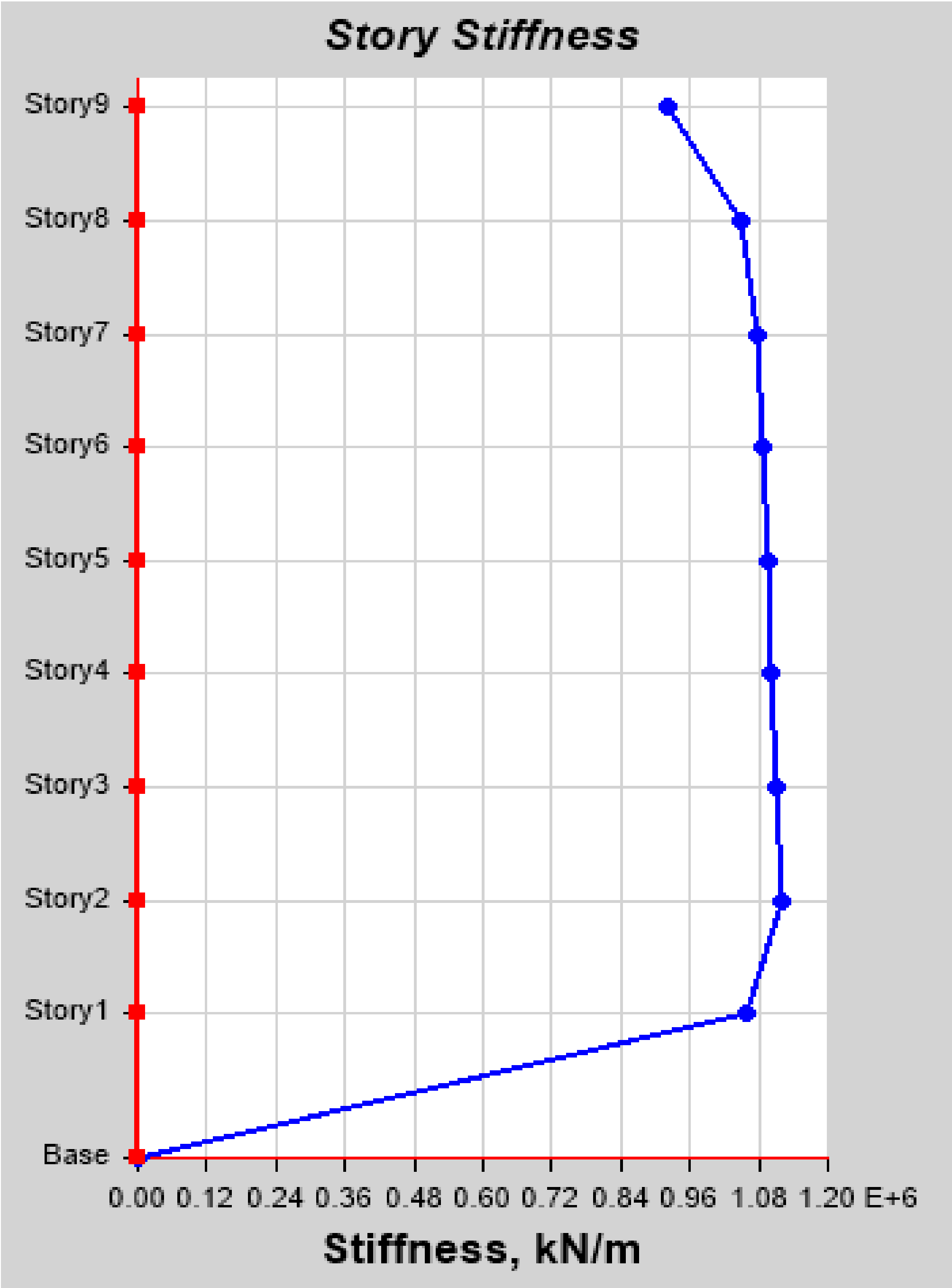


Figure: 4.8- Storey Stiffness for MODEL-1

TABLE: Story Stiffness				
Story	**Location**	**Elevation**	**X-Dir**	**Y-Dir**
		m	kN/m	kN/m
Story9	Top	29.2	921479	0
Story8	Top	26.05	1050285	0
Story7	Top	22.9	1075355	0
Story6	Top	19.75	1086540	0
Story5	Top	16.6	1094270	0
Story4	Top	13.45	1101313	0
Story3	Top	10.3	1109590	0
Story2	Top	7.15	1119758	0
Story1	Top	4	1060064	0
Base	Top	0	0	0

Table 4.8- Story Stiffness for MODEL-1

- In MODEL-2 Story Stiffness is observed to be increases by an average of 8.11 % in X direction from Story 1 to Top Story as compared to MODEL- 1

4.6. Comparative tables of Results:

TABLE: Max Story Displacement						
Story	Location	Elevation m	MODEL-1		MODEL-2	
			X-Dir	Y-Dir	X-Dir	Y-Dir
			mm	mm	mm	mm
Story9	Top	29.2	30.8123514	0.004962469	28.90062	0.00508
Story8	Top	26.05	29.45502846	0.005367979	27.62812	0.00532
Story7	Top	22.9	27.24307073	0.003697602	25.55396	0.00372
Story6	Top	19.75	24.31279066	0.00276242	22.80482	0.00277
Story5	Top	16.6	20.84614292	0.00197682	19.55148	0.00198
Story4	Top	13.45	17.00670255	0.00133773	15.94755	0.00134
Story3	Top	10.3	12.93307513	0.000814452	12.12326	0.00081
Story2	Top	7.15	8.738972363	0.000235755	8.18569	0.00028
Story1	Top	4	4.517252454	0.004494027	4.22404	0.00400
Base	Top	0	0	0	0.00000	0.00000

Table 4.9- Maximum Storey Displacement for MODEL-1 & MODEL-2

TABLE: Max Story Drift						
Story	Elevation	Location	MODEL-1		MODEL-2	
			X-Dir	Y-Dir	X-Dir	Y-Dir
	m					
Story9	29.2	Top	0.000431	1.29E-07	0.000404	7.64E-08
Story8	26.05	Top	0.000702	5.3E-07	0.000659	5.1E-07
Story7	22.9	Top	0.00093	2.97E-07	0.000873	3E-07
Story6	19.75	Top	0.001101	2.49E-07	0.001033	2.51E-07
Story5	16.6	Top	0.001219	2.03E-07	0.001144	2.05E-07
Story4	13.45	Top	0.001293	1.66E-07	0.001214	1.69E-07
Story3	10.3	Top	0.001332	1.86E-07	0.00125	1.67E-07
Story2	7.15	Top	0.001346	1.35E-06	0.001263	1.18E-06
Story1	4	Top	0.001129	1.12E-06	0.001056	9.99E-07
Base	0	Top	0	0	0	0

Table 4.10- Maximum Storey Drift for MODEL-1 & MODEL-2

TABLE: Story Shear						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m		kN	kN	kN	kN
Story9	29.2	Top	-1061.24	1.82E-09	-1169.63	1.79E-09
		Bottom	-1061.24	1.82E-09	-1169.63	1.79E-09
Story8	26.05	Top	-1973	3.5E-09	-2176.73	3.39E-09
		Bottom	-1973	3.5E-09	-2176.73	3.39E-09
Story7	22.9	Top	-2677.59	5.01E-09	-2954.99	4.84E-09
		Bottom	-2677.59	5.01E-09	-2954.99	4.84E-09
Story6	19.75	Top	-3201.68	6.37E-09	-3533.88	6.12E-09
		Bottom	-3201.68	6.37E-09	-3533.88	6.12E-09
Story5	16.6	Top	-3571.92	7.6E-09	-3942.83	7.2E-09
		Bottom	-3571.92	7.6E-09	-3942.83	7.2E-09
Story4	13.45	Top	-3814.97	8.57E-09	-4211.3	8.11E-09
		Bottom	-3814.97	8.57E-09	-4211.3	8.11E-09
Story3	10.3	Top	-3957.51	9.3E-09	-4368.75	8.8E-09
		Bottom	-3957.51	9.3E-09	-4368.75	8.8E-09
Story2	7.15	Top	-4026.2	9.8E-09	-4444.62	9.27E-09
		Bottom	-4026.2	9.8E-09	-4444.62	9.27E-09
Story1	4	Top	-4048.13	1.01E-08	-4468.85	9.51E-09
		Bottom	-4048.13	1.01E-08	-4468.85	9.51E-09
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

Table 4.11- Maximum Storey Drift for MODEL-1 & MODEL-2

TABLE: Story Stiffness						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m		kN/m	kN/m	kN/m	kN/m
Story9	29.2	Top	783624.5	0	921479	0
Story8	26.05	Top	892646.3	0	1050285	0
Story7	22.9	Top	914121.7	0	1075355	0
Story6	19.75	Top	923796.6	0	1086540	0
Story5	16.6	Top	930495.4	0	1094270	0
Story4	13.45	Top	936584.8	0	1101313	0
Story3	10.3	Top	943667.5	0	1109590	0
Story2	7.15	Top	951902	0	1119758	0
Story1	4	Top	897860.3	0	1060064	0
Base	0	Top	0	0	0	0

Table 4.12- Storey Stiffness for MODEL-1 & MODEL-2

4.7. Base Reaction:

Load Case/Combo	FX	FY	FZ	MX	MY	MZ	X	Y	Z
	kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	0	0	49154.66	593094.9	-591152	0	0	0	0
Live	0	0	15552	186624	-186624	0	0	0	0
EQ1 1	-4048.13	0	0	0	-92687.5	48577.51	0	0	0
EQ1 2	0	-4048.13	0	92687.48	0	-48577.5	0	0	0
DCon1	0	0	73731.99	889642.4	-886727	0	0	0	0
DCon2	0	0	97059.99	1169578	-1166663	0	0	0	0
DCon3 Max	0	0	77647.99	1046888	-933331	58293.02	0	0	0
DCon3 Min	-4857.75	-4857.75	77647.99	935662.7	-1044556	-58293	0	0	0
DCon4 Max	4857.752	4857.752	77647.99	935662.7	-822106	58293.02	0	0	0
DCon4 Min	0	0	77647.99	824437.7	-933331	-58293	0	0	0
DCon5 Max	0	0	73731.99	1028674	-886727	72866.27	0	0	0
DCon5 Min	-6072.19	-6072.19	73731.99	889642.4	-1025758	-72866.3	0	0	0
DCon6 Max	6072.189	6072.189	73731.99	889642.4	-747696	72866.27	0	0	0
DCon6 Min	0	0	73731.99	750611.2	-886727	-72866.3	0	0	0
DCon7 Max	0	0	44239.19	672816.7	-532036	72866.27	0	0	0
DCon7 Min	-6072.19	-6072.19	44239.19	533785.4	-671068	-72866.3	0	0	0
DCon8 Max	6072.189	6072.189	44239.19	533785.4	-393005	72866.27	0	0	0
DCon8 Min	0	0	44239.19	394754.2	-532036	-72866.3	0	0	0

Table 4.13- Base Reaction for MODEL-1

Load Case/Combo	FX	FY	FZ	MX	MY	MZ	X	Y	Z
	kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	0	0	59584.46	715013.5	-715013	0	0	0	0
Live	0	0	29376	352512	-352512	0	0	0	0
EQ 1	-4468.85	0	0	0	-102304	53626.2	0	0	0
EQ 2	0	-4468.85	0	102304	0	-53626.2	0	0	0
DCon1	0	0	89376.69	1072520	-1072520	0	0	0	0
DCon2	0	0	133440.7	1601288	-1601288	0	0	0	0
DCon3 Max	0	0	106752.5	1403795	-1281031	64351.44	0	0	0
DCon3 Min	-5362.62	-5362.62	106752.5	1281031	-1403795	-64351.4	0	0	0
DCon4 Max	5362.62	5362.62	106752.5	1281031	-1158266	64351.44	0	0	0
DCon4 Min	0	0	106752.5	1158266	-1281031	-64351.4	0	0	0
DCon5 Max	0	0	89376.69	1225976	-1072520	80439.31	0	0	0
DCon5 Min	-6703.28	-6703.28	89376.69	1072520	-1225976	-80439.3	0	0	0
DCon6 Max	6703.275	6703.275	89376.69	1072520	-919064	80439.31	0	0	0
DCon6 Min	0	0	89376.69	919064.2	-1072520	-80439.3	0	0	0
DCon7 Max	0	0	53626.01	796968.2	-643512	80439.31	0	0	0
DCon7 Min	-6703.28	-6703.28	53626.01	643512.1	-796968	-80439.3	0	0	0
DCon8 Max	6703.275	6703.275	53626.01	643512.1	-490056	80439.31	0	0	0
DCon8 Min	0	0	53626.01	490056.1	-643512	-80439.3	0	0	0

Table 4.14- Base Reaction for MODEL-2

4.8. Modal Results:

MODEL- 1

Modal Participating Mass Ratios (Part 1 of 2)								
Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ
Modal	1	0.868	0.0113	0.8386	0	0.0113	0.8386	0
Modal	2	0.868	0.8386	0.0113	0	0.8499	0.8499	0
Modal	3	0.762	0	0	0	0.8499	0.8499	0
Modal	4	0.283	0.0004	0.0953	0	0.8504	0.9452	0
Modal	5	0.283	0.0953	0.0004	0	0.9457	0.9457	0
Modal	6	0.249	0	0	0	0.9457	0.9457	0
Modal	7	0.162	1.08E-05	0.03	0	0.9457	0.9756	0
Modal	8	0.162	0.03	1.08E-05	0	0.9757	0.9757	0
Modal	9	0.144	0	0	0	0.9757	0.9757	0
Modal	10	0.111	0.0128	0.0002	0	0.9885	0.9759	0
Modal	11	0.111	0.0002	0.0128	0	0.9887	0.9887	0
Modal	12	0.099	0	0	0	0.9887	0.9887	0

Table 4.15- Modal Participating Mass Ratios (Part 1 of 2)- MODEL-1

Modal Participating Mass Ratios (Part 2 of 2)							
Case	**Mode**	**RX**	**RY**	**RZ**	**Sum RX**	**Sum RY**	**Sum RZ**
Modal	1	0.1686	0.0023	1.06E-05	0.1686	0.0023	1.06E-05
Modal	2	0.0023	0.1686	3.62E-05	0.1709	0.1709	4.68E-05
Modal	3	0	0	0.854	0.1709	0.1709	0.854
Modal	4	0.6593	0.0029	9.82E-07	0.8302	0.1737	0.854
Modal	5	0.0029	0.6593	4.28E-06	0.8331	0.8331	0.854
Modal	6	0	0	0.092	0.8331	0.8331	0.946
Modal	7	0.0635	2.29E-05	0	0.8965	0.8331	0.946
Modal	8	2.29E-05	0.0635	1.44E-06	0.8966	0.8966	0.946
Modal	9	0	0	0.0298	0.8966	0.8966	0.9758
Modal	10	0.001	0.0647	6.71E-07	0.8976	0.9613	0.9758
Modal	11	0.0647	0.001	0	0.9623	0.9623	0.9758
Modal	12	0	0	0.013	0.9623	0.9623	0.9888

Table 4.16- Modal Participating Mass Ratios (Part 2 of 2)- MODEL-1

Modal Load Participation Ratios				
Case	Item Type	Item	Static	Dynamic
			%	%
Modal	Acceleration	UX	99.99	98.87
Modal	Acceleration	UY	99.99	98.87
Modal	Acceleration	UZ	0	0

Table 4.17- Modal Load Participation Ratios

Modal Direction Factors						
Case	Mode	Period	UX	UY	UZ	RZ
		sec				
Modal	1	0.868	0.013	0.987	0	0
Modal	2	0.868	0.987	0.013	0	0
Modal	3	0.762	0	0	0	1
Modal	4	0.283	0.004	0.996	0	0
Modal	5	0.283	0.996	0.004	0	0
Modal	6	0.249	0	0	0	1
Modal	7	0.162	0	1	0	0
Modal	8	0.162	1	0	0	0
Modal	9	0.144	0	0	0	1
Modal	10	0.111	0.985	0.015	0	0
Modal	11	0.111	0.015	0.985	0	0
Modal	12	0.099	0	0	0	1

Table 4.18- Modal Direction Factors

MODEL- 2

Modal Results								
Modal Participating Mass Ratios (Part 1 of 2)								
Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ
Modal	1	0.814	0.0152	0.8345	0	0.0152	0.8345	0
Modal	2	0.814	0.8345	0.0152	0	0.8496	0.8496	0
Modal	3	0.715	0	0	0	0.8496	0.8496	0
Modal	4	0.265	0.084	0.0118	0	0.9336	0.8614	0
Modal	5	0.265	0.0118	0.084	0	0.9454	0.9454	0
Modal	6	0.234	0	0	0	0.9454	0.9454	0
Modal	7	0.152	0.0104	0.0197	0	0.9558	0.9651	0
Modal	8	0.152	0.0197	0.0104	0	0.9755	0.9755	0
Modal	9	0.135	0	0	0	0.9755	0.9755	0
Modal	10	0.104	0.0016	0.0115	0	0.9771	0.987	0
Modal	11	0.104	0.0115	0.0016	0	0.9886	0.9886	0
Modal	12	0.092	0	0	0	0.9886	0.9886	0

Table 4.19- Modal Participating Mass Ratios (Part 1 of 2)- MODEL-2

Table 2.5 - Modal Participating Mass Ratios (Part 2 of 2)							
Case	Mode	RX	RY	RZ	Sum RX	Sum RY	Sum RZ
Modal	1	0.1577	0.0029	0	0.1577	0.0029	0
Modal	2	0.0029	0.1577	0	0.1606	0.1606	0
Modal	3	0	0	0.8538	0.1606	0.1606	0.8538
Modal	4	0.0825	0.5867	0	0.243	0.7473	0.8538
Modal	5	0.5867	0.0825	0	0.8297	0.8297	0.8538
Modal	6	0	0	0.092	0.8297	0.8297	0.9458
Modal	7	0.0425	0.0224	0	0.8722	0.8521	0.9458
Modal	8	0.0224	0.0425	0	0.8946	0.8946	0.9458
Modal	9	0	0	0.0299	0.8946	0.8946	0.9757
Modal	10	0.0585	0.0084	0	0.9531	0.903	0.9757
Modal	11	0.0084	0.0585	0	0.9615	0.9615	0.9757
Modal	12	0	0	0.013	0.9615	0.9615	0.9887

Table 4.20- Modal Participating Mass Ratios (Part 2 of 2)- MODEL-2

Modal Load Participation Ratios				
Case	Item Type	Item	Static	Dynamic
			%	%
Modal	Acceleration	UX	99.99	98.86
Modal	Acceleration	UY	99.99	98.86
Modal	Acceleration	UZ	0	0

Table 4.21- Modal Load Participation Ratios - MODEL-2

Modal Direction Factors						
Case	Mode	Period	UX	UY	UZ	RZ
		sec				
Modal	1	0.814	0.018	0.982	0	0
Modal	2	0.814	0.982	0.018	0	0
Modal	3	0.715	0	0	0	1
Modal	4	0.265	0.877	0.123	0	0
Modal	5	0.265	0.123	0.877	0	0
Modal	6	0.234	0	0	0	1
Modal	7	0.152	0.345	0.655	0	0
Modal	8	0.152	0.655	0.345	0	0
Modal	9	0.135	0	0	0	1
Modal	10	0.104	0.125	0.875	0	0
Modal	11	0.104	0.875	0.125	0	0
Modal	12	0.092	0	0	0	1

Table 4.22- Modal Direction Factors - MODEL-2

CHAPTER 5
CONCLUSION

1. Increasing percentage of steel fibre in SFRC (Vf) provides higher flexural strength of SFRC, another relationship has been revealed between flexural strength, tensile strength splitting. This concludes an important relation in designing of SFRC members.
2. Tensile Strength of the ultra high reinforced steel Fibre capacity from 0 percent to 3.0 % hooked based steel Fibre reinforced concrete increases considerably.
3. The strength-effectiveness showed at each volume fraction a maximum for splitting tensile strength, and compressive strength.
4. The compressive strength of the concrete increases significantly as the volume of steel fibers increases from 0.5 per cent to 1 per cent and the increase is almost similar to all the normal concrete grade that is M20, M25, M30, M40.
5. Higher percentage of Steel Fibres slump was down.
6. Performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete
7. Addition of Steel Fibres into Concrete somehow decreases the adhesion between cement and aggregates.
8. Maximum storey Displacement is decreased in case of SFRC Model (MODEL-2)
9. Maximum storey Drift at both top and 1st story of the building was found to be decreased in case of SFRC model (MODEL-2)
10. Storey Shear is increased at respective stories in case of SFRC Model (MODEL-2)
11. Story Stiffness is observed to be increased by an average of 8.11 % in case of SFRC Model (MODEL-2)
12. Performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete

5.1. FUTURE SCOPE

1. Behaviour of SFRC based model has shown significantly better performance under seismic loads, hence it can be opted as a seismic resistant material in future research work.
2. Further study is required to understand the effect of other Fibre types, such as straight steel Fibres and synthetic Fibres.

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APPENDIX

URKUND

Document Information

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Steel Fibre Reinforced Concrete as a Structural Material: A Review

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Abstract - This Paper discusses the application of Steel Fibre Reinforced Concrete (SFRC) as a structural material in the modern construction practices as an more effective substitute to the conventional concrete. Use of SFRC has become more prominent nowadays and is likely to increase in future; hence it becomes very important to understand the role of various types of steel fibres that are used in SFRC, its geometrical, mechanical properties and strength outcomes that will surely enhance its application. Various types of steel fibres used are discussed in this paper, also what are the essential tests that are needed to perform on SFRC in order to predict its various mechanical properties that will compare its certain parameters with the conventional concrete.

Keywords: Steel fibre, concrete, Steel–concrete composite beams, SFRC, Compressive Strength,

I. INTRODUCTION

Use of Fibre reinforced concrete as a Structural material is something not new, its use to some extent has been seen several times as an old technique, but as the time changes, its importance and applications have evolved. Studies have proved that the use of Fibre Reinforced Concrete changes the properties of concrete that make it more useful material to be used as a structural component in Structures [5]. Use of Steel Fibre Reinforced Concrete(SFRC) is very prominent in the modern age as it is much cheaper, easier to use and experimental studies has shown it increases the strength of concrete to some extent.. Nowadays Steel Fibre Reinforced Concrete (SFRC) is widely used in the construction of many complex structures like industrial slabs, airfields, tunnels, elevated slabs, pedestrian bridges, roadways and many modular prefabricated buildings [9-14]. The SFRC has many benefits in the modern construction practices but the only disadvantage is that it decreases the workability and increases the stiffness of fresh concrete [6]. SFRC sometimes also used with certain admixtures like Fly Ash and silica fume, and shown a marginal increase in its workability as well with increasing the percentage of such admixtures [1]. The performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete[6].

It can be said that the addition of steel Fibres has an influe nce on the stressstrain relationship in compression,and the level of critical stresses increases in conjunction with the a mount of steel Fibres added to the concrete mixture[2].

II. TYPES OF STEEL FIBRES

Steel Fibre is a composite of metals. Steel Fibre for reinforcing concrete is defined as short, discrete lengths of steel Fibres with an aspect ratio (length to diameter ratio) of about 20 to 100, with different cross-sections, and which are small enough to be dispersed randomly in an unhardened concrete mixture using the usual mixing methods [8]. There are two methods by which Fibres can be classified according to their elasticity modulus or roots. From the elasticity module point of view, Fibres can be classified into two basic categories, namely those with a higher elastic modulus than concrete mix (called hard intrusion) and those with lower elastic modulus than concrete mix (called soft intrusion) [6]. On the basis of formation Steel Fibres can be categorized as a cold drawn wire Fibre with corrugated and flatted shape.

The five most popular steel Fibre types are: traditionally straight, hooked, crimped, coned, and deformed mechanically. The geometries of the described non-straight fibres is shown in Figure 1.1, 1.2 and 1.3.

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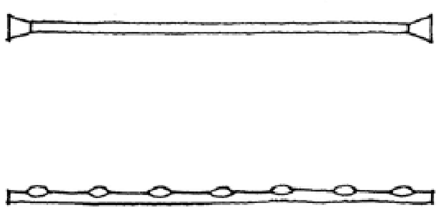
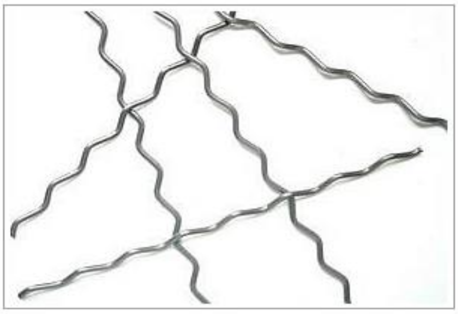


Coned and Mechanically Deformed Steel Fibres (Figure1.1)

Flatted shape Steel Fibre with Hook (Figure1.3) [15]



Corrugated Type Steel Fibre (Figure1.2) [15]

Concrete with Steel Fibre[8]

III. EFFECT OF ADDING STEEL FIBRES IN CONCRETE

A certain amount of steel Fibre in concrete can cause qualitative changes in the physical properties of concrete, greatly increasing cracking resistance, fatigue and Flexural Strength, toughness, durability and other properties [16]. [17] used 6 mm long steel Fibres are used to manufacture self sensing with tensile strain sensing properties.

IV. PROPERTIES OF STEEL FIBRE REINFORCED CONCRETE

Nowadays Steel Fibre Reinforced Concrete is widely used as important building material in civil engineering applications such as bridges and road engineering, and the associated experimental study of the mechanical properties of concrete will also be fruitful. Some of the important Properties to consider are as follows:

1.1. Compressive Strength:

Brittleness with low tensile strength and strain capacities of ultra high strength concrete (UHSC) can be overcome by the addition of steel Fibres [26].

UHSC's compressive strength increased with steel Fibres applied at different volumes Faults. The strength showed a maximum fraction at 0.75% but a slight decrease at 1.0% and 1.5% fraction compared to 0.75 percent, which is still 10.6 percent higher than before the addition of Fibre [27].

In an experimental research performed by [28] on SFRC, the variation of compressive strength for different grade of concretes for SFRC(0%, 0.5%, 1%, 1.5% steel Fibre reinforced concrete) is shown by the Tabular representation as follows:

Days of Curing	Volume of Steel Fibres(%)	COMPRESSIVE STRENGTH(N/mm2)			
		M20	M25	M30	M40
3days	0%	13.2	15.69	19.41	27.17
	0.50%	15.2	18.34	22.87	32.91
	1%	17.11	20.63	25.6	36.4
	1.50%	18.69	22.12	27.89	39.39
7days	0%	18.9	24.6	32.21	41.45
	0.50%	21.11	28.78	37.37	47.67
	1%	24.38	33.1	42.81	54.37
	1.50%	27.73	35.71	46.03	59.93
28days	0%	28.7	33.4	41.37	52.76
	0.50%	32.98	37.83	46.79	60.8
	1%	37.93	43.74	53.76	68.79
	1.50%	41.02	48.03	59.86	75.84

Table- 1: Compressive Strength of Concrete

The experimental work performed by [3] shows that the increase in percentage of steel fibre in concrete subjected to hogging moment increases its compressive strength.

1.2. Tensile Strength:

As per experimental study done by [27], the strength enhancing ultra high reinforced steel Fibre capacity Concrete strength (SFRC) containing 0.5%, 0.75%, 1.0%

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and 1.5% volume of hooked-end steel Fibres. Compared with the counterpart for plain ultra high-strength concrete (UHSC).Increase of SFRC compressive resistance. Compared to UHSC, 0.5 percent volume fractions, 0.75 percent, 1.0 percent, and 1.5 percent steel Fibre.

$$\text{Strength-effectiveness} = \frac{\text{SFRC strength - UHSC strength}}{\text{UHSC strength}} \times 100\%$$

Specimen	Fiber volume fraction V_f [%]	Compressive strength f_{cf} Measured [MPa]	Compressive strength f_{cf} Strength-effectiveness* [%]	Splitting tensile strength f_{tf} Measured [MPa]	Splitting tensile strength f_{tf} Strength-effectiveness* [%]
UHSC	0.00	103.6	—	5.05	—
SFRC-0.50	0.50	115.4	11.4	6.98	38.2
SFRC-0.75	0.75	119.7	15.5	9.38	85.7
SFRC-1.00	1.00	116.3	12.3	9.49	87.9
SFRC-1.50	1.50	114.6	10.6	9.69	91.9

Table 1: Compressive strength and splitting tensile strength of SFRC

The tensile strength increases significantly as the volume of steel Fibres is increase is similar to the grade of concrete [3, 28].

1.3. Shear Strength:

Previous work has shown that addition of Steel Fibres significantly increases concrete's shear strength [30]. The ultimate shear strength of SFRC which contains 1% by volume of Steel Fibres increases by up to 170% compared to RC without Steel Fibres [31]. The ultimate shear strength of SFRC which contains 1% by volume of SFs increases by up to 170% compared to RC without SFs [30, 32].

V. TESTING ON SFRC

The main objective of testing SFRC members is to investigate various important properties for the consumptive use of it. Various mechanical properties of SFRCs helps to understand its behavior as a structural element and limitations as well. Some of the important Tests performed for SFRC are as follows:

1.4. Ultrasonic pulse velocity test of SFRC:

Ultrasonic pulse velocity test is a kind of non-destructive test method carried out, involving ultrasonic pulse velocity test applied to different SFRC mixtures. The theory of this test is that sound velocity in a solid material (V) is a function of the square root ratio of its Young's Modulus (E) to its density (ρ) [18]. The equation is as follows according to Polish standards:

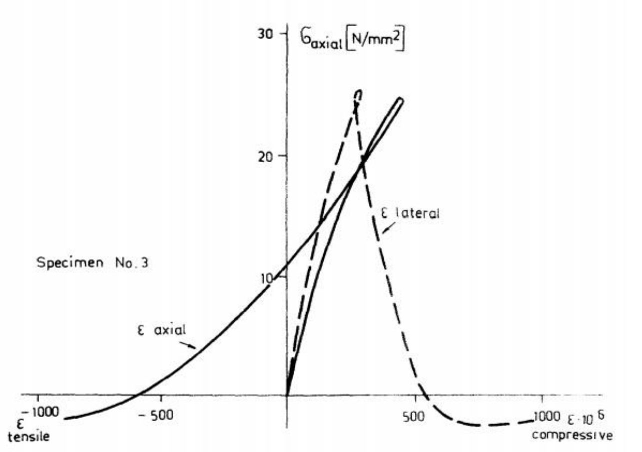
$$E = V^2 \cdot \rho$$

This relationship can be used to evaluate the elasticity modulus and thus as a means of testing the concrete consistency.

The test is also useful for detecting voids, corrosion caused by frost or fire and uniformity of concrete in similar elements [22]. The ordinary concrete's pulse velocity depends on the aggregate elasticity modulus and the aggregate content of the mix. Steel reinforcement is also well known to contribute to increased ultrasonic pulse velocity. Both of these drawbacks have led the ultrasonic pulse velocity test to be rarely used to determine the characteristics of reinforced concrete made from steel Fibre (SFRC) [18].

1.5. Tri-axial loading Tests on SFRC:

The stress-strain relationships were obtained for the direct tension and flexure control tests and the typical stress-strain curves for the tri-axially tested specimens and shown in figure



Stress-strain curves for the specimen in triaxial loading [23]

1.6. Uniaxial Tension Test for SFRC:

Uniaxial tension test was performed for SFRC and an experimental program was conducted by [24] to investigate the pre- and post-cracking behavior of a single SFRC mix through uniaxial stress tests with varying boundary conditions (fixed-fixed (FF), rotating-rotating (RR), and fixed-rotating (FR)). For each research set-up four specimens were produced. The steel Fibres were 35 mm in length, 0.55 mm in diameter and 1340 MPa in ultimate notional tensile force. The dosage of Fibres used in this analysis was 60 kg / m3. The concrete was delivered through a local prepared mixing plant and shipped to Laboratory without the included Fibres in this combination. The specified concrete compressive strength was 40 MPa (the compressive strength of the measured cylinder concrete was 63 MPa at the time of the test), and the coarse aggregate used was basalt with a maximum particle size of 10 mm. The Fibres were inserted into the Stirrer on site and mixed 10 minutes beforehand To cast exemplars. A standard drop in

Test was used to evaluate the operability of the New SFRC, and the recession assessed Found 200 mm long. The test

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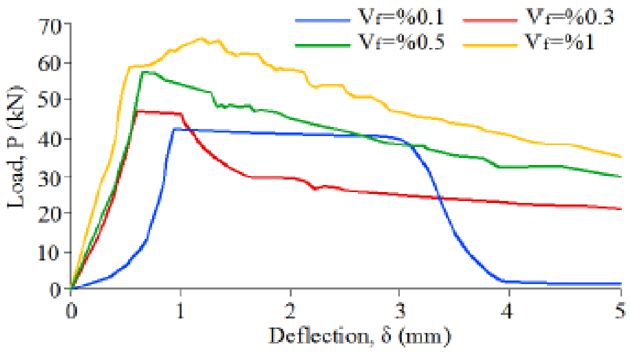
result shows Concrete Elastic Deformations near the crack there are negligible relative to the opening of the ripple; also the concentrations of shape-induced tensile stress are low and can be heterogeneous, and the specimen's ability to redistribute stresses in the experiment [24].

1.7. Split Tensile Test:

The addition of Fibres to concrete significantly improves its tensile strength and a good correlation exists between the st rength of the splitting tensile and the volume fraction of the fibre, as well as between the strength of the splitting tensile and the index of Fibre strengthening. Splitting tensile strength and flexural resistance testing are preferred to evaluate SFRC tensile efficiency. The splitting test of tensile strength needs a standard cube or cylinder specimen while the flexural strength test requires a heavy beam specimen with larger dimensions provided by most norms [25, 26]. Hardened concrete experiments were carried out in water on 28 days of cured concrete specimens. According to the TS EN 12390-3 (2010) and the TS EN 12390-6 (2010) specifications, compressive and splitting tensile strength tests were evaluated for the investigation of mechanical properties. Additionally, in accordance with the TS 10515 (1992) standard, a 4-point flexural strength test was performed using 150 environ1505500 mm of beam specimens. Load-deflection data of the SFRC specimens were collected during flexural strength tests. The maximum flexural resistance of SFRC specimens was determined using peak load. Toughness values for maximum 5 mm midpoint displacement value of the beam specimens were taken into account as the area under the load-deflection curves. Figure shows typical load-deflection curves of SFRC specimens [25]. The toughness of SFRC is significantly higher than normal concrete without Fibres (ACI 544.1R, 2002),



Load-deflection curves of SFRC specimens.

1.8. Workability Test:

[28] Workability is carried out by conducting the slump test and compaction factor test as per IS 1199-1959 on ordinary concrete and Fibre reinforced concrete. The properties of fresh concrete can be evaluated by slump cone test & compaction factor test with W/C ratio 0.4. The result of properties are given in

S.No.	Mix type (SF %, SF&FA %)	Slump value(mm)	compaction factor
01	MS0(0.0%, 0.0%&0.0%)	78	0.952
02	MS1 (0.5%, 5%&5%)	23	0.820
03	MS2 (0.5%, 10%&10%)	38	0.810
04	MS3 (0.5%, 15%&15%)	49	0.902
05	MS4 (1.0%, 5%&5%)	18	0.801
06	MS5 (1.0%, 10%&10%)	21	0.786
07	MS6 (1.0%, 15%&15%)	31	0.802
08	MS7 (1.5%, 5%&5%)	12	0.740
09	MS8 (1.5%, 10%&10%)	15	0.792
10	MS9 (1.5%, 15%&15%)	19	0.810

VI. BENEFITS OF SFRC

- Steel Fibres' beneficial influence in concrete depends on many factors, such as type , shape, length, cross section, strength, Fibre content, bond strength of steel Fibres, matrix strength, mixing design and concrete mixing [6].
- Steel Fibres also improves the Brittle Nature of the Concrete.
- Steel Fibres increase the tensile strength of the matrix, thereby improving the flexural strength of the concrete.
- Increase ductility of the concrete
- SFRC is more durable and serviceable than conventional Reinforced Concrete [29].
- In SFRC structures, corrosion in concrete structures due to cracks is less severe than in conventional RC structures[19- 21, 4].

VII. APPLICATIONS OF SFRC

- There are numerous applications of steel Fibre reinforced concrete (SFRC) for large blocks such as heaw vibrating equipment foundations, dolos armor units, spillways, road overlays, etc [23].
- Adding Steel Fibres increases the stability, ductility and integrity of conventional RC members under earthquake and blast loads (dynamic loads) [6].
- Increases the strength of RC members to shear. As a result, the shear strength of the slabs will increase and sudden punching failure can be transformed into a slow ductile failure [37].
- SFRC may be found in prefabricated items such as manhole coverings, concrete tubing, and machine bases and frames.
- Can provide enhanced impact resistance to traditional RC members, enhancing local damage and spreading resistance (spalling) [37].
- Adding SFs can prevent crack growth and crack widening; this may allow the use of high-strength steel bars without undue crack width or duty load deformation [38, 39].

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VIII. CONCLUSION

- Increasing percentage of steel fibre in SFRC (V_f) provides higher flexural strength of SFRC, another relationship has been revealed between flexural strength, tensile strength splitting and Vf value varying from 0.1% to 1% [25]. This concludes an important relation in designing of SFRC members.
- Tensile Strength of the ultra high reinforced steel Fibre capacity from 0 percent to 1.5 % hooked based steel Fibre reinforced concrete increases considerably.
- The strength-effectiveness showed at each volume fraction a maximum for splitting tensile strength, and compressive strength [27].
- Further study is required to understand the effect of other Fibre types, such as straight steel Fibres and synthetic Fibres.
- The concrete's compressive strength increases considerably as the volume of steel Fibres increases from 0.5 percent to 1 percent and the increase is nearly similar to all the normal concrete grade that is M20, M25, M30, M40.
- Higher percentage of Steel Fibres slump was down.
- Performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete
- Addition of Steel Fibres into Concrete somehow decreases the adhesion between cement and aggregates [2].

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An Analytical Modeling of Steel Fiber Reinforced Concrete as a Structural Member

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Abstract: *The purpose of this research work is to introduce the application of Steel Fiber Reinforced Concrete (SFRC) as a structural material in building structural load bearing elements like Columns and beams, for this purpose first the previous research work was referred that have been done to obtain various important mechanical properties of SFRC which helps us to understand its behavior as a structural element. After getting most appropriate properties obtained by experimental material testing on SFRC, the material was simulated using software approach. The software used in this analysis was ETABS 17.0.0. After modifying this SFRC material with Conventional M40 grade concrete, seismic analysis of G + 8 story RC frame building was performed and the results have definitely shown that SFRC building Model have performed better under seismic loading.*

Keywords: Steel Fiber, Concrete, Steel Fiber Reinforced Concrete Beams, Steel Fiber Reinforced Concrete Column, SFRC MODEL, Seismic Analysis

1. INTRODUCTION:

As the market for high-resistance concrete has risen, reinforced concrete's structural nature has become more brittle. To mitigate this side effect, steel fiber-reinforced concrete (SFRC) has emerged as a viable method for obtaining ductility not only during tensioned post-cracking behaviour, but also during compressed post-peak softening behaviour. Use of SFRC as a structural member has also found to increase its ductility to some extent that may be proved to be a better material under seismic loading as well. Steel fiber reinforced concrete (SFRC) has a distinctive tensile strength, impact resistance, resistance to fatigue, flexural resistance ductility and crack arrest capability. They also diminish concrete permeability and thus decrease water bleeding. It is, such building material is studied for over 40 years as well as for pavement construction [1]. Many experimental research in past have been performed that aims to collect data on the effect of steel fiber and its combination on workability, compressive strength , flexural strength and non-destructive testing (NDT) such as Rebound Hammer, in order to assess SFRC efficiency relative to traditional concrete[2- 12]. There are many types of steel Fiber available in the market but majorly used types are: traditionally straight, hooked, crimped, coned, etc. In the present framework various mechanical properties of hooked end steel fiber is used for the modeling of SFRC.

The experimental research performed by [13] shows that the rise in the proportion of steel fibers in concrete subjected to the moment of hogging increases their compressive power. As per experimental study done by [14], the strength enhancing ultra high reinforced steel Fiber capacity Concrete strength (SFRC) containing 0.5%, 0.75%, 1.0% and 1.5% volume of hooked-end steel Fibers. Steel Fiber reinforced concrete (SFRC) is utilized in various applications for broad blocks such as heaw vibrating machinery frames, dolos shield systems, spillways, bridge overlays, etc [15]. Also addition of Steel Fibers in concrete improves the resilience, ductility and durability of standard RC members under earthquake and blast loads (dynamic loads) [16]. In terms of minimizing the development of cracks in concrete by Adding SFs one can prevent crack growth and crack widening; this may allow the use of high-strength steel bars without undue crack width or duty load deformation [17, 18]. Spalling of concrete is seen many times due to excessive loading and low confinement, use of SRFC may reduce this problem to some extent by providing enhanced impact resistance to traditional RC members, enhancing local damage and spreading resistance [19].

2. METHODOLOGY:

Based on previous research and experimental works performed by many researches on determination of various mechanical properties and behavior of SFRC under Flexural, Compression as well as Tension further seismic analysis for this research was done. Research has shown that behavior of SFRC is much similar to that of normal concrete with minor exception. In an experimental work on M20 concrete [9] observed that its superior resistance to cracking and crack propagation is one of the important properties of Steel Fiber Reinforced Concrete (SFRC). And the concrete is reinforced in various amounts with the steel fiber such as 0 percent, 0.5 percent, 1.0 percent, 1.5 percent, 2 percent, 2.5 percent and 3 percent by cement weight. Aspect Ratio 60 (30 mm long and 0.5 mm diameter) has been tested for all volume proportions. On the 7th, 14th and 28th day of curing the Compressive and Tensile Strength were analyzed as per IS standards. The results obtained were as follows:

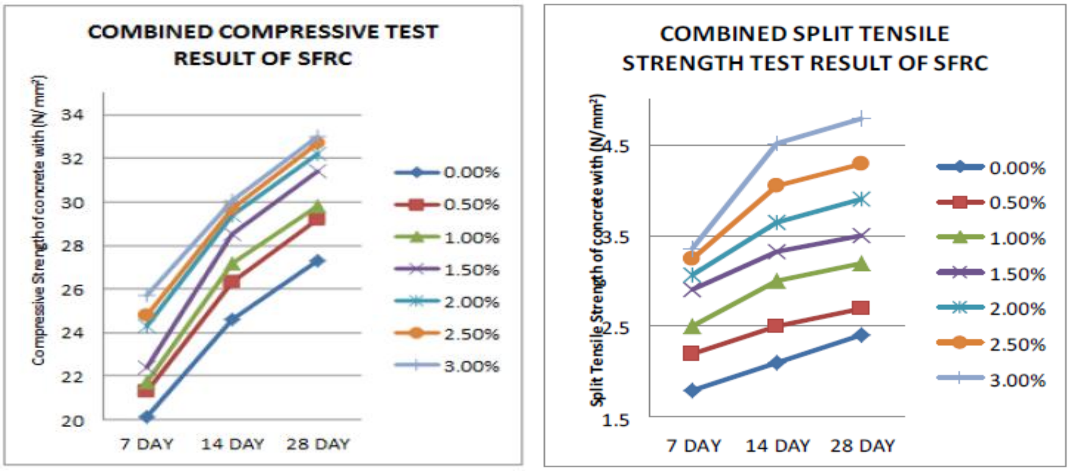


Figure: 2.1 Comparision of Strength parameters of SFRC [9]

It can be observed that the Compressive strength for M20 concrete is in increasing order from 0.0 % to 3 % of steel fiber use concrete and the maximum strength is gained at 3.0% that is 33 MPa. Also for the same samples the Split Tensile strength is in increasing order and the maximum strength is gained at 3.0 % that is 4.8MPa.

In an another experiment performed by [10, 11] in which Hook end steel fiber with different aspect ratio of 50, 60 and 67 were used in M40 grade concrete with with 0%, 1%, 2% and 3% Steel Fiber. For the same samples with different aspect ratios maximum increase in percentage flexural strength was found with Hook end steel Fiber Reinforced M40 concrete with aspect ratio 50. The results for the percentage increase in flexural strength and compressive strengths of different % of steel fiber containing SFRC for Aspect ratio 50 is represented by the graph shown in

FLEXURAL STRENGTH OF SFRC WITH 0%, 1%, 2% and 3% FIBERS				
Different aspect ratios of fibers	**For Normal M40**	**For SFRC**	**For SFRC**	**For SFRC**
	with 0% fibers	**with 1% fibers**	**with 2% fibers**	**with 3% fibers**
	Flexural strength (MPa)			
	Avg.	**Avg.**	**Avg.**	**Avg.**
	7.47	8.8	9.47	10.4
		8.4	9.2	10
		8.27	9	9.73

Table: 2.1 Flexural Strength of SFRC with 0% of steel fiber in M40 grade concrete

COMPRESSIVE STRENGTH OF SFRC WITH 0%, 1%, 2% and 3% FIBERS				
Different aspect ratios of fibers	For Normal M40	For SFRC	For SFRC	For SFRC
	with 0% fibers	with 1% fibers	with 2% fibers	with 3% fibers
	Comp. strength (MPa)			
	Avg.	Avg.	Avg.	Avg.
50	45.19	52	53.33	56.3
60		50.37	52.59	54.07
67		50.22	51.41	53.04

Table2.2 Compressive Strength of SFRC with 0% of steel fiber in M40 grade concrete

Hence from the experimental work based on different types, aspect ratio and % of steel fibers used in SFRCs we can say that SFRC with 3% of steel fibers is showing maimum flexural, tensile and compressive strength as compared to the normal conventional concrete [9, 10, 11].

It can be observed from the results that the flexural strength is maximum in the case of Hook end SFRC with 3% steel fiber and aspect ratio 50 i.e. 10.40 MPa. Also the compressive strength of the same sample was found to be maximum i.e. 56.30 MPa.

2.1 Modeling:

In the present research work, SFRC with Hooked shaped steel fiber(Aspect ratio= 50 and 3% steel fiber) is used as a Structural material in Beam and Column. Also the same was simulated and modelled in ETABS 17.0.0 sofware in which the a comparitive seismic analysis was performed to study the behaviour of M 40 grade SFRC based G+8 storey model in which only Beam and Column material was replaced with 3% SFRC, where as slab was same as conventional M40 grade. The same model was compared with conventional M40 grade concrete Reinforced Concrete model in which all structural elements such as Beam, Column and slab were of standard M 40 Grade (0% SFRC). Based on various Results Outcomes after seismic analysis of both the Models various Comparisons were done.

The other relevant data for modifying the material properties of M 40 grade concrete to M 40 SFCR- 3% (Molel-2) Model was referred to previous research work and literature available and mentioned in this paper. Some of the comparison of various Material properties of Conventional M40 Model (Model-1) is shown in the table below:

Propeties	Specific Weight Density (kN/m^3)	Mass per unit volume (kg/ m^3)	Modulus of elasticity (Mpa)	Poisson's ratio	Coefficient of thermal expansion	Shear Modulus (Mpa)
MODEL- 1	24.9926	2548.538	31622.78	0.2	0.0000055	13176.16
MODEL - 2	26.59	2711.424	37516.661	0.2	0.0000055	15631.94

Table: 2.3 Material Properties of used for simulation: MODEL- 1 and MODEL- 2

MODEL-1: Conventional M40 Model

MODEL-2: M 40 SFCR- 3% Model in which M40 grade concrete with 3 % steel fiber was used in Beam and Columns only, Slab remains same as M 40 grade Conventional concrete)

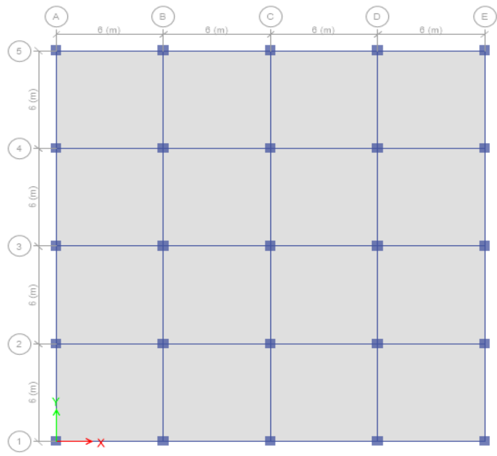


Figure: 2.1

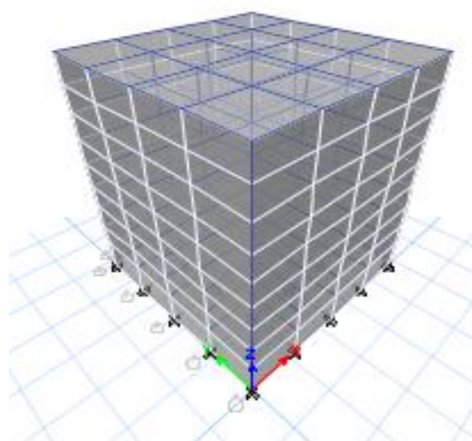


Figure: 2.2

Figure: 2.1- Plan view of G+8 multi - story building Model

Figure: 2.2- 3-D view G+14 multi-story building Model

2.1.1 Loads:

The data here is showing the loading information as applied to the models.

The Following Loads were applied to both the Models:

1. Dead Load = 3 kN/m on slab
2. Live Load Load = 6 kN/m on slab
3. Cladding Load on exterior beams = 0.2 kN/m
4. Earthquake Load in X direction = As per IS 1893:2016
5. Earthquake Load in X direction = As per IS 1893:2016
6. Seismic Zone: V
7. Response reduction factor = 3
8. Soil Type = 2 (medium)
9. Importance Factor = 1

2.1.1.1 Load Patterns:

Name	Type	Self Weight Multiplier	Reference
Dead	Dead	1	Auto Load
Live	Live	0	
EQ	Seismic	0	IS 1893:2016

Table 2.4 - Load Patterns

2.1.1.2 Load Combination as per IS 1983: 2016:

- 1.2 [DL + LL + (ELx+ 0.3 Ely + 0.3 ELz)]
- 1.2 [DL + LL - (ELx+ 0.3 Ely + 0.3 ELz)]
- 1.2 [DL + LL+ (ELy+ 0.3 Elx + 0.3 ELz)]
- 1.2 [DL + LL - (Ely + 0.3 Elx + 0.3 ELz)]
- 1.5 [DL + (ELx + 0.3 Ely + 0.3 ELz)]
- 1.5 [DL - (ELx + 0.3 Ely + 0.3 ELz)
- 1.5 [DL + (Ely + 0.3 ELx + 0.3 ELz)]
- 1.5 [DL - (Ely + 0.3 ELx + 0.3 ELz)] 0.9 DL + 1.5 (ELx + 0.3ELy + 0.3ELz)
- 0.9 DL - 1.5 (ELx + 0.3Ely + 0.3 ELz) 0.9 DL + 1.5 (Ely + 0.3ELx+ 0.3ELz)
- 0.9 DL - 1.5 (Ely + 0.3ELx + 0.3 ELz)

Name	Type
Dead	Linear Static
Live	Linear Static
EQ	Linear Static

Table 2.5 - Load Cases - Summary

3.1.2 Model Sectional and Material Parameters:

Parameter	Rebar in all members (Main)	Rebar in all members (Confinement)	Beam Material (Concrete)	Beam Size	Column Material (Concrete)	Column Size	Slab material (Concrete)	Slab Thickness	Height of Building
Model-1	FE 500	FE 250	M40	600 x 600 mm	M40	600 x 600 mm	M40	150 mm	29.2 m (9 Storey)
Model-2			SFRC M40 3%		SFRC M40 3%				

Table 2.6 Material parameters of MODEL-1 & MODEL-2

3. RESULTS AND DISCUSSION:

The following Results were obtained after the Seismic analysis of both the Models (MODEL-1 and MODEL-2). Also the results compared here are only for Earthquake Load case.

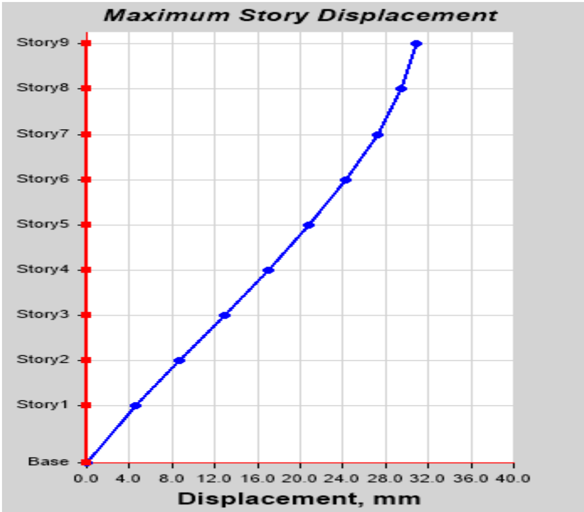


Figure: 3.1 **Figure: 3.2**

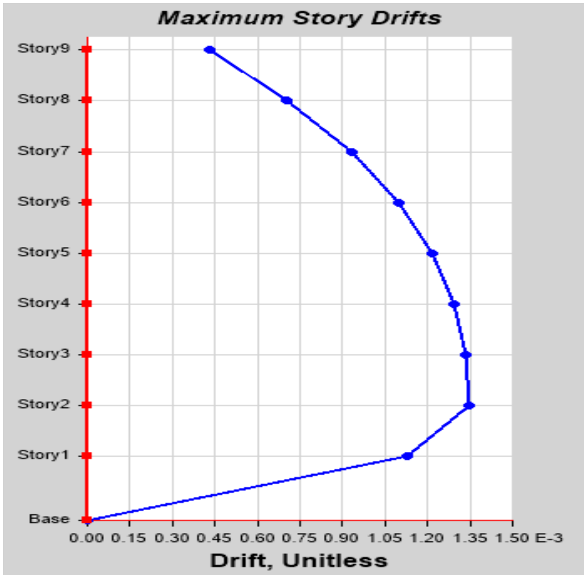
Figure: 3.1- Maximum storey Displacement for MODEL-1

Figure: 3.2- Maximum storey Displacement for MODEL-2

TABLE: Max Story Displacement						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m		mm	mm	mm	mm
Story9	29.2	Top	30.8123514	0.004962469	28.90062	0.00508
Base	0	Top	0	0	0.00000	0.00000

Table 3.1

- In Model- 2 the Maximum storey Displacement is decreased in X direction by 3.201529 % and increased in Y Direction by a very low margin of 1.2 % from Model-1 in the top storey



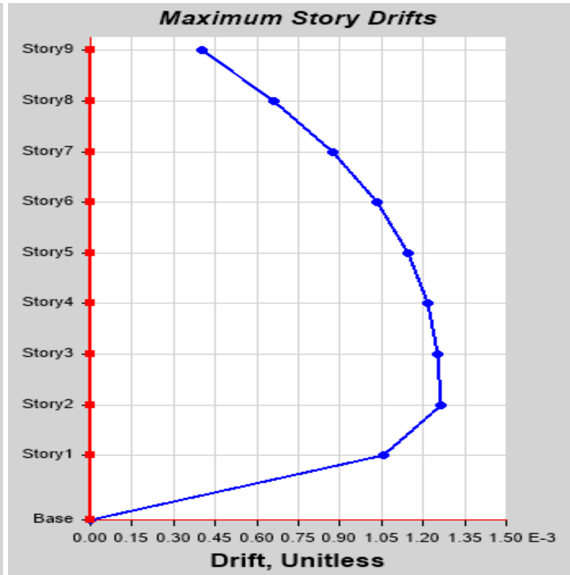


Figure: 3.3 **Figure: 3.4**

Figure: 3.3- Maximum Storey Drift for MODEL-1

Figure: 3.4- Maximum Storey Drift for MODEL-2

TABLE: Max Story Drift						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m					
Story9	29.2	Top	0.000431	1.29E-07	0.000404	7.64E-08
Story3	10.3	Top	0.001332	1.86E-07	0.00125	1.67E-07
Story2	7.15	Top	0.001346	1.35E-06	0.001263	1.18E-06
Story1	4	Top	0.001129	1.12E-06	0.001056	9.99E-07
Base	0	Top	0	0	0	0

Table 3.2

- In Model- 2 the Maximum storey Drift is decreased in X direction by a average 3.22% throughout the height and decreased in Y Direction by 5.857194 % at story 1 and 25.50189 % at top story from Model-1

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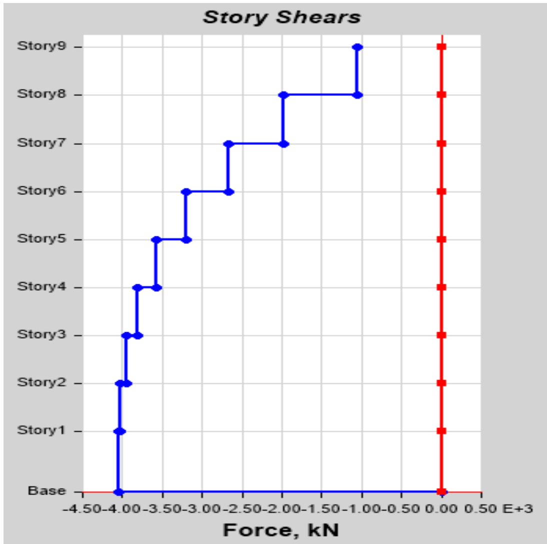


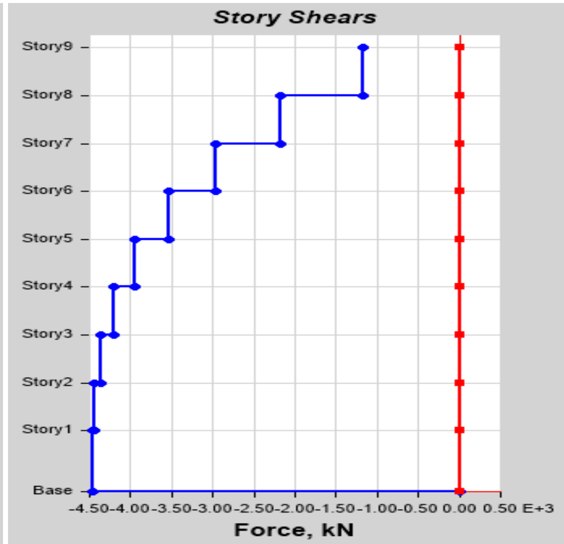


Figure: 3.5 **Figure: 3.6**

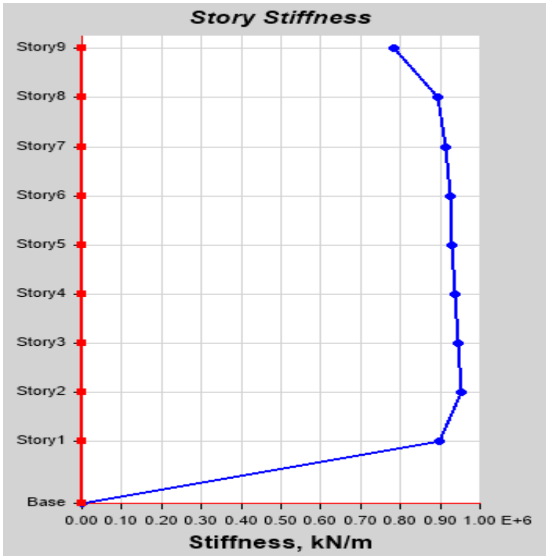
Figure: 3.5- Storey Shear for MODEL-1

Figure: 3.6- Storey Shear for MODEL-2

TABLE: Story Shear						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m		kN	kN	kN	kN
Story9	29.2	Top	-1061.24	1.82E-09	-1169.63	1.79E-09
		Bottom	-1061.24	1.82E-09	-1169.63	1.79E-09
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

Table 3.3

- In Model- 2 the storey Shear is increased in X direction by a average 4.24% throughout from Story 1 to the top story Y Direction it was increased by 2.822787 % at story 1 and 0.803174 % at top story as compared to Model-1



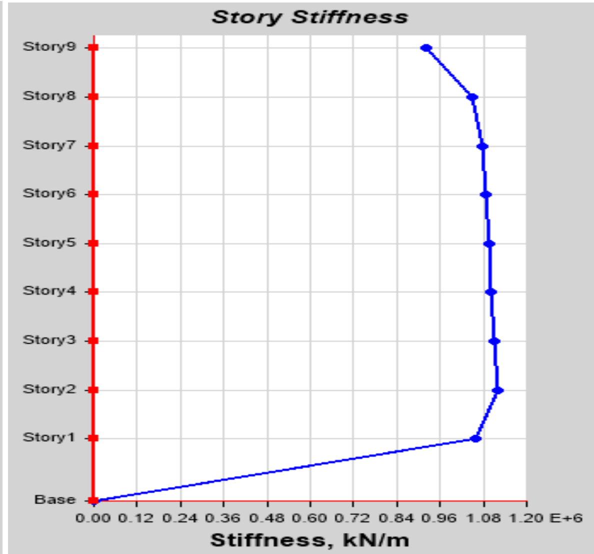


Figure: 3.7 **Figure: 3.8**

Figure: 3.7- Storey Stiffness for MODEL-1

Figure: 3.8- Storey Stiffness for MODEL-2

TABLE: Story Stiffness						
Story	**Elevation**	**Location**	**MODEL-1**		**MODEL-2**	
			X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	m		kN/m	kN/m	kN/m	kN/m
Story9	29.2	Top	783624.5	0	921479	0
Story8	26.05	Top	892646.3	0	1050285	0
Story2	7.15	Top	951902	0	1119758	0
Story1	4	Top	897860.3	0	1060064	0
Base	0	Top	0	0	0	0

Table 3.4

- In MODEL-2 Story Stiffness is observed to be increases by an average of 8.11 % in X direction from Story 1 to Top Story as compared to MODEL- 1

4. CONCLUSION AND FUTURE SCOPE:

- Maximum storey Displacement is decreased in case of SFRC Model (MODEL-2)
- Maximum storey Drift at both top and 1st story of the building was found to be decreased in case of SFRC model (MODEL-2)
- Storey Shear is increased at respective stories in case of SFRC Model (MODEL-2)

- Story Stiffness is observed to be increased by an average of 8.11 % in case of SFRC Model (MODEL-2)
- Performance of the Steel Fiber Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete
- Behaviour of SFRC based model has shown significantly better performance under seismic loads, hence it can be opted as a seismic resistant material in future research work.

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