# KAUNAS UNIVERSITY OF TECHNOLOGY
# FACULTY of CIVIL ENGINEERING AND ARCHITECTURE

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# Investigation of Residual Strength of Concrete Reinforced by Steel and Polypropylene Fibres

Master's Degree Final Project

**Supervisor**
Assoc. Prof. Dr. Nerijus Adamukaitis

**KAUNAS, 2017**

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**(621H30001)**

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“Investigation of Residual Strength of Concrete Reinforced by Steel and Polypropylene Fibres"

# DECLARATION OF ACADEMIC HONESTY

____ ________________ _____
Kaunas

I confirm that the final project of mine, **Arun Kishore Talluru Ramakrishnan**, on the subject, **Investigation of Residual Strength of Concrete Reinforced by Steel and Polypropylene Fibres** is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

I fully and completely understand that any discovery of any facts of dishonesty inevitably results in me incurring a penalty under procedure effective at Kaunas University of Technology.

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Reikšminiai žodžiai: PPFRC, SRFC, CMOD, Mid Span Deflection.

Kaunas, 2017. 49p.

## Santrauka

Pluoštu armuoto betono (FRC) yra sustiprintas betono mišinys su paskirstyta atsitiktiniais mažų fragmentų pluoštais. Į FRC, iš mažyčių skaidulų pasiskirsto atsitiktinai betono maišymo metu, ir taip pagerina konkrečias savybės tam tikromis kryptimis. Pluoštai lengviau perduoda apkrovą esant mažiems plyšiams. FRC yra fibromis armuotas betonas, kuris buvo sukurtas per pastaruosius metus. Dabar jis yra sėkmingai naudojamas statyboje su savo geru lenkimo-tempimo stipriu, atsparumas smūgiams ir geru pralaidumu ir atsparumu šalčiui ir įvairius kitus veiksnius, kurie padeda užtikrinti ilgą pastato kokybę. Ši darbas remiasi šio pluošto tyrimu, tyrime buvo naudojami dviejų skirtingų rūšių pluoštai, studijuoti likutinį betono stiprį, naudojant polipropileno ir plieninės skaidulas. Šeši bandiniai buvo pagaminti polipropileno pluošto ir išbandyti naudojant tritaškį lenkimo bandymą, gauti rezultatų yra palyginami su plieno pluošto gautais rezultatai iš literatūros. Nustatyta, kad plienas yra didesnio liekamojo stipri, palyginti su polipropileno.

Arun Kishore Talluru Ramakrishnan. Investigation of Residual Strengths of Concrete Reinforced by Polypropylene and Steel Fibres. Master's Final Project / supervisor assoc. prof. dr. Nerijus Adamukaitis; Faculty of Civil Engineering and Architecture, Kaunas University of Technology.

Keywords: PPFRC, SRFC, CMOD, Mid Span Deflection.

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## SUMMARY

In this thesis, the research of criteria is regarding the concept of investigation of residual strengths of polypropylene and steel reinforced concrete. Six samples of polypropylene reinforced concrete samples were tested using three-point bending test and is compared against reference samples of steel fibre reinforced concrete for various parameters like displacement and crack width opening. The crack width opening is calculated for polypropylene samples under different readings and is compared with steel samples. It is found that steel fibre reinforced concrete samples is known to have a higher residual strength when compared against polypropylene samples. Steel fibre reinforces concrete samples also have a higher tolerating capacity when a heavy load is applies against them.

# KAUNAS UNIVERSITY OF TECHNOLOGY
## FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE

## MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT

**Study programme CIVIL ENGINERING -621H30001**

Assigned to the student **ARUN KISHORE TALLURU RAMAKRISHNAN**

*(Name, Surname)*

1. Title of the Project

Investigation of Residual Strength of Concrete Reinforced by Polypropylene and Steel Fibres

2. Aim of the project

To study and analyse the residual strengths and properties for polypropylene reinforced concrete and steel reinforced concrete.

3. Tasks of the project

- Sample preparations and Casting process.
- The sample must be left to set for 28 days after casting.
- To perform three point bending test for polypropylene reinforced concrete sample.
- Study on properties, calculation of residual strengths and analyse the results.
- Comparing residual strength test results between polypropylene reinforced concrete samples and steel concrete reinforced samples.

4. Specific Requirements

Conducting the final experimental project thesis according to KTU regulations and requirements.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 MAY 31st.

Task Assignment received

(*Name, Surname of the Student*) (*Signature, date*)

Supervisor

(*Position, Name, Surname*) (*Signature, date*

# ABSTRACT

Fibre reinforced concrete (FRC) is cementing concrete reinforced mixture with fibres distributed at random parts in small fragments. In the FRC, a number of tiny fibres are distributed at random within the concrete at the time of blending, and thus improve concrete properties in specific directions. The fibers facilitate to transfer load to the interior small cracks. FRC is cement that has been developed in recent years. Now a days it is being successfully utilized in construction with its wonderful flexural-tensile strength, resistance to forcing out, impact resistance and wonderful permeability and frost resistance and various other factors that helps in providing an eternal quality in the structural components of a building . This thesis is based on this study of fibre reinforced concrete of which two different types of fibres were used to study the residual strength of concrete using polypropylene and steel fibres. Six samples specimens were casted for polypropylene fibres and tested using three point bending test and results are validated against reference results of steel fibres .It is found that steel has higher resdual strength value compared to polypropylene and hence it can used for improving shear strength of concrete at joints and complex junction connections.

Keywords:

Fibre Reinforced Concrete, Residual Strength , Polypropylene fibre , Steel fibre , CMOD , Mid span deflection .

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# Introduction:

Fibre Reinforced Polymer concrete is a versatile construction material which many field applications in the field of civil engineering. This thesis is an attempt to study two different types of fibres namely polypropylene fibre which is derived from petroleum sources and steel fibres which is made of mild steel. These two fibres are studied by incorporating them into a regular reinforced beam which was cast in accordance to euro code procedure and cured for 28 days. To study its mechanical properties of which residual strength is our current area of study in this thesis.

The first stereo regular polymer to have achieved industrial importance. The fibres from Polypropylene were introduced to the textile arena and have become an essential member of the increasingly growing family of synthetic fibres. Today Polypropylene holds the fourth spot behind the other three fibre classes, behind polyester, nylon and acrylic. Nowadays as opposed to other commodity fibres, its use as apparel and household textiles has been rather restricted and the bulk of the fibre produced is used for various industrial applications. Polypropylene fibers was first recommended as an admixture to concrete in 1965 for the construction to blast resistant buildings for the United States Corps of Engineers. The fiber has frequently been improved further and currently it is used as short discontinuous fibrillated material for manufacturing of fiber reinforced concrete and also for a continuous mat for production of thin sheet components. Since then the usage for these fibres has risen in construction of structures since addition of fibers in concrete improves the toughness, flexural strength, and tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is economic, widely available, and like all manmade fibers has a consistent quality.

Cracks play an important role as they change concrete structures to permeable elements and consequently with a higher risk of corrosion. Cracks not only decrease the quality of concrete and change it into aesthetically unsuitable but also will make structures out of service. If these cracks do not exceed a certain width, they are neither dangerous to a structure nor to its serviceability. Hence, it is important to reduce the crack width and this can be achieved by adding polypropylene fibers to concrete.

Prior to mixing the concrete, the fiber length, amount and design mix parameters are modified to prevent the fibers from balling. Good Polypropylene Fibre mixes generally contain a high mortar volume as compared to other concrete mixes. There must be sufficient compaction so that the fresh concrete flows satisfactorily and the Polypropylene fibers are uniformly segregated in the mixture.

The fibers should not float to the surface or sink to the bottom in the fresh concrete. Chemical admixtures should be added to fiber-reinforced concrete mixes to increase the workability of the concrete mixture. Air-entraining agents and water-reducing admixtures are generally added to mixes with a fine aggregate content of 50% or more.
Steel fiber reinforced concrete (SRFC) is composite material having fibers as additional ingredients, segregated evenly at random in trivial percentages, between 0.3% and 2.5% by volume in plain concrete. SRFC products are manufactured by adding steel fibers to the ingredients of concrete in the mixer and by transferring the concrete into various moulds. The newly manufactured product is then compacted and processed by different conventional methods. Segregation or balling is one of the main problems that takes place during mixing and compacting of SFRC. This should be avoided for uniform distribution of fibers. The energy that is required for mixing, conveying, placing and finishing of SFRC is slightly higher. Use of pan mixer and fiber dispenser to assist in betterment of mixing and to restrict the formation of fiber balls is important. Steel fibers are added to concrete to improve the structural properties of buildings, especially tensile and flexural strength. The amount of improvement as far as the mechanical properties is concerned, is achieved with SFRC compared to of plain concrete depends on various factors, such as volume, size, shape, percentage and distribution of fibers. Plain, straight and round fibers that are developed had a very weak bond and hence resulted in low flexural strength. For a given shape of fibers, flexural strength of SFRC is bound to increase with aspect ratio (ratio of length to equivalent diameter).

Concrete that is reinforced with steel fibres is been widely utilised in the building industry in recent years for applications such as industrial and airport pavements, reinforcement of projected concrete, and precast elements with reduced thickness. These applications of SRFC has been based on the studies of the mechanical behaviour of SRFC under tensile stresses, fatigue or even impact. Studies have shown the outstanding fracture properties that steel fibres contribute in low strain states. However, the proximity of the steel fibres to the free surface of the concrete piece generally reduces the life span of the structure mainly due to the corrosion of the fibres, especially in aggressive environments consisting of CO2. Just like any other type of concrete, the mix proportions for SFRC depend upon the various requirements for a job, in terms of strength, workability, and several other factors. Different types of procedures for mix proportions for SFRC are available, which gives importance on the workability factors of the resulting mix.

Generally, SFRC mixes contain higher cement contents and higher ratios of fine to coarse aggregate than do ordinary concretes, and so the mix design procedures the apply to conventional concrete may not be entirely applicable to SFRC.

# 1.LITERATURE REVIEW:

**Theoretical Background:**

The literature review is divided into various sections which relates to the theoretical background of polypropylene and steel fibres. The first part consists of basic information related to fibres. The second part is about polypropylene, describing about its uses, advantages and disadvantages in the industry. The third part explains about steel, its various uses and explained about the pros and cons. Final section of the review explains about the different types of experiments conducted to calculate the residual strength of steel and polypropylene fibres.

## 1.1 What are fibers?

Fibre are a hair-like strand of fabric. They are found to be the smallest visible unit of a cloth and are denoted by being considerably long in relevance to their breadth. Fibers are often spun into a yarn and then created into fabrics. Synthetic fibers are a set of the large area of textiles. Textiles are often natural or artificial. Natural fibers consist of cotton, fur, wool, etc. Regenerated fibers are natural materials that are often processed into a fiber structure. Regenerated fibers like cellulose and wood pulp were accustomed to build materials like fabric and acetate. Artificial fibers are not natural form of chemicals. They are usually the type of polymers that are stronger than natural and regenerated fibers.

Figure 1 Schematic Presentation of a fibre.

### 1.1.2 Types of Fibres:

Fibres are made from different types of materials in numerous shapes and sizes. Typical Fibre materials are:

- Steel Fibres are known to be straight, crimped, twisted, hooked, ringed, and paddled ends. The diameter varies from 0.25 to 0.76mm.
- Glass Fibres are straight. Their Diameter ranges from 0.005 to 0.015mm (may be secure along to form parts with diameters of 0.13 to 1.3mm).
- Natural Organic and Mineral Fibres include Wood, asbestos, cotton, bamboo, and rock wool. They are available in different types of sizes.
- Polypropylene Fibres are Plain, twisted, fibrillated, and are found with fastened ends.
- Other artificial Fibres Kevlar, nylon, and polyester. Diameter ranges from zero.02 to 0.38mm. A convenient parameter describing a fibre is its ratio (LID), is defined because the fibre length divided by constant fibre diameter. Typical ratio ranges from about thirty to one hundred fifty for length of half dozen to 75mm**.**

### 1.1.3 Mixed Compositions and placing of FRC:

Mixing of FRC are often accomplished by several methods. The combination is must have a uniform dispersion of the fibers so that to stop segregation or balling of the fibers during compounding. Most balling takes place during the fiber addition method. Increase of aspect magnitude relation, volume share of fiber, and size and amount of coarse combination will intensify the balling tendencies and reduce the workability. To coat the massive surface area of the fibers with paste, previous experiences indicated that a water cement aggregate ratio between 0.4 and 0.6, and minimum cement content of 400 kg/m should be needed. Compared to conventional concrete, fiber reinforced concrete mixes are typically characterized by higher cement ratio, higher fine combination content, and smaller size coarse combination. A fiber mix usually needs a lot of vibration to consolidate the combination. External vibration is desirable to stop fiber segregation. Metal trowels, tube floats, and rotating power floats will be accustomed finish the surface.

### 1.1.4 Uses of Fibres in construction industry:

Natural fibers are used for attire and residential fashion for thousands of years, with the utilization of wool going back over 4000 years. In relation to the man-made fibers, the business began with the primary commercial production of textile in 1910. The idea of exploitation fibers as reinforcement is not new. Fibers are used as reinforcement since ancient times. Traditionally, horsehair was used in mortar and straw in mud bricks. Within the 1900s, asbestos fibers were utilized in concrete. in the 1950s, the idea of composite materials came into limelight and fibre-reinforced concrete was one amongst the topic of interest. Once the health risks related to asbestos were discovered, there was a requirement to seek out a replacement for the substance in concrete and other building materials. In Africa, sisal Fiber concrete has been used extensively for creating roof tiles, furrowed sheets whereas wood and sisal Fibers are being employed for creating cement composite panel lining, eaves, soffits, and for sound and hearth insulation. Kraft pulp Fiber reinforced cement has known to be in use for major industrial applications for the manufacture of flat and furrowed sheet, non-pressure pipes, cable pit, and outside Fiber reinforced cement paste or mortar product for agriculture.

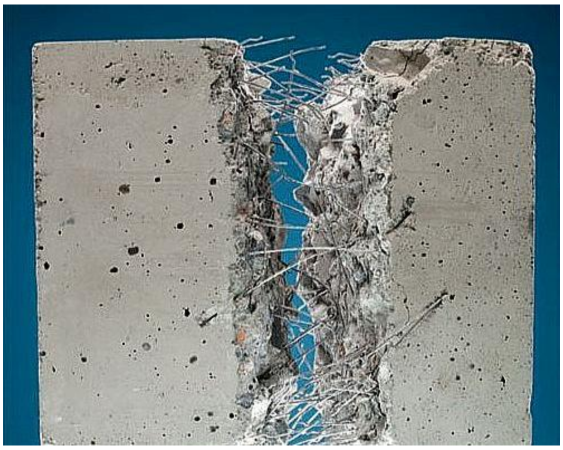


Figure 2  Schematic presentation of steel fibre reinforced in concrete mix

M. Zhu and D.D.L. Chung et at (1997) Carbon fibres minimized the drying shrinkage of mortar. The drying shrinkage from 2 to 24 hours is very important, although it's usually neglected. As a result of the drying shrinkage reduction, brick/brick joint strength was enhanced by adding carbon fibers to the mortar. The highest joint strength was earned at a fibre content of 0.5% by weight of cement. [1]

Yining Ding, Cecília Azevedo et al 2012 analyzed the result of different types of fibres on the residual flexural strength,. The small polypropylene fibre (PP fibre) could mitigate the spalling of SCHPC member considerably, however failed to show clear result on the mechanic properties of concrete. The macro steel fibre (SF) reinforced SCHPC showed higher flexural toughness and ultimate load before and during high temperatures. The mechanical properties of hybrid fibre strengthened SCHPC (HFSCHPC) when heating where was found to higher than that of mono fibre reinforced SCHPC. The failure mode changed from pull-out of steel fibres at lower temperature to diminish of steel fibres at higher temperature. The use of hybrid fibre are often effective in providing the residual strength and failure pattern and in up the toughness and fracture energy of SCHPC when warmth. [2]

## 1.2 Steel Fibres:

Steel fibres in general are be made by using standard concrete technique, although there are

Known to be some vital variations. The fundamental drawback is to introduce an adequate volume of uniform distribution of the steel fibres to attain the required enhancements in mechanical behaviour, while retaining ample workability in the recent mix to allow correct combination, placing and finishing. The performance of the hardened concrete is increased a lot of by fibres with a high aspect magnitude relation, and this improves the fibre-matrix bond. On the other hand, a high ratio adversely affects the workability of the recent mix. In general, the issues of each workability and uniform distribution increase with increasing fibre length and volume. One of the chief difficulties in getting a homogenous fibre distribution is that the tendency for steel fibres to ball or clump along. Clumping is also caused by variety of factors.

Figure 3  Schematic Presentation of steel reinforcement constructed on S.R. 288 in Virginia

SFRC are often placed adequately using traditional concrete equipment. It seems to be considerably stiff because the fibres tend to inhibit flow; but once vibrated, the fabric can flow promptly into the forms. It must be noted that water should be added to SFRC mixes to boost the workability solely with proper technique, on top of a w/c quantitative ratio of about 0.5. Additional water will result in increasing the slump of the SFRC without increasing its workability and place below the area of beneath vibration. The finishing operations with SFRC are primarily similar just like standard concrete, but a lot of care should be taken relating to working principle.

### 1.2.1 Uses of Steel Fibres in Construction Industry:

The use of steel fibres in construction are generally for reinforcing concrete grade slabs and also for applications like industrial floors, warehouses, ports and road pavements all over the world. They are additionally widely employed in underground support infrastructure, significantly shot Crete linings, tunnels and ground stabilization. The largest application for steel fibre reinforced concrete is floor block construction, though they are used as a replacement. Steel fibres for floor/slab applications will be economic when compared to other reinforcing systems. Also, joint spacing will be accumulated and hence they can be used as a replacement for structural reinforcement in some cases. Just adding steel fibres to a load of concrete does not ensure in guarantying success. Steel fibres in concrete represents just one component the system. There are alternative essential parameters to contemplate, like subgrade preparation, concrete mix style, and the total water during a concrete mix.

### 1.2.2 Advantages and Disadvantages of Steel Fibres:

Reinforcing concrete with Steel fibres ends up in durability of concrete with a high flexural and fatigue flexural strength, improved abrasion, spalling and impact resistance. The elimination of standard reinforcement, and in some cases the reduction in section thickness will contribute to some important productivity enhancements. Steel fibres will deliver important value savings, beside reduced material volume, a lot of speedy construction and reduced labour prices. The random distribution of Steel fibres in concrete ensures that crack free stress accommodation happens throughout the concrete. Therefore, small cracks will be intercepted before they develop and impair the performance of the concrete. However, on the downside steel fibres won't float on the surface of a properly finished block, however rain damaged slabs permit each combination and fibres to be exposed and can be present as atheistically poor while maintaining structural soundness. Fibres will be capable of subbing reinforcement on all structural components (including primary reinforcement) however, amongst every component there will be a degree where the fibre alternative's price saving and perspective design economies is diminished. Strict management of concrete wastage should be monitored so as to keep it at a minimum. Wasted concrete suggests that there will wasted fibres.

## 1.3 Literature on Experimental Methods to Determine Residual Strength in Steel Fibres:

In study by F.A.Olutoge et al 2013, he evaluated residual strength properties of concrete reinforced with steel fibers. The target was to determine its role in rising some of the mechanical properties of concrete. The purpose and aim of the study is to verify the power of steel fibres to stop the onset of cracking as well as propagation of cracks within the concrete structures. After 28days of natural process, the cubes, cylinders and prisms were subjected to compressive, split tensile and residual strength tests severally. Residual strength check data was obtained from reloading of cracked beam specimens during a four-point bending check. The compressive Strength check results accumulated from 47MPa 1/3 fibre volume to 48MPa at zero.5% fibre volume. This value however diminished to 45MPa at zero.75% fibre volume, indicating that the injection of straight steel fibres have little influence on the compressive strength. The split tensile test result accumulated steadily from three.17MPa at 1/3 fibre volume to five.66MPa at 125th fibre volume indicating that addition of steel fibres to concrete increased its tensile strength. The residual strength test result also showed an increment in the average residual strength from 1.81mpa at 0.5% to 3.37MPa at 1% fibre volume.

This study has confirmed that addition of steel fibres to concrete increased its tensile and residual strength properties. [3]

Figure 4  Schematic representation of steel fibres used in the above experiment

In results Outlage concluded by stating that the peak load was observed to at 26.9kN, 38.4kN and 43.2kN respectively for 0.5%, 0.75% and 1%. He also added that by the injection of straight steel fibers show that they have little influence on the residual flexural strength. It had been discovered that average residual strength will increase with increase in fiber volume.

A. Orbe and E. Rojí et al 2013 predicted the residual strength of 11 specimens of steel fibre reinforced concrete by a new non-destructive testing (NDT) techniques that were developed for its analysis. Since the observation of these fibres is not possible once the concrete is hardened the test was performed before the concrete is hardened by applying of a field of force to the concrete, as they will result in checking the homogeneity of the material that are supported by the porous properties that offer the fibres to be consistent with their distribution and orientation based on the mentioned magnetic technique.

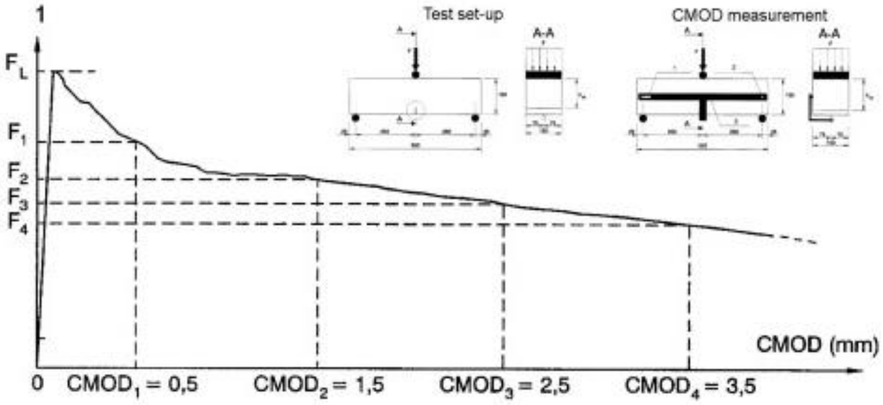


Figure 5 Schematic representation of graph of residual strength by analysing force and CMOD

Measurements within the centre of the specimen, taken on the X -axis of coil, were used as input data for the strength prediction of the eleven specimens. It is performed by a three-point bending test on notched prismatic specimens in line with UNE-EN 1465 1. The LOP is obtained because the peak point reached among those at intervals a variety of CMOD < 0.05 mm. The strengths were similar to the forces applied throughout the test once the Crack Mouth gap Displacement (CMOD) reaches 0.5, 1.5, 2.5 and 3.5 mm, and was taken into account by the sequential four residual strengths, as illustrated in Fig 1.7. Cracks appeared throughout the three-point bending test within the centre of the specimens, because of weakening caused by the notch. The inductance variation values had to be reworked by the correction factors that were determined to eliminate the influence of the fibres outside the fracture section. This test was hence useful in predicting the residual flexural strength of the specimens in Non – Destructive testing method in a simple way. In this study, it is been evidenced that inductance variation measurements for eleven prismatic specimens will offer a prediction of residual strength and might contribute to higher internal control. This procedure could simply be executed to completely different fibre sorts and side ratios. [4]

N. Buratti and C. Mazzotti et al 2010 investigated about the results of an experimental investigation on the performances of concrete specimens bolstered with both steel and macro-synthetic fibres with the help of three-point bending. Test results were accustomed calculate the parameters of stress-crack gap relations via inverse analysis. Specifically, the introduction of fibres provides the concrete a major tensile residual strength within the cracked section and reduces the crack propagation. During this campaign, the many concrete beams were casted using a concrete bolstered with differing kinds and amounts of steel and macro-synthetic fibres and were tested during a three-point bending test. All the beams where casted by a similar concrete combine style. The mix composition was outlined during a preliminary experimental campaign, in order to possess the required durability and to predict the residual flexural behaviour. Information obtained throughout the tests were accustomed calibrate the parameters of a stress crack opening relation by means that of an inverse analysis procedure. To better understand the explanations of the high scatter of the results obtained for a few kinds of fibres, the quantity of fibres crossing the crack were determined. The fibres on the two faces of the crack were then counted identifying between broken fibres.

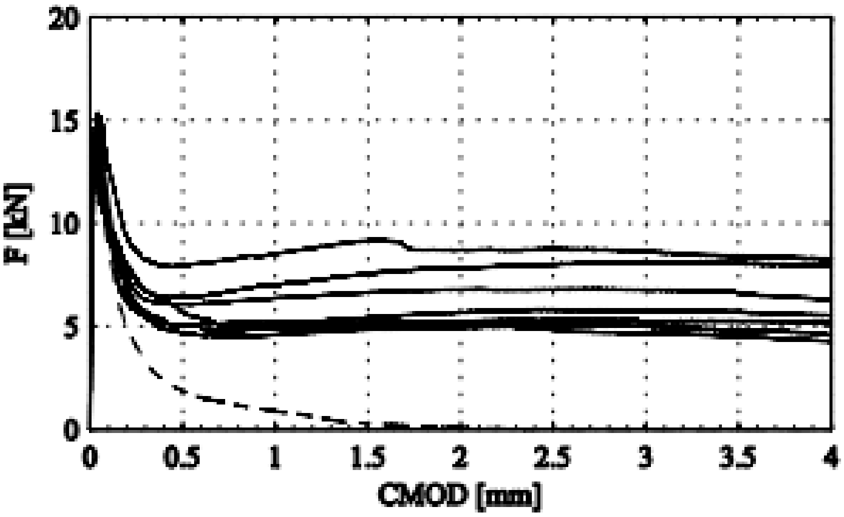


Figure 6 Schematic representation of graph of residual strength of force and CMOD of steel fibre concrete specimen

In the results, the authors explained about the present work that are investigated to the flexural behaviour of notched beams fabricated from concretes fibre-reinforced with differing kinds and amounts of fibres. They further explained that steel fibres showed usually higher performances than macro synthetic fibres however with a larger scatter of force CMOD curves. The experimental information was used as input for inverse analysis that cause the optimum additive stress-crack gap relations to be used with Olesen's model so as to produce the experimental behaviour of the beams. [5]

Woosuk Kim and Jubum Kim et al 2016 studied an experimental programme to analyse the results of steel fibres on flexural strength of steel fibre-reinforced concrete (SFRC) beams. Four-point bending check was administered on the 11 SFRC beams which are half-dozen normal-strength SFRC beams and five high-strength SFRC beams. The variables studied within the investigation were steel fibre volume fractions (0, 0.75 and 1.50%), flexural reinforcement ratios (1.0 and 2.0%), and concrete compressive strengths (28 and 56 MPa). The final results confirmed that final flexural strength multiplied with increasing fibre volume contents. The constitutional model for SFRC was projected, that incorporated strength of fibre-reinforced concrete and strain-hardening of tensile reinforcement.

The experimental programme on eleven, normal-strength (28 MPa) and high-strength (56 MPa) SFRC beams demonstrated the consequences of steel fibres on flexural strength. The strength increase on normal-strength concrete beams (15%) was further pronounced than on high-strength ones was not more than 9%, because the fibre volume inflated from 0 to 0.75%. The cracking moment conjointly raised for normal-strength concrete beam with low steel reinforcement ($\rho = 1\%$). The addition of steel fibres minimized crack spacing and its sizes, increasing deformation capability. The simple, organic model for a SFRC beam was developed, during which the residual flexural strength of SFRC was expressed as a fraction of concrete strength and strain hardening of steel reinforcement was accounted for. The moment–curvature curves from the analytical model matched well with the determined ones.

In results, the researchers concluded that by using the analytical results, a style equation for residual flexural strength of SFRC beams was projected. The projected equation accounted for the influence of fibre volume fraction, fibre ratio and tension reinforcement index. A total of 129 test results from different investigations were assembled with a large variation of fibre volume ratios (0.22 to 3%), flexural reinforcement ratios (0.8 to 3.1%) and concrete compressive strengths (21 to 112 MPa). Existing prediction equations for flexural strength of such beams were examined. [6]

M.N. Soutsos et al 2012, investigated about the Flexural stress–deflection relationships that were accustomed determine: residual flexural strength, flexural toughness, equivalent flexural strength, and equivalent flexural strength relation. The flexural toughness of concrete was found to extend significantly once steel and synthetic fibres were used. However, equal dosages of different types of fibres failed to result in specimens with identical flexural toughness. Flexural toughness variations of just about 35 J existed even at identical fibre dose. This conjointly resulted in significant variations within the minimum needed ground supported slab thickness. The required block thickness was found to scale back because the fibre dose was accrued. The thickness of the slabs was conjointly influenced by the kind and shape of the steel fibre.

In results, the author concluded saying that he flexural strength decided from the failure load, i.e. the height value within the stress–deflection relationships, by using the following equation:

$$fb = \frac{P.L}{h^2}$$

where *fb* is that the flexural strength in MPa, *P* the failure load in N, *L* the span of the specimen in millimetre, during this case L = 450 millimetre, b the dimension of specimen's cross section in millimetre and h is the height of specimen's cross section in millimetre. [

The flexural strength of plain concrete was 4.2 MPa and incorporation of steel fibres seemed to increase it by about 0.4 to 0.6 MPa. The increase within the flexural strength of artificial fibres was found to be lower, about 0.2 to 0.25 N/mm2 for dose rates of 4.5 to 5.3 kg/m3. It should be noted that all over that incorporation of fibres didn't considerably improve the flexural strength. The most edges of victimization fibres was the improved malleability within the post-crack region and this might solely be determined from load–deflection measurements. [7]

B.I.G. Barr and M.K. Lee et al 2003 carried out a test programme that enclosed both plain and steal fibre reinforced concrete (SFRC) beams. An in-depth analysis was carried out to analyse the influence of various test configurations on measurements of the crack mouth gap displacement (CMOD). Linear elastic fracture mechanics (LEFM) and non-linear fracture mechanics (NLFM) methods were used to research process analytically. From the analytical studies applied, it's projected that the CMOD should not be measured at a distance of 5mm from the bottom fibre of the beam. A larger distance than 5mm can cause the deviation between the measured CMOD and also the CMOD to reach an unacceptable level. A simple rigid body model has been projected to relate the CMOD to the mid-span deflection. The NLFM analysis and experimental results were compared for both the plain and SFRC beam results and it absolutely was proved that results supported the premise of CMOD are often compared to those based on deflections, practical functions, using the simple rigid body model. The experimental results powerfully counsel that the rigid body model might be effectively applied for all the types of materials tested within the round robin test programme. In addition, it absolutely was found that the conversion from CMOD to the equivalent mid-span deflection, disclosed sensible agreement between the load-average mid-span deflection curve and the load-equivalent mid-span deflection particularly to the SFRC specimens. The results show that toughness may be evaluated from either the deflection or CMOD curves. With the support of from both analytical and experimental proof, it's therefore suggested that the CMOD curve be used for evaluating the toughness and residual strengths of SFRC. [8]

## 1.4 Polypropylene fibres:

Polypropylene is a form of thermoplastic chemical compound resin. It is used as a vital source of material in industrial applications. The chemical designation is C3H6. One of the advantages of using this kind of plastics is that it is generally utilized in various applications as as a form of structural plastic and as a fibre-type plastic. Polypropylene fibres are hydrophobic, that is they don’t absorb water. Therefore, once placed in a concrete matrix they should be mixed long enough to ensure dispersion in the concrete mixture. The mixing time of fibrillated or tape fibres must be to a minimum to avoid shredding of the fibres. Polypropylene. Fibre concrete is an anembryonic construction material which is known to be represented as a concrete having high mechanical strength, stiffness and durability. By using polypropylene fibres in concrete, helps in optimum utilization of materials and helps in price reduction.

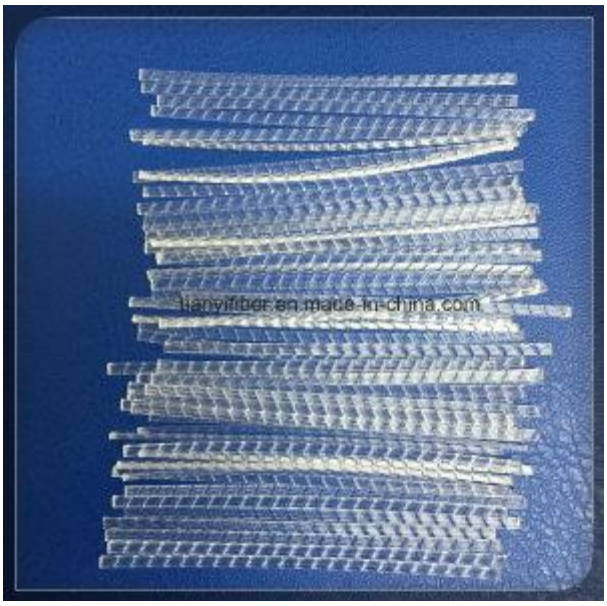


Figure 7  Schematic Presentation of a polypropylene fibre used for concrete mix

### 1.4.1 Uses of Polypropylene Fibres in construction industry:

In the past few years, an increasing number of builders are promoting concrete containing polypropylene fibres. Companies that manufacture fibre have promoted polypropylene as a sensible replacement to the utilization of welded wire fabric for reducing shrinkage and temperature cracking: Adding fibers reduces the slump of concrete. There seems to be less plastic shrinkage cracking once concrete contains polypropylene fibers.

### 1.4.2 Advantages and Disadvantages of Polypropylene Fibres:

The main advantage of polypropylene is that they are economic compared to other polymers. In addition, it contains a flexible resistance in cold weather with ultraviolet stability, and it is also possible to simply repair them from mechanical harm with general field instruments.

They are easy to spread into place. There are additional minor disadvantages, like the material's high flammability once they are utilized in its natural state, beside they also possess inability to bond well with paint. Another primary disadvantage of polypropylene is that it tends to possess a high thermal growth constant, causing it difficult to work with at high temperatures. Once exposed to high temperatures, the fabric tends to deform at fast rate.

## 1.5 Literature on Experimental Methods to Determine Residual Strength in Polypropylene Fibres:

In this study, Sheba Sam and M. Perarasan et al 2015 states that high temperature will cause the development of cracks which will eventually cause loss of structural integrity and reduction in service life. Because the concrete is used for special purpose, the danger of exposing it to heat additionally increases. Polypropylene fibre reinforced concrete is one such innovation that an experimental program is administrated by the process of using different volume fraction of 0.33, 0.2%, 0.4%, and 0.6% to find the fire resistance characteristics and also to determine the residual strength. Beams of size 500x100x100 mm size wherever accustomed realize the flexural behaviour change below 1000C, 2000C, 3000C. Experiment shows that addition of polypropylene fibres enhances the flexural behaviour of concrete compared to concrete without the presence of fibres.

The experiment deals with the results of addition of different proportions of polypropylene fibres on the properties of concrete below elevated temperatures. An experimental program was performed to explore its effects on flexural strength and cracking pattern under elevated temperatures. The spalling depth of concrete subjected to fire that decreases with increasing quantity of polypropylene (PP) fibres within the concrete. Test specimens are heated inside a furnace to the target temperature till it reaches a standardized value, the external temperature is at control constant. The specimens are air cooled to temperature and therefore the residual properties are measured. The beam specimens are tested by loading until the specimen fails. The result obtained is best suited for finding the post fire (residual) properties of concrete. Flexural strength test is completed as per IS: 516-1959. The specimen is loaded until it fails and therefore the maximum load (P) applied to the specimen throughout check is noted.

In results, Sheba Sam at 2015 stated that as temperature increases the flexural strength loss occurs for all the polypropylene fiber reinforced concrete (PPFRC) mixes PPF0, PPF0.2, PPF0.4 & PPF0.6. For PPF0, it absolutely was determined that increase in flexural strength up to 200$^o$c for 2 & 4hrs exposure amount and additional increase in temperature higher than 200$^o$c and considerable decrease in flexural strength happens for an exposure time of 6hrs. The flexural strength of concrete specimens containing fiber (PPF) indicates higher strength as compared to concrete specimens without fibers for all temperature. As fire bridges the cracks and controls the crack dimension, an increase within the load carrying capability and strength is seen. PPF with VF of 0.2, 0.4 & 0.6% shows high fracture resistance for all tested temperature than plain concrete. But for PPF with VF of 0.6% shows substantial decrease in flexural strength was determined for all temperatures from 100ºc, 200ºc to 300ºc for sustained exposure amount of 2hrs, 4hrs&6hrs. [9]

Md Azree Othuman Mydin at 2012, has discussed about the impacts of volume fraction of polypropylene fiber (PF) on the bending behaviour of light-weight foamed concrete (LFC) before and after exposing it to extreme temperature. Five mixes of LFC with 600, 800, 1000, 1200 and 1400 kg/m³ densities were created for the investigation. Then, the result of adding Polypropylene fibres with volume fraction of zero.1, 0.2, 0.3, 0.4, 0.45 and 0.5% on the flexural strength and pore structure of each was considered for closed density and for elevated temperatures up to 600 °C were examined. The outcomes demonstrated that an increasing temperature had a harmful influence on LFC property particularly during a temperature variation of 200 to 600 °C degrees within which flexural resistance was reduced by concerning 15 to 60 minutes because of the small diffusion of certain water molecules, detachment of the C-S-H gel and CH, weakness in attractive force structure of cement paste and suppresses of the cohesive forces within the micropores.

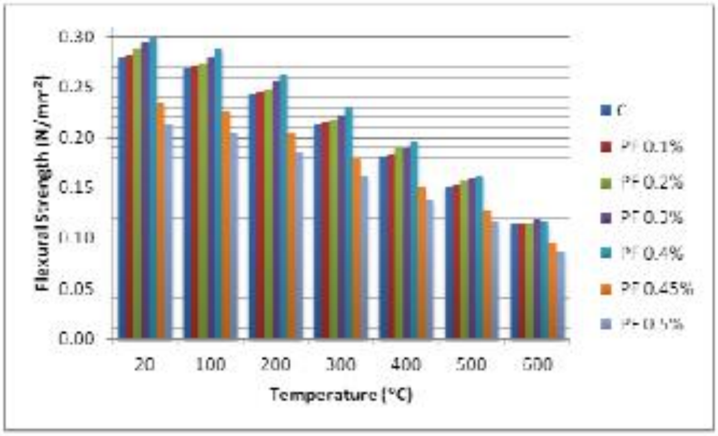


Figure 8 Schematic representation of Elevated Flexural tensile strength of LFC made by different composition

In results, Mydin stated that the results indicated a reduction in flexural strength for each of the plain Light Weight Foamed Concrete and Polypropylene Fibre with increasing temperature. However, addition of Polypropylene Fibre up to a precise volume of 0.4% of combine volume enabled LFC to resist high temperatures higher compared to plain concrete in the slightest degree applied temperatures. Adding 0.1, 0.2, 0.3 and 0.4% of mix volume Polypropylene Fibre to Light Weight Foamed Concrete with completely different densities during a range of 600-

1400 kg/m³, improved bending strength by concerning 1- 14%, 3-20%, 5-22% and 7-26% respectively. Improvement proportion was directly proportional to LFC density in such the way that; LFC with higher density had higher improvement percentage. [10]

Kumar et al studied the with M15, M20 and M25 grade concrete with 1/3, 0.5 attempt to 125th fibers for flexure and shear behaviour of deep beams and it's reported that there is marginal increase in flexural strength initially crack as fibre content multiplied from 1/3 to 1.0 [11]

Murahari, Rama Mohan Rao tested 500 x 100 x 100 mm specimens by using 3-point loading in accordance with ASTM C78. it's determined that the flexural strength increased with content up to 0.3% and gained a lot of strength at 28 days compared to 56 days. Gencel et al reported that the flexural strength will increase with addition of fiber content. [12]

Rama devi and Venkatesh babu studied the Flexural behaviour of Hybrid Steel-Polypropylene Fiber Reinforced Concrete Beams and determined that use of steel polypropylene Hybrid fiber concrete improve flexural performance of the beams throughout loading. [13]

Mahendra Prasad et al conducted investigations on Polypropylene fiber reinforced silica fume concrete of M30 grade. The cement replacement by silicon dioxide fume was 0.33, 5%, 10%, 15% and fibers were further added 0.33, 0.2%, 0.4%, and 0.6% by volume fraction of concrete. It’s observed that the increase in flexural strength was around 400th with use of Polypropylene fibers and silica fume in concrete. [14]

Tamil Selvi and Thandavamoorthy , from their experimental investigations on hybrid fibres with crimped steel and polypropene in concrete matrix to review the improvements in strength and sturdiness properties, reported that the addition of steel and polypropylene fibres to concrete exhibit higher performance. [15]

# 2. Preparation of Sample:

## 2.1 Concrete Mix Proportions:

Concrete grade was between C45/55 and C50/60.

Table 1 Aggregate mix ratio

| Concrete $1m^3$ mix proportions | | $0.049m^3$ |
|---|---|---|
| Material | | Content, Kg |
| Cement CEM I42.5R | 330 | 16.17 |
| Water | 165 | 8.09 |
| Sand 0/4 | 831 | 40.72 |
| Gravel 4/16 | 1034 | 50.67 |
| Fiber | 3 | 0.147 |
| Superplasticizer<br>SikaViscocrete D187 | 2.604 | 0.128 |

The test specimens shall be prisms according to to euro code 12390-1 with a nominal size (width and depth) of 150 millimetre and a length L measuring 550 millimetre ≤ L ≤700 millimetre. The specified shape and size of test specimens should be appropriate for concrete with the maximum size of aggregate mixture not more than 32 millimetre and/or bimetal fibres not more than 60 millimetre.

## 2.2 Manufacturing of test specimens:

- The procedure for filling the mould is presented in the figure below; the scale of increment one must be almost twice in comparison to the increment of second one.
- The mould shall be crammed up to around 90 % of the height of the test specimen before compaction.
- The mould shall be lidded up and levelled off when it under goes compaction. Compaction shall be carried out by external vibration.
- As far as the case of self-compacting is been performed for the metallic fibre concrete, the mould shall be filled and levelled off with no compaction.

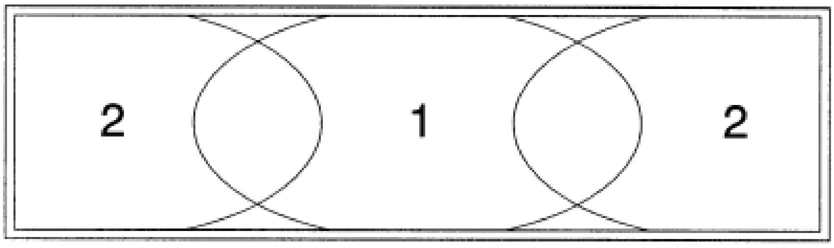


Figure 9 Schematic Representation of Procedure for filling the mould

## 2.3 Notching of Beams:

- Wet sawing shall be accustomed notch the test specimens. Specimens should be revolved over 90° around their longitudinal axis then sawn through the breadth of specimen at mid-span as specified in the figure below.
- The breadth of the notch was found to be 5 millimetre or less, the distance of the gap was found to be 125 millimetre ± 1 millimetres. The test specimens were cured with respect to the euro code 12390-2, for a minimum of 3 days after sawing which was not more than three hours before testing, leaving spare time for preparation as well as any devices for the transducers. Testing shall usually be performed at twenty-eight days.

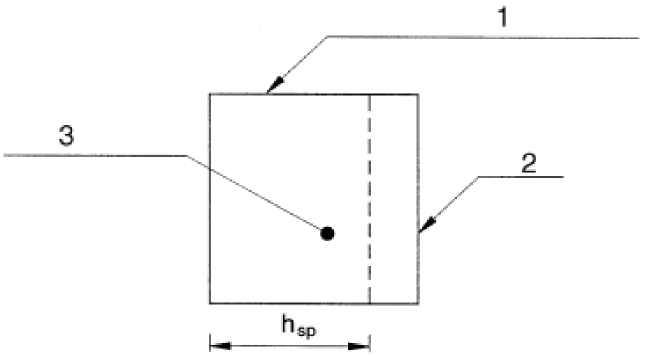


Figure 10 Schematic Representation of Position of the notch sawn into the test specimen before rotating

## 2.4 Preparation and Positioning of Test Specimens:

- The average breadth of the specimen and distance between the tip of the specimen in the mid-span section is determined from 2 measurements to the closest zero.
- 1 millimetres of breadth and distance in the notched a part of the test specimen, with the use of callipers.
- When the crack mouth opening displacement (CMOD) is measured, a displacement electrical device is mounted on the longitudinal axis at the mid-width of the test specimen, such the gap between the bottoms of the specimen and therefore the line of measure is five metric linear unit or less.
- When the deflection is measured other than the CMOD, a typical arrangement is done by a displacement transducer that is mounted on a rigid frame and then mounted to the test specimen at mid-height over the supports.
- One at one end of the frame was mounted to the specimen with a slippery fixture and also the alternative end with a rotating fixture.
- The electrical device was used to measure the deflection, a skinny plate mounted at one end was placed at mid-width across the notch mouth at exact point of measure.
- All bearing surfaces was cleaned and any loose grit or different extraneous material from the surfaces of the test specimen that is be in-tuned with the rollers was removed.

Figure 11  Typical arrangement for measuring CMOD in the KTU laboratory for one of the specimen used for experiment

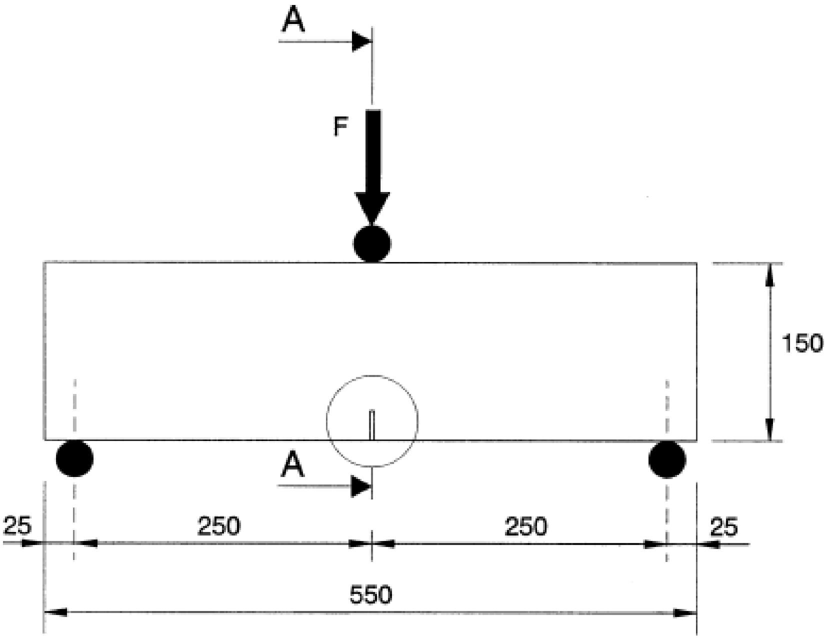


Figure 12  Schematic Representation of CMOD according to Euro code

## 2.5 Three Point Bending Test:

- Before the three-point bending test, the average span length of the test specimen shall be determined from two measurements to the closest millimetre of the axis distance between the supporting rollers on both sides of the specimen, by the use of ruler.
- The load was not applied till all loading and supporting rollers are resting evenly against the test specimen.
- In case of a testing machine which controls the varying rate of increase of CMOD, the machine was operated in a way that CMOD will increase at a constant rate of 0.05 mm/min.
- Once CMOD= 0,1 mm, the machine was operated so that CMOD showed an increase at a continuing rate of 0,2 mm/min.
- During the initial two minutes of the test, the values of the load and corresponding CMOD shall be recorded at a rate not less than five cycle per second, after this rate was reduced to not less than one cycle per second.

Figure 13 Image of specimen set up for three-point bending test from laboratory

Figure 14 Image of specimen set up for three point bending test from laboratory

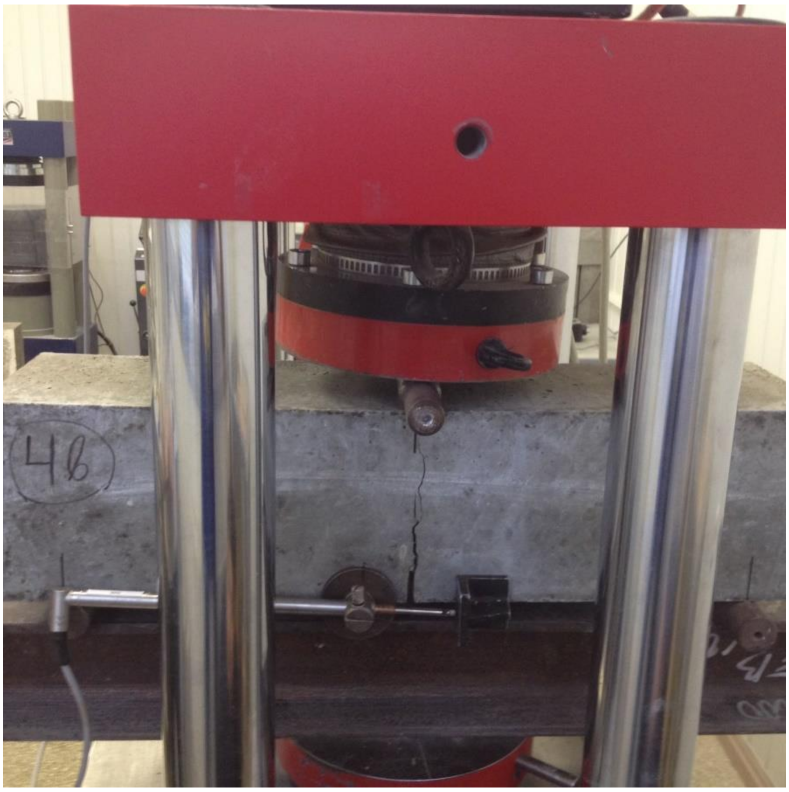


Figure 15 Image of the cracked specimen of polypropylene fibre concrete after the completion of three-point bending test

## 2.6 Formulas Used for Calculations of Results:

- The relationship between CMOD and Deflection was calculated by:

$$\delta = 0.085CMOD + 0.04$$

where;

δ is the deflection in millimetres;

CMOD is the CMOD value, in millimetres, measured just in case the gap between the bottom of the test specimen and the line of measurement shows y= zero.

- Limit of Proportionality:

  The limit of proportionality (LOP) is given by;

$$f.\frac{f}{ct}.L = \frac{3F_L.l}{2bh_{sp}^2}$$

Where;

$f^f_{cl}$ is the LOP, in Newton per square millimetre;

FL is the load corresponding to the LOP,

l is the span length, in millimetres;

b is the width of the specimen, in millimetres;

$h_{sp}$ is the distance between the tip of the notch and the top of the specimen, in millimetres.

- Residual Flexural Strength:

$$f_{rj} = \frac{3f_j l}{2bh_{sp}^2}$$

where;

$f_{Rj}$ is the residual flexural tensile strength corresponding with CMOD= $CMOD_j$ or δ= $\delta_j$ (j= 1,2,3,4), in Newton per square millimetre;

$F_j$ is the load corresponding with CMOD= CMOD j or δ= $\delta_j$ (j= 1,2,3,4).

## 3. Results:

Table 2 Computed Residual Strength from experimental data

| Specimen | ff | ff 0.5 | ff 1.5 | ff 2.5 | ff 3.5 |
|---|---|---|---|---|---|
| No | n/mm2 | n/mm2 | n/mm2 | n/mm2 | n/mm2 |
| 1 | 18.812 | 4.3671 | 4.031 | 4.535 | 4.031 |
| 2 | 16.194 | 4.29 | 4.957 | 4.957 | 4.957 |
| 3 | 15.712 | 3.343 | 3.008 | 4.011 | 3.677 |
| 4 | 15.326 | 4.331 | 4.997 | 5.997 | 5.664 |
| 5 | 16.436 | 3.689 | 4.360 | 4.360 | 4.360 |
| 6 | 13.660 | 3.665 | 3.998 | 4.664 | 4.664 |
| | | | | | |
| Average | 16.023 | 3.948 | 4.225 | 4.754 | 4.559 |

Table 3 Sample dimensions and initial design data

| Specimen | Thickness | Width | f{lo max} | {sigma}{lo m} | f{lo b} |
|---|---|---|---|---|---|
| No | mm | Mm | mm | mm | mm |
| 1 | 122 | 150 | 16.65 | 5.59 | 5.6 |
| 2 | 123 | 150 | 14.94 | 4.94 | 4.9 |
| 3 | 122.5 | 149.5 | 14.22 | 4.75 | 4.7 |
| 4 | 122.5 | 150 | 13.87 | 4.62 | 4.6 |
| 5 | 122.5 | 149 | 14.62 | 4.9 | 4.9 |
| 6 | 122.5 | 150 | 12.27 | 4.09 | 4.1 |
| | | | | | |
| Average | | | 14.428 | 4.815 | 4.8 |

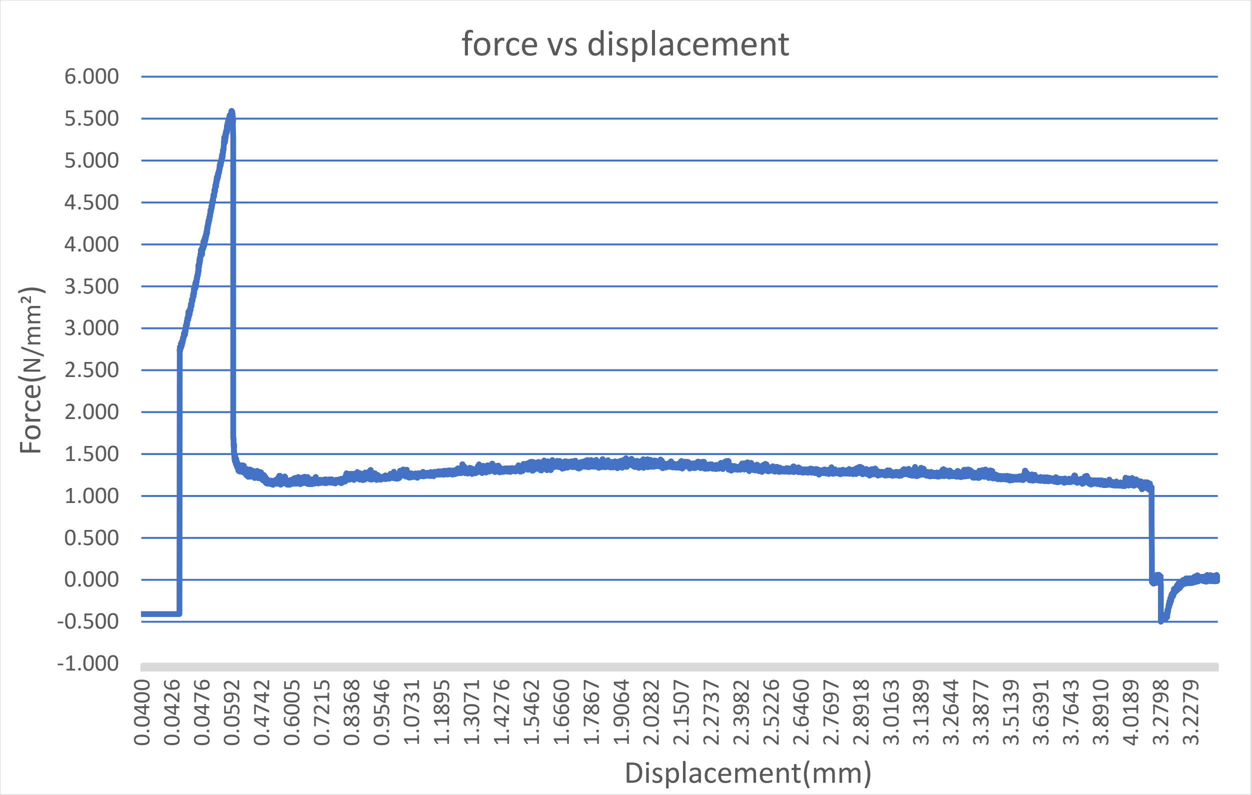
Table 4 Computed FJ values at CMOD (0.5,1.5,2.5,3.5)

| Specimen | fj0.5 | f 1.5 | f 2.5 | ff 3.5 |
|---|---|---|---|---|
| no | n/mm2 | n/mm2 | n/mm2 | n/mm2 |
| 1 | 1.3 | 1.2 | 1.35 | 1.2 |
| 2 | 1.3 | 1.5 | 1.5 | 1.5 |
| 3 | 1 | 0.9 | 1.2 | 1.1 |
| 4 | 1.3 | 1.5 | 1.8 | 1.7 |
| 5 | 1.1 | 1.3 | 1.3 | 1.3 |
| 6 | 1.1 | 1.2 | 1.4 | 1.4 |
| | | | | |
| Average | 1.183 | 1.266 | 1.425 | 1.366 |

Table 5  Additional parameters RE as per euro code

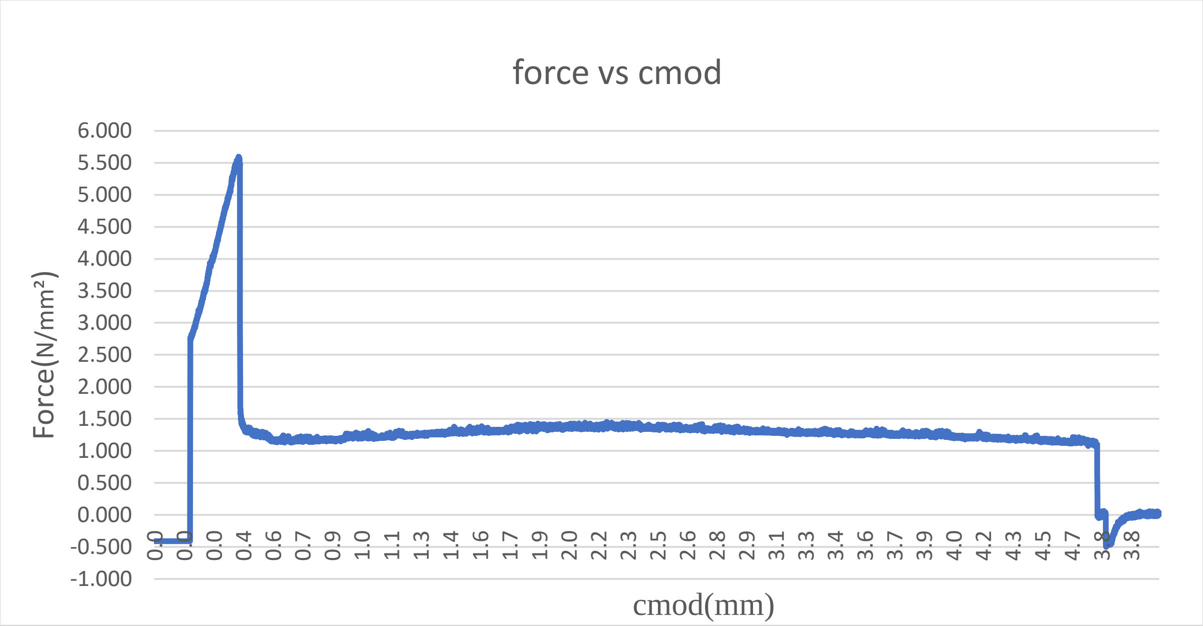
| Specimen | D1.5 | D3 | Re1.5 | Re3.5 |
|---|---|---|---|---|
| no | n/mm2 | n/mm2 | n/mm2 | n/mm2 |
| 1 | 1.35 | 1.42 | 0.016 | 0.024 |
| 2 | 1.45 | 1.38 | 0.014 | 0.033 |
| 3 | 1.5 | 1.7 | 0.024 | 0.025 |
| 4 | 1 | 1 | 0.009 | 0.040 |
| 5 | 1.65 | 1.7 | 0.018 | 0.029 |
| 6 | 1.4 | 1.3 | 0.017 | 0.038 |
| | | | | |
| Average | 1.391 | 1.41 | 0.0169 | 0.0319 |

## 3.5 Results obtained from graph:



Graph 1 Force vs Displacement for specimen 1 of polypropylene fibre reinforced concrete

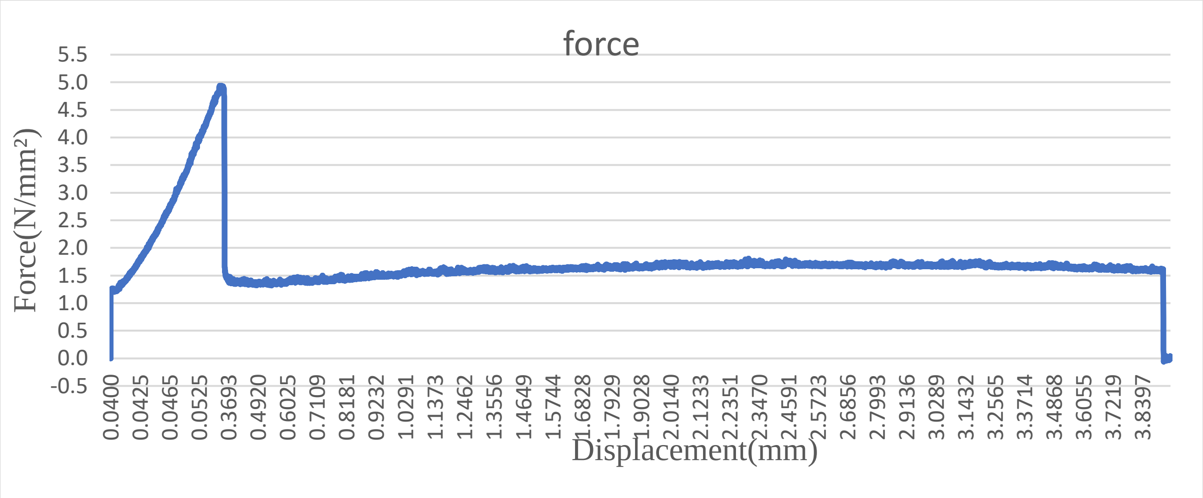
From the above graph we can obtain $F_{max} = 5.7$ N/mm$^2$ and the displacement is computed from CMOD values obtained from experimental data.



Graph 2  Force vs cmod for specimen 1 of polypropylene fibre reinforced concrete

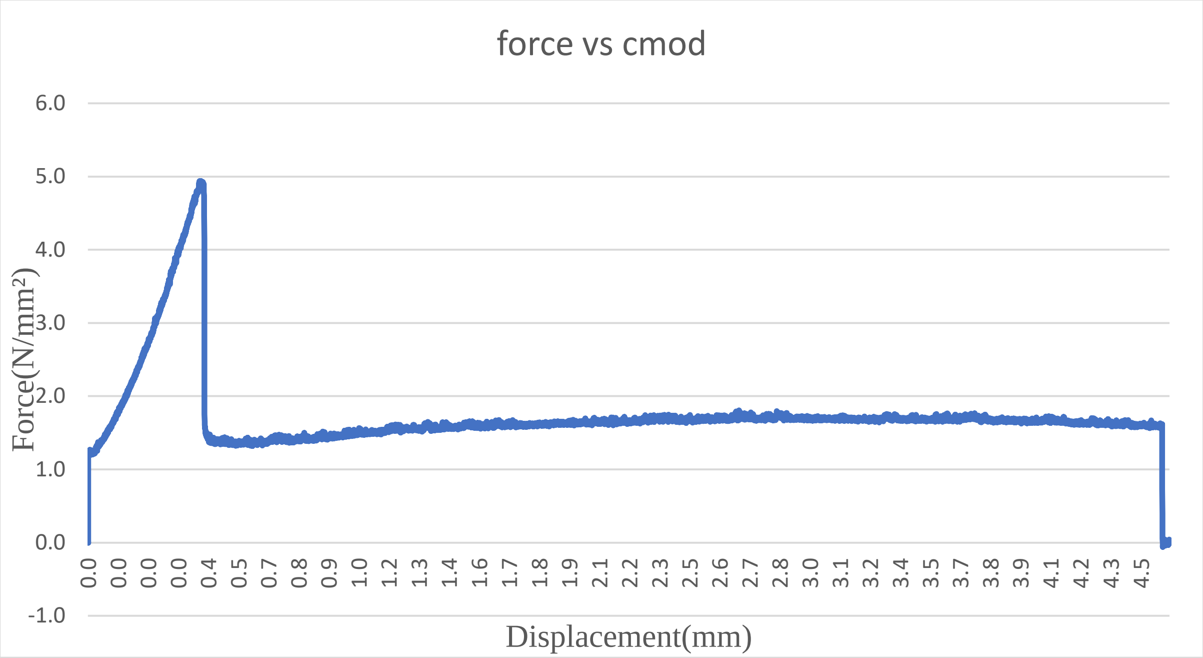
From the above graph we can obtain $F_{max}$ =5.6 N/mm$^2$ and $F_{j\ at}$ different deflection points were computed from the graph

3.5.2 Graph of Sample 2 of Polypropylene Fibre Reinforced Concrete prism:



Graph 3  Force vs Displacement for specimen 2 of polypropylene fibre reinforced concrete

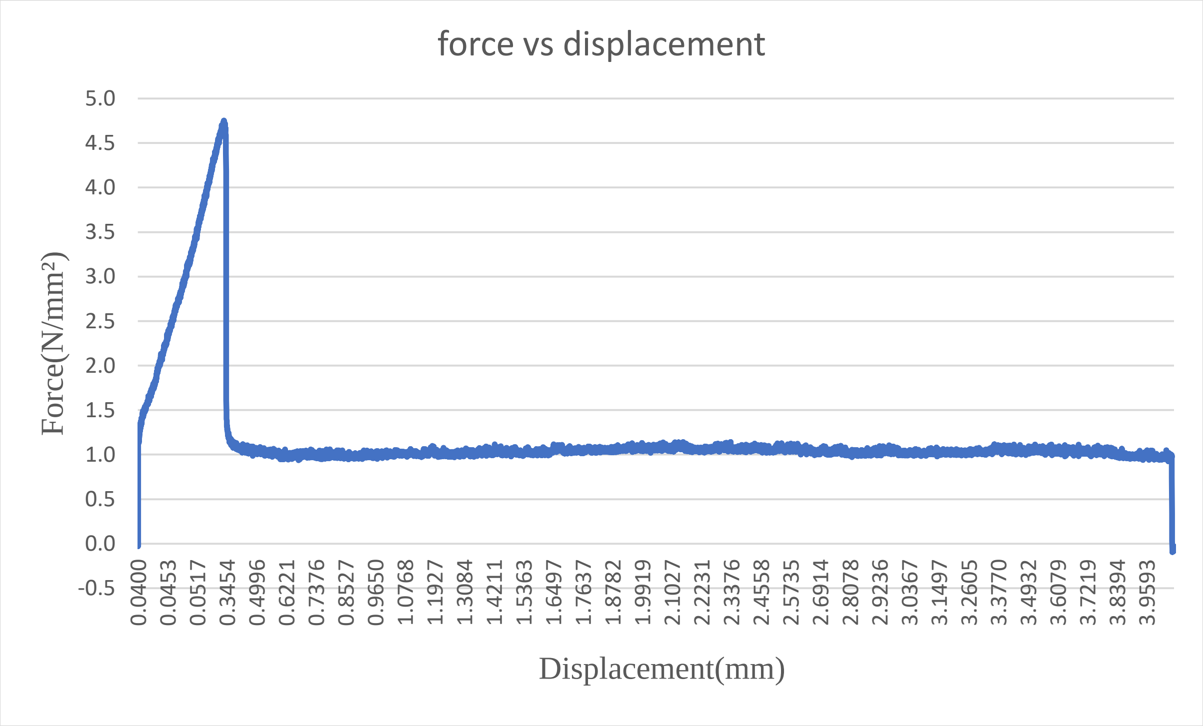
From the above graph we can obtain $F_{max}$ = 5.0 N/mm$^2$ and the displacement is computed from CMOD values obtained from experimental data.



Graph 4  Force vs cmod for specimen 2 of polypropylene fibre reinforced concrete

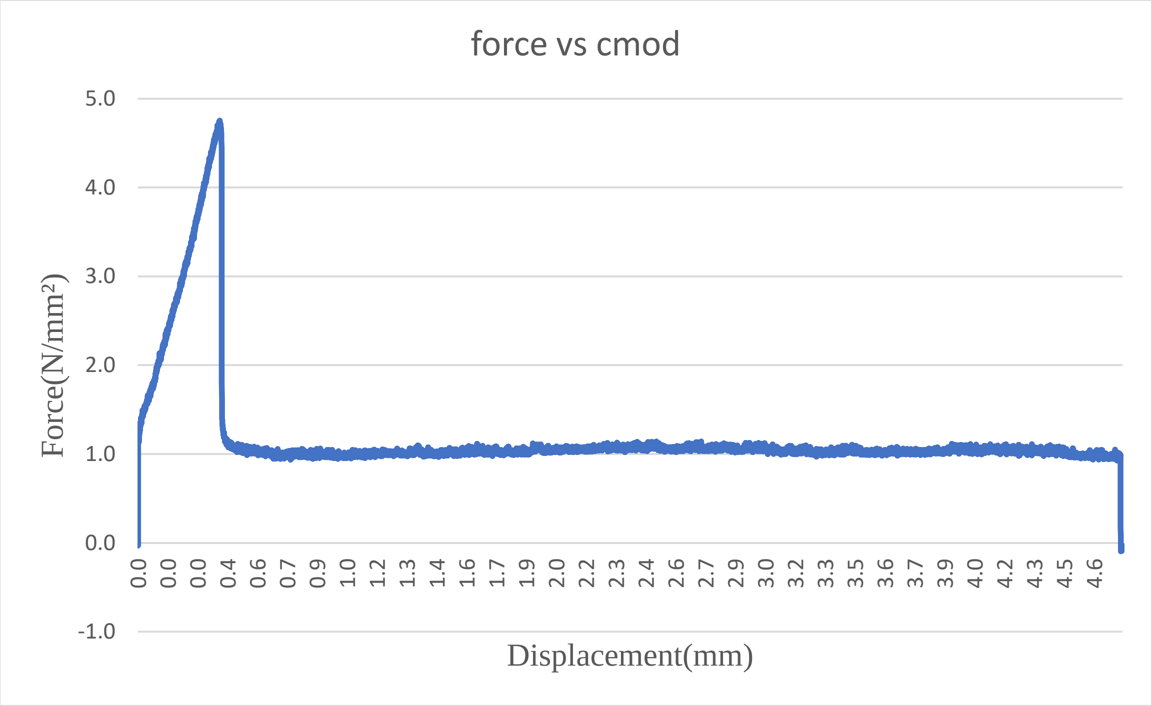
From the above graph we can obtain $F_{max}$ =5.0 N/mm$^2$ and $F_{j\ at}$ different deflection points were computed from the graph

3.5.3 Graph of Sample 3 of Polypropylene Fibre Reinforced Concrete prism:



Graph 5  Force vs Displacement for specimen 3 of polypropylene fibre reinforced concrete

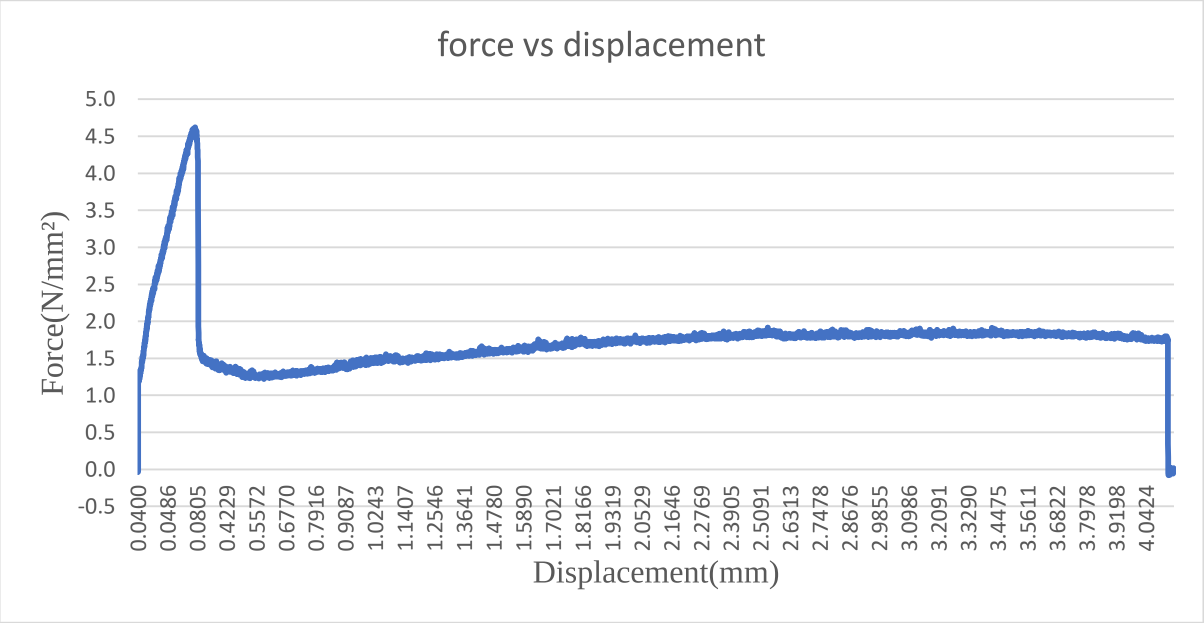
From the above graph we can obtain $F_{max} = 5.0\ N/mm^2$ and the displacement is computed from CMOD values obtained from experimental data



Graph 6  Force vs cmod for specimen 3 of polypropylene fibre reinforced concrete

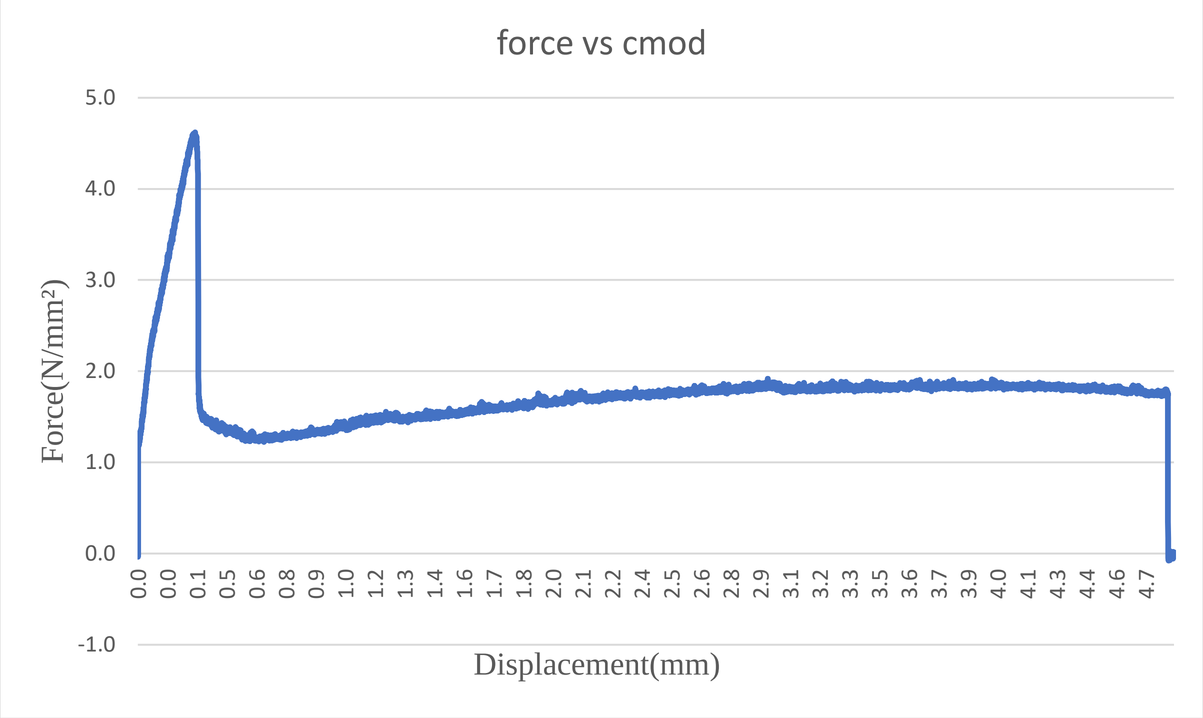
From the above graph we can obtain $F_{max} = 5.0\ N/mm^2$ and $F_{j\ at}$ different deflection points were computed from the graph

3.5.4 Graph of Sample 4 of Polypropylene Fibre Reinforced Concrete prism:



Graph 7  Force vs Displacement for specimen 4 of polypropylene fibre reinforced concrete

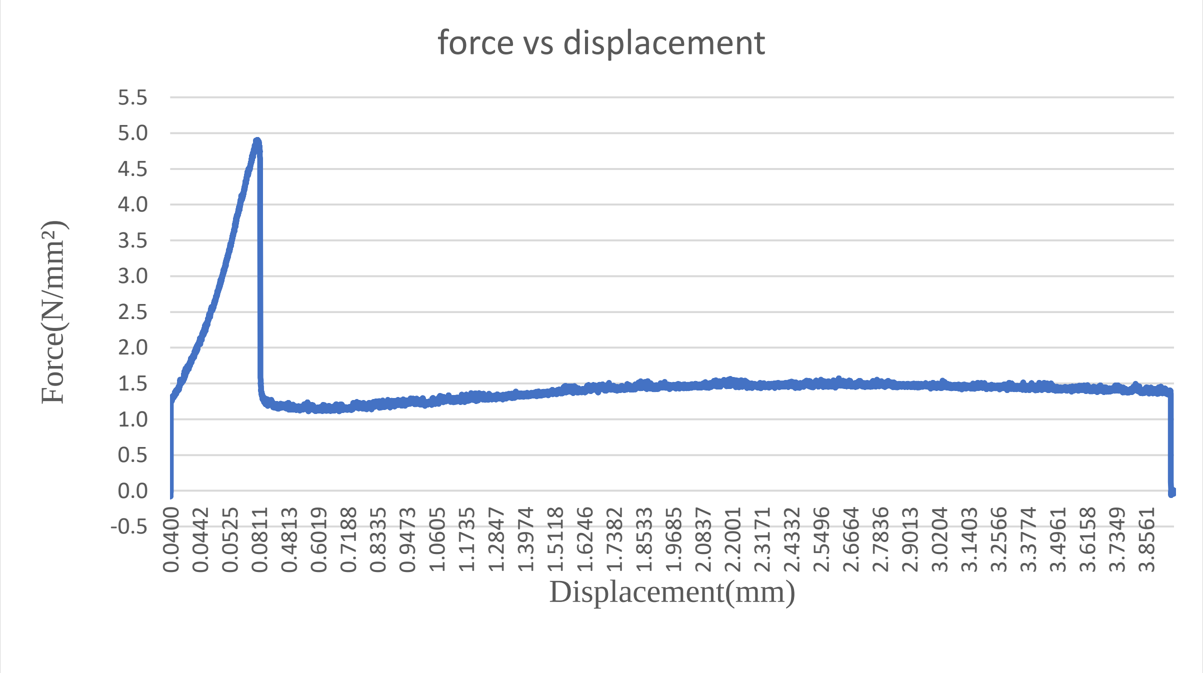
Graph 7 From the above graph we can obtain $F_{max}$ = 4.57 N/mm$^2$ and the displacement is computed from CMOD values obtained from experimental data.



Graph 8 Force vs cmod for specimen 4 of polypropylene fibre reinforced concrete

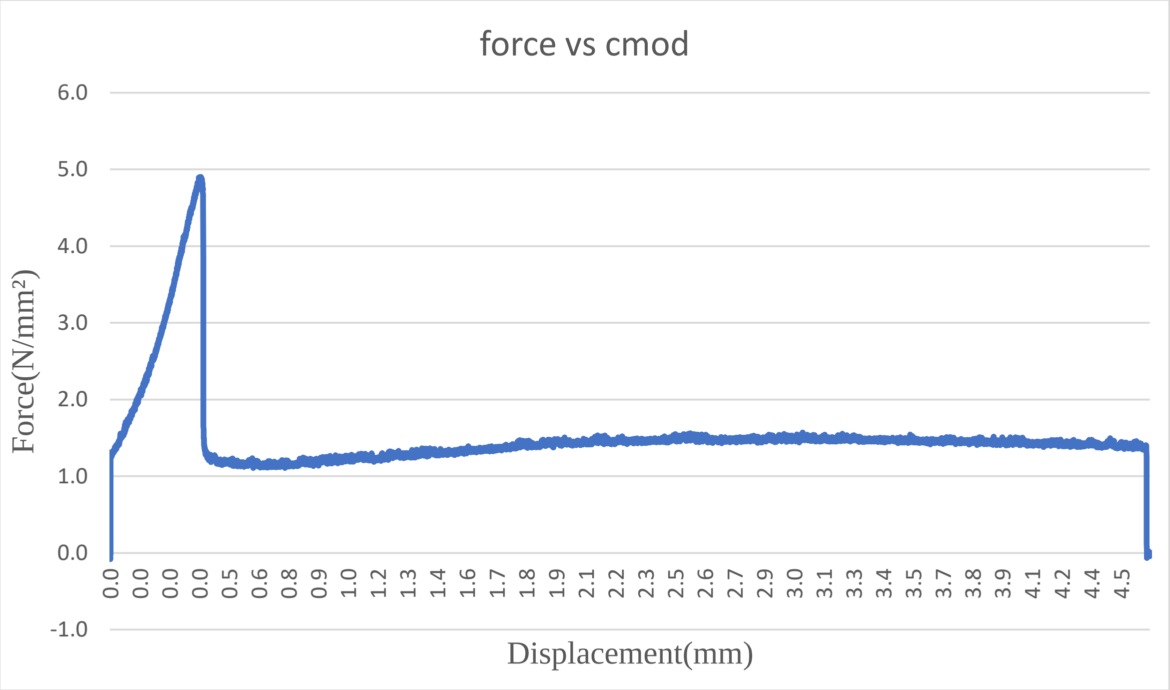
From the above graph we can obtain $F_{max}$ =4.60 N/mm$^2$ and $F_{j \text{ at}}$ different deflection points were computed from the graph

3.5.5 Graph of Sample 5 of Polypropylene Fibre Reinforced Concrete prism:



Graph 9 Force vs Displacement for specimen 5 of polypropylene fibre reinforced concrete

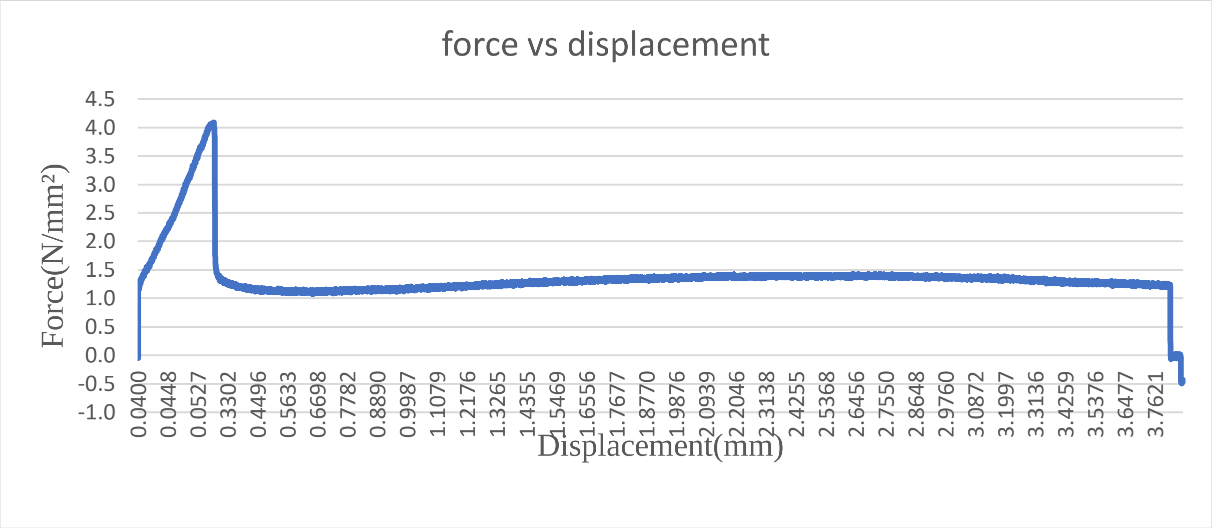
From the above graph we can obtain $F_{max}$ = 4.80 N/mm$^2$ and the displacement is computed from CMOD values obtained from experimental data.



Graph 10 Force vs cmod for specimen 5 of polypropylene fibre reinforced concrete

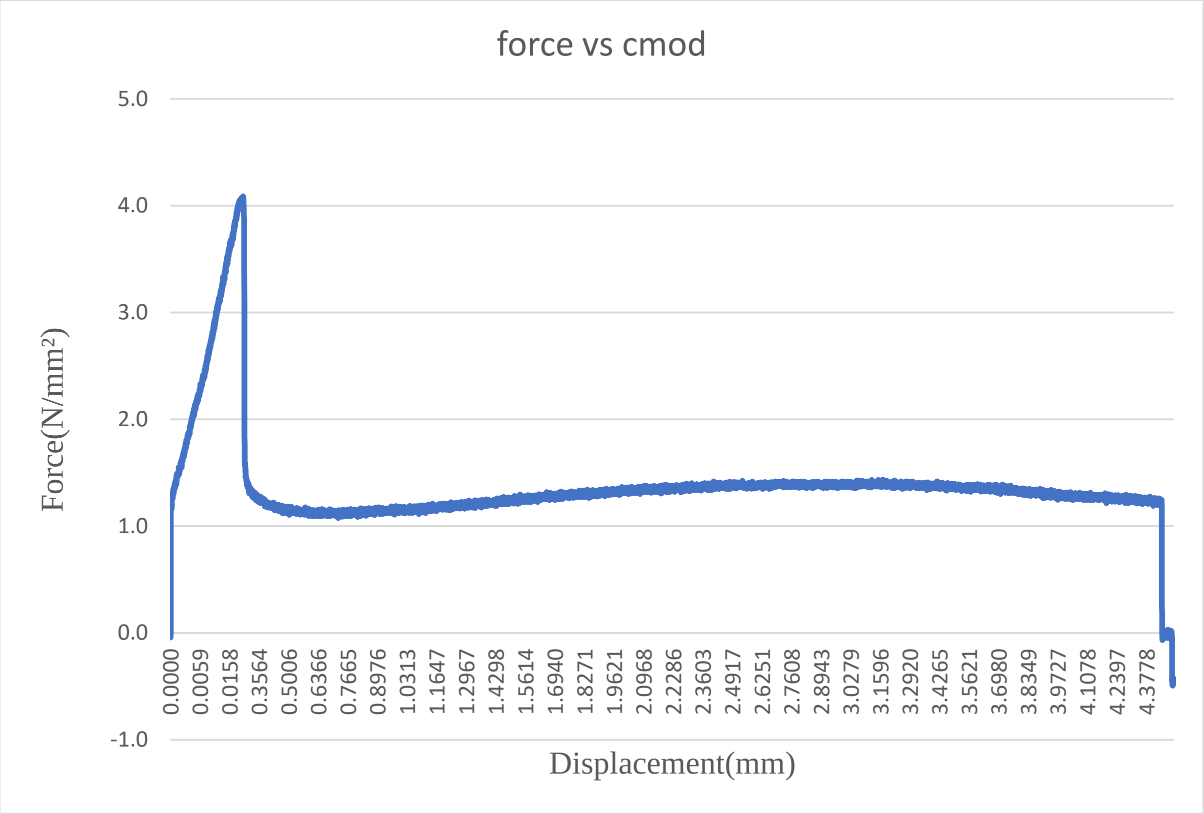
From the above graph we can obtain $F_{max}$ =4.90 N/mm$^2$ and $F_{j\ at}$ different deflection points were computed from the graph

### 3.5.6 Graph of Sample 6 of Polypropylene Fibre Reinforced Concrete prism:



Graph 11 Force vs cmod for specimen 6 of polypropylene fibre reinforced concrete

From the above graph we can obtain $F_{max}$ =4.20 N/mm$^2$ and $F_{j\ at}$ different deflection points were computed from the graph



Graph 12 Force vs Displacement for specimen 6 of polypropylene fibre reinforced concrete

From the above graph we can obtain $F_{max}$ = 4.20 N/mm$^2$ and the displacement is computed from CMOD values obtained from experimental data.

### 3.7 Table of residual strength data for SFRC at 0.25, 0.75, 1. 1.25:

Table 6 Residual strength data for SFRC at 0.25, 0.75, 1. 1.25

| Tabulated ratios of 5/CMOD at various prescribed average mid-span deflections and their coefficients of variation for the SFRC beams | | | | | |
|---|---|---|---|---|---|
| Concrete grade | Ratio of $\delta$ /CMOD at prescribed average mid-span deflections ($\delta = \frac{L}{4} * \frac{1}{H}$) | | | | |
| | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 |
| C25/30 (25) | 0.917 | 0.856 | 0.833 | 0.828 | 0.824 |
| C25/30 (50) | 0.898 | 0.854 | 0.840 | 0.835 | 0.832 |
| C25/30 (75) | 0.969 | 0.894 | 0.865 | 0.851 | 0.843 |
| C70/85 (25) | 0.923 | 0.870 | 0.850 | 0.840 | 0.835 |

Table 7 Residual strength data for SFRC at 1.5, 1.75, 2 , 2.5,3

| Tabulated ratios of 5/CMOD at various prescribed average mid-span deflections and their coefficients of variation for the SFRC beams | | | | | |
|---|---|---|---|---|---|
| Concrete grade | Ratio of $\delta$ /CMOD at prescribed average mid-span deflections ($\delta = \frac{L}{4} * \frac{1}{H}$) | | | | |
| | 1.5 | 1.75 | 2.0 | 2.5 | 3.0 |
| C25/30 (25) | 0.823 | 0.822 | 0.821 | 0.822 | 0.823 |
| C25/30 (50) | 0.830 | 0.830 | 0.832 | 0.833 | 0.836 |
| C25/30 (75) | 0.837 | 0.833 | 0.829 | 0.828 | 0.824 |
| C70/85 (25) | 0.831 | 0.829 | 0.828 | 0.824 | 0.822 |

Table 8 P- δ and P- δe for concrete grade C25/30

| Comparison between the loads obtained from the P- $\delta$ and P- $\delta_e$ curves at various mid-span deflections for the C25/30 (with 25kg/m 3 of Dramix 65/60 BN fibers) SFRC beams | | | | | | |
|---|---|---|---|---|---|---|
| Curve | Load at prescribed mid-span deflections (kN) | | | | | |
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| P- $\delta$ | 7.75 | 7.54 | 7.31 | 6.98 | 6.60 | 6.33 |
| P- $\delta_e$ | 7.85 | 7.65 | 7.39 | 7.00 | 6.61 | 6.31 |

Table 9 Comparison of P- δ and P- δe For C25/30 fibres Grade of Concrete with 50kg/m3

| Comparison between the loads obtained from the P- $\delta$ and P- $\delta_e$ curves at various mid-span deflections for the C25/30 (with 50kg/m 3 of Dramix 80/60 BN fibers) SFRC beams | | | | | | |
|---|---|---|---|---|---|---|
| Curve | Load at prescribed mid-span deflections (kN) | | | | | |
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| P- $\delta$ | 16.5 | 18.0 | 18.2 | 17.8 | 17.0 | 16.6 |
| P- $\delta_e$ | 16.6 | 18.0 | 18.2 | 18.7 | 16.8 | 16.4 |

Table 10 Comparison of P- δ and P- δe For C25/30 Grade of Concrete with 50kg/m3 of fibres

| Comparison between the loads obtained from the P- $\delta$ and P- $\delta_e$ curves at various mid-span deflections for the C25/30 (with 75kg/m 3 of Dramix 65/60 BN fibers) SFRC beams | | | | | | |
|---|---|---|---|---|---|---|
| Curve | Load at prescribed mid-span deflections (kN) | | | | | |
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| P- $\delta$ | 20.0 | 20.4 | 19.8 | 18.9 | 18.0 | 17.3 |
| P- $\delta_e$ | 19.9 | 20.1 | 19.5 | 18.4 | 17.6 | 16.7 |

Table 11 Comparison of P- δ and P- δe For C25/30 Grade of Concrete with 25kg/m3 of fibres

| Comparison between the loads obtained from the P- $\delta$ and P- $\delta_e$ curves at various mid-span deflections for the C25/30 (with 25kg/m 3 of Dramix 80/60 BN fibers) SFRC beams | | | | | | |
|---|---|---|---|---|---|---|
| Curve | Load at prescribed mid-span deflections (kN) | | | | | |
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| P- $\delta$ | 13.2 | 15.6 | 16.8 | 17.3 | 17.2 | 16.7 |
| P- $\delta_e$ | 13.2 | 15.5 | 16.5 | 17.0 | 16.9 | 16.5 |

## 4. Conclusions:

From experimental data the residual strengths were computed for six different samples of polypropylene fibre reinforced concrete and reference samples of steel fibres of varying fibre content so as to analyse its influence on compressive strength of concrete when fibres are used as additional crack inhibiting additives.

- It is found that steel reinforced concrete has higher residual strength capacity at failure when compared to polypropylene due to its inherent material properties like ductility and malleability.
- When both polypropylene and steel fibre concrete were subjected to testing, the crack width opening was found to more on polypropylene fibres when compared to steel fibres.
- For Polypropylene fibre reinforced concrete, the load corresponding to crack width opening for parameters 0.5, 1.5, 2.5, 3.5 was found to be 1.183 n/mm$^{2,}$ 1.266n/mm$^{2,}$ 1.425 n/mm$^2$ and 1.366 n/mm$^{2.}$
- In the case of steel reinforced concrete, the load corresponding to crack width opening for parameters 0.5, 1.5, 2.5, 3 was found to be 0.856 n/mm$^{2,}$ 0.823 n/mm$^2$, 0.822 n/mm$^2$and 0.823 n/mm$^{2.}$
- The higher length of the crack width in polypropylene reinforced concrete proved that they were subjected to a lower residual strength as compared to steel reinforced concrete.
- The crack width opening was testing for various variations and the results proved that polypropylene fibre reinforced concrete was found to be weak in terms of flexural strength with respect to steel fibre reinforced concrete.
- It is found that higher the fibre content better is the crack controlling mechanism.
- Polypropylene being an organic derived has brittle nature and has lower crack controlling capabilities.
- The injection of straight steel fibers has a major influence on the residual strength as insignificant increment and reduction was found to be present for varied volumes of fiber in concrete.
- There's a decent quantity of improvement in the strength of concrete upon the addition of the steel fibers.

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