An Experimental Study on Axial Compressive Behaviour of Rubberized Concrete Filled Circular Steel Tublar Columns

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ABSTRACT

RCC and steel frames have been the most common frame systems for a long time whereas the composite frame system has also emerged as a popular system for high-rise buildings for a few decades. Multi-story composite Structures are generally composed of steel members made composite with concrete. The use of concrete-filled steel tubes (CFST) in building construction has seen a renaissance in recent years due to their numerous advantages, apart from their superior structural performance making a typical composite frame structure. Their usage as columns in high-rise and multi-story buildings, as beams in low-rise industrial buildings, and as arch bridges, has become extensive in many countries in the last four decades with abundant examples. But, their usage in Nepal is a new concept. Hence, this paper shall primarily emphasize investigating the various aspects of CSFT members in the building industry; primarily considering the various aspects of these members which have turned its unique phase with the advancement of technology. With different volume replacement ratios of rubber coarse aggregate concrete-filled steel tube (RUCFST) columns were fabricated. Then axial compressive tests were completed. With different volume replacement ratios of rubber coarse aggregateConcrete-filled steel tube (RUCFST) columns were fabricated. Then axial compressive tests were completed. The test results show that RUCFST columns reveal lesser axial compressive capacity and higher ductility than normal CFST columns. In this paper, an attempt is made to study the strength properties of CFST Structure Using Waste Tyre Rubber in different proportions i.e. 5%, 10%,15%,20% replacing Coarse Aggregate, and strength is tested.

Keywords - Concrete-filled steel tubes(CFST), Waste Rubber Tyre, OPC Cement, Compressive Strength.

1 INTRODUCTION

Due to its difficulty in being reused and high incidence of landfilling, waste rubber has become a major cause of environmental pollution in recent years. Only 60% of the annual million tonnes of rubber trash produced worldwide is recycled. Due to the habitat that the landfills gave to dangerous insects, the ecology was harmed. Tyre fires at landfills pose a significant threat to the environment by emitting toxic fumes. The international community is becoming more and more concerned about the environmental impact of tyre disposal. The scarcity of natural resources and the advancement of society are in conflict. The path to sustainable growth is low-carbon green development. The inventory of used tyres in garbage has increased by one billion annually, according to WHO, to reach three billion. The difficulty of getting rid of such a large quantity of trash tyres is posing a severe problem for waste management. Thus, rubberized concrete (RUC) was created by adding rubber particles in place of coarse or fine aggregate. Cryogenic or mechanical techniques are used to separate the rubber particles from the used tyre trash. Less natural resource exploitation results from this solution. RUC and regular concrete have very different mechanical qualities from one another. The strength of concrete is considerably altered by a fractional change in aggregate volume. RUC's ductility was significantly increased as compared to traditional concrete. However, the ductility of rubber concrete was increased. It was discovered that the volume fraction of rubber particles was inversely proportional to the concrete's compressive strength, tensile strength, and young modulus. Some of the mechanical characteristics of traditional concrete, such as impact resistance, toughness, and crack resistance, are mechanically similar to those of rubber concrete. Because RUC had a greater ultimate strain, it was easier for structural components to dissipate excess energy. Although rubber concrete has been employed in the building of roads and airports, there are few structural components that use it. The goal of structural engineers is to strengthen rubber concrete.

According to studies, the production process, replacement ratio, and rubber particle size all have a significant impact on the RUC qualities. The weak connection between rubber particles and cementitious matrix (to promote bonding, rubber particles are bathed in NaOH and methylcellulose) and the mechanical differences between rubber and natural aggregates may be the causes of the drop in RUC concrete strength. There is a difference between poisson’s and modulus of elasticity between aggregates and rubber particles, hence the deformation of rubber and concrete was not synchronous when the RUC was under compression, which leads to the cracking of concrete. The effective measure to control this cracking in RUC is to test the CFST column. Concrete Filled Steel Tube (CFST) referred to the core concrete poured inside the steel tube, which helps to resist the external loads together with the steel tube and hence improves the strength of concrete. The addition of rubber as aggregate replacement in steel tubes, which is also called RUCFST columns could improve the plasticity of members, which contributes to absorbing and dissipation of seismic energy and met the requirements of seismic resistance.

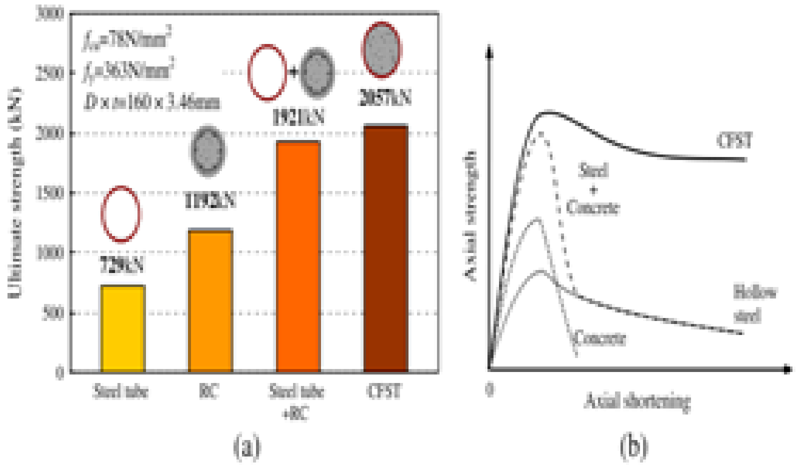

Fig.1Comparison of different forms of steel and concrete column

1.1 Statement of the problem

Various Studies quantify the global waste tyre problem at between 1 to 1.8 billion used tyre disposed of worldwide each year. This represents approximately 2-3% of total waste materials collected. The population of developing countries like Nepal is increasing day by day, with the increase in population there comes an increase in vehicles. So the number of waste tyre produced also increases. The disposal of waste rubber tyre is challenging as there is a high risk of fire in landfills and also it releases harmful gases during incineration.

The Gorkha earthquake occurred in Nepal on 20 April 2015 and had a magnitude of 7.6. Over 500,000 houses were destroyed and another 260,000 **were** damaged. Thousands of people lost their lives and millions of properties were damaged. A Few RCC frame structures and high-rise buildings were also damaged during the earthquake. This shows that Only the RCC frame structure is not able to sustain high earthquake magnitude. So wide research must be done to develop the structure that can resist the high magnitude earthquake. Under various active confinement conditions, Gholampur performed an axial compression test on rubberized concrete with a maximum volume replacement of 18%. The findings demonstrate that, like ordinary concrete, rubberized concrete's axial strength and peak strain rise with confinement pressure. In other words, rubberized concrete under active confinement has distinct mechanical properties from regular concrete.In 2019, Abuzaid tested RUCFST short columns with rubber as a 10% replacement ratio for fine aggregate and various steel tube thicknesses under axial compression. According to the findings, the RUCFST column's axial compression capacity is only 1.4 to 6.6% less than the CFST short column's.The RUCFST column has excellent ductile behaviour under both monotonic and cyclic bending situations, Silva found by conducting a bending test.A circular column has better durability than a square or rectangular column, according to Duarte's analysis of the impact of cross-sectional shape and concrete mix on the strength and durability of RUCFST columns.Over the course of 15 axially compressed short columns, Chai conducted experimental studies. The test demonstrates that a change in diameter thickness ratio has some bearing on a specimen's characteristic. The inclusion of rubber particles enhances a specimen's ductility to a certain level. Hence to resist the high magnitude earthquake composite column like RUCFST is important.Moreover, the RUCFST column can be advantageous due to following reasons:

2LITERATURE REVIEWS

This chapter describes a review of the behavior of concrete-filled steel cannular sections CFST subjected to load, bending moment, and each combination. The study on the analysis and design of CFST sections is reviewed and discussed.

2.1 behavior of concrete-filled steel columns:

The earliest research on CFST columns subjected to concentric loading was carried out by Gardner and Jacobson (1967), Knowles and Park (1969), and Sen (1972). In that investigation of the behavior of concrete-filled circular tubes, they found that the concrete containment results in an enhancement of the compressive strength. More experiments and theoretical studies were performed by other researchers and found that the total ultimate load of circular CFST is considerably larger than the nominal load, which is the combination of two component strengths, this is due to strain hardening of steel and the confinement of concrete. It ensures that the column behaves in a ductile manner, which is an advantage for seismic applicants. For slender CFST columns, stability rather than strength will govern the ultimate load capacity. Many authors have agreed that a slender ratio (L/D) equal to 15 generally marks an appropriate boundary between short and long column behavior. Neogi, Sen, and Chapman originally proposed this value for an eccentrically loaded column.

2.2 Review of literature:

Numerous researchers have conducted extensive analysis work utilising a variety of approaches on the concrete-filled steel tube, including

1. **Muhammad Naseem Baig, FAN Jiansheng NIE Jianguo**

In this study, trials were conducted on 28 samples, of which 12 were hollow tubes and 16 were filled with concrete. To investigate the impact and behaviour of steel tubes filled with concrete when subjected to just axial loads, an associate's degree experimental study was conducted.The empirically acquired results were contrasted with other results that had already been published and with theoretical methods. A thorough analytical investigation was also carried out to compare the outcomes.Twelve specimens filled with concrete and twelve hollow steel tubes made up the twenty-eight utilised Specimens. Experimental research was used to determine the column's load carrying capacity. The magnitude connection between the specimen's length and diameter ranged from 4 to 9.

2. De Nardin and A. L. H. C. El Debs

The purpose of this study was to evaluate the usefulness of style codes in determining their accuracy and ability to handle loads. The behaviour of the substance was examined. Coaxial specimens were the focus of the authors' investigations, which helped them determine their failure patterns and load capacities. This essay focuses mostly on how the steel tube's thickness and form affect the specimens' ability to support loads.They also investigated the behaviour of cold-rolled steel tubes filled with concrete. In this investigation, rectangular specimens were also examined. There were six short stubs that were subjected to concentric loading. Different thicknesses of square, rectangular, and circular sections were examined, and each was filled with highly durable concrete.This study provided information on ductility, the maximum load at which a structure may break, and how CFST columns will respond to concentric loading. All four faces of the specimen's vertical shortening were measured using LVDT.

3. Georgios Giakoumelis Dennis Lam

The strength and behaviour of CFST filled with concrete of various strengths under the influence of axial load are shown in this study. Additionally, the impact of tube thickness on column strength, the confinement of steel on concrete, and consequently the bond between concrete and steel were investigated. The outcomes were compared to the codal provisions provided in the Australian, Yankee, and Eurocode 4 systems. It was clear that the experiments' value was higher than the results that the three codes had produced. There have been suggestions made to the Australian and Yankee codes that would discriminate between the behaviour of the sample that was greased and ungreased from the inside side, as well as to incorporate the influence of confinement. The outcomes lined up with Euro code 4. The tests fell within the Euro code 4 range of 17%. The outcomes for high-strength concrete are excellent.

4. Dalin Liu, Wie-Min GhoJie

The load capacity of stub columns with concrete-filled steel hollow sections (CFSHS) was tested experimentally, and the findings were compared to those of the applicable codes. The strength of the stub columns reduces as the cross-sectional area grows, as had been obvious. The outcomes were discovered to be the same as the earlier study. Until failure was reached, 22 rectangular CFSHS columns with aspect ratios of 1, 1.5, and 2 were put under concentric loading. The stubs were built using materials with high strength. A 5000KN test rig equipped with a linear voltage displacement electrical device (LVDT) was used to evaluate each specimen, and axial shortening was determined. It was discovered that concrete had strengths of 70.8 MPa and 82.1 MPa, while steel had a yield strength of 550 MPa. Two single-element strain gauges were placed at mid-height on each face of the specimen to calculate the strains.It was discovered that the Yankee Concrete Institute and AISC provide lower values of loads for failure when compared to codes. The acquired values were down by 14% and 16%, respectively. It was because these laws do not consider how confinement affects actual value, which increases as a result of confinement. With Euro code 4, the values only differ by 6%. The strength of the rectangle specimen varied very little from the circular and square specimens.

5. Lin-Hai Han, Guo-Huang Yao

The impact of compaction on the strength of the CFST column is examined in this study. It is commonly known that compaction is a key factor in strength for typical concrete. However, the purpose of this study is to find out what function it serves in the CFST column. This analysis determines the impact of the compaction method on the strength as well as concrete samples generated using various methods of compaction. The resulting results are contrasted with the codes' values. The strength as well as the interaction between the concrete core and steel tube are shown to be affected by the efficiency and method of concrete compaction.

A total of 35 samples were evaluated both under eccentric and concentric loading. Studies were done on both the maximum loading capacity and the behaviour up until failure. After twenty-eight days, the concrete utilised had a typical compressive strength of twenty-two MPa. By hand and poker vibrator, the cubes were tightly compressed (three layers having forty strokes for every layer). There were eight transducers altogether.utilised to determine the distortion at each face. Axial deformation is measured in addition using two transducers. A tenth of the expected load capacity was represented by the load increase. for a period of 2-3 minutes. The specimens that were compressed by hand had more buckling due to lower buckling efficiency, and steel tubes buckled sooner. The specimens were discovered to have achieved their maximum load in thirty minutes, and failure was measured at one and a half hours. All samples were loaded until they broke. Each test took about thirty minutes.As a result, the poker vibrator's strength was significantly higher than that of hand-compacted material. Samples compacted using a poker vibrator had three to thirty percent higher strength than samples compacted by hand.

6. Bao-Chun Chen

This study provides a brief overview of the current state of CFST arch bridges in China. We looked into and examined over 200 CFST arch bridges using a variety of criteria, including type, span, erection method, geometric factors, and material. Some significant design calculation issues were discussed, including a strength check, section stiffness calculation, and joint fatigue strength. It will give designers and builders of bridges complete references for the CFST arch bridge.

7. Quin Quan Liang

An effective theoretical model for the nonlinear spring-less analysis of circular CFST short columns under eccentric loading is presented in this work. To account for confinement effects that increase both the strength and ductility of concrete, correct material constitutive equations for normal and high strength concrete confined beneath normal or high strength circular steel tubes are included in the theoretical model. The vertical theoretical model is used to examine the elemental behaviour of circular CFST columns with different diameter to thickness ratios, concrete compressive strength, steel yield strength, and sectional forms. A replacement design model for calculating the ultimate pure bending strength of circular CFST columns is planned and is based on extensive numerical investigations.

2.3 RESEARCH GAP:

Reviewing literature from different authors, there are researches done before for CFST and RUCFST columns towards axial loading by using various grades of steel and different proportions of aggregates in different parts of the world.The main research gap is that there is an insufficient number of studies in the RUCFST column under axial loading in the context of Nepal. In most of the research conducted in the world, fine aggregates are replaced by rubber in the RUCFST column, but there is insufficient research about replacing natural coarse aggregates with waste rubber tyre as coarse aggregates in the RUCFST column. Also, the composite column structures are not much practice in the context of Nepal. Hence this research may be a new research topic for the RUCFST column.

3MATERIALSANDMETHODOLOGY

In the RUCFST columns, we tend to used different materials like Cement, sand, aggregate, rubber particles, and steel tube. The brief descriptions of materials are given below:

3.1 Cement:

Cement is a binder substance that is used for the construction that sets, hardens, and adheres to other materials to bind them together. Cement is used to bind sand and aggregate together to form concrete. Concrete is the most used material in construction works. Cement is factory-made from calcareous materials, such as limestone or chalk, and silica and alumina are found as clay or shale.

The producing method includes grinding the raw materials into a very fine powder and mixing them in suitable proportions and burning them in a large rotary kiln at a temperature of 1400 degrees Celsius and forming a clinker. Then the clinker is cooled and ground to a fine powder with the addition of gypsum to form cement. In this project, we used OPC 53 grade Sarbottam cement. The normal consistency of this cement is 30%.

Fig.2 53 grade OPC Sarbottam Cement.

3.2 Fine aggregate:

Fine mixture is that the essential ingredient in concrete that consists of natural sand or crushed stone. Fine aggregates are the materials that pass through a 4.75mm sieve and retain in a 0.075mm sieve.

The quality of fine aggregate density powerfully influences the hardened property of the concrete. The concrete can be made more durable, cheaper, and stronger if the selection of fine aggregate is based on grading zone, particle size, particle shape, texture abrasion, and moisture absorption.

A good concrete mix must include aggregate that is clean, strong, and freedfrom absorbed chemicals or coating of clay or fine materials. Negligence of these characteristics may cause the deterioration of concrete, thus grading fine aggregate, where each zone defines the percentage of fine aggregate passed from the 600-micron sieve size.

1 Zone I:15% to 34%

2 Zone II:34% to 59%

3 Zone III:60% to 79%

4 Zone IV:80% to 100%

We can access the quality of fine aggregate with the help of a grading zone. In this project, we used Zone II river sand.

Fig.3 River fine aggregate

3.3 Coarse aggregate:

Aggregate whose size is bigger than 4.75mm is known as coarse aggregate. The aggregates are typically obtained from stone quarries or breaking them with a hand or crusher machine. In construction, aggregates are used in concrete considering its economic factor and the strength provided to concrete. The coarse aggregate has a major effect on concrete properties such as abrasion resistance, hardness, elastic modulus, and other characteristics like durability stronger and cheaper. It acquires 60-65% volume of concrete. It is used to provide a rigid structure to the concrete. Aggregates help in reducing shrinkage and surface cracking of concrete. In this project, we used angular coarse aggregates of size 20mm.

Fig. 4 Crushed coarse aggregate

3.4 Water:

Water is the key ingredient, that once mixed with cement, forms a paste that helps to bind the aggregate together. The water causes the hardening of concrete mixture through a process called hydration. Hydration is the chemical process in which the major components in cement form chemical bonds with water molecules and become hydrates. The role of water is vital because the water-to-cement ratio is the most important factor in the production of perfect concrete mixture. An excessive amount of water reduces the concrete strength, while too less will make the concrete unworkable. Concrete should to be workable so that it may be consolidated and shaped into different forms. As concrete must be both strong and workable, a balance cement water ratio is required while making concrete. In this project, we used a water cement ratio of 0.5.

3.5 Rubber as Coarse Aggregates:

Rubber is created extensively worldwide annually. It cannot be discharged easily into the surroundings as its decomposition takes a lot of time and also produce environmental pollution. In such a case, the reuse of rubber would be the better choice. In order to reuse rubber wastes, it was added to the concrete as coarse aggregates and its different properties like compressive strength, tensile strength, ductility, etc. were investigated and compared with ordinary concrete. The rubber aggregate is obtained from the waste tyre. The waste tyre from the garage was cut into coarse aggregate size. It was difficult to make rubber aggregate size exact 20mm due to difficulty in the cutting process. In this project, coarse aggregates are partially replaced by rubber aggregates.

Fig. 5 Waste tyre coarse rubber aggregate

3.6 Circular hollow steel column:

Nowadays, CFST columns are increasingly used in composite construction. Under axial compression steel tube will sustain the partial axial force and provides the confinement to the infill concrete. The high axial strength capacity of CFST columns is due to the confinement provided by the steel tube. One of the main advantages of a CFST column is the interaction between steel tube and concrete. Here the occurrence of the local buckling of the steel tube is delayed by the restraint of concrete, and the strength of concrete is increased by confining effect provided by the steel tube. The infilled concrete increases the buckling load capacity of the steel tube. The circular steel section was taken from the iron grill shop. The diameter of the steel tube is provided 110mm. The height of the steel column is 500mm and the thickness is 2.5mm.

Fig. 6 Circular steel column

In this research the methodology followed is to meet the objective of the study which is described in this section. The research is divided into two folds: first was the collection and preparation of rubber aggregate and performing the laboratory-based works and the second was the desk-based study.

3.7 DESK-BASED STUDY:

Detail study of articles, journals and books related to rubber aggregate concrete and RUCFST was carried out at first. After finding the research gap in the subject matter, the collection of materials and laboratory experiment was performed.

3.8LAB-BASED STUDY:

The main outlines of laboratory experiment are given below:

- Source and preparation of materials (waste rubber tyre from the garage)
- Properties of materials (steel tube, cement and aggregates)
- Mix proportions design (concrete cubes and RUCFST)
- Slump test
- Curing method (water tank and wet cloth sheet)
- Strength test procedure (experiment test of concrete cubes and RUCFST)
- UTM test and loading intensity

CONCLUSIONS

This study provides new data on the behavior of concrete filled steel tubes using waste rubber tyre crumb as a partial replacement for coarse aggregates. Based on the experimental investigations obtained in this research, the following conclusions can be made:

- ❖ The workability of fresh concrete increased by using crumb waste tyre rubber as a partial replacement for coarse aggregate. The increase in workability is seemed to be more at higher rubber contents. The increase in the slump of rubber concrete is due to the hydrophobic nature of rubber, it causes a weak transition zone between rubber and cement matrix. And another reason is due to the smooth surface texture of rubber it provides poor bonding between rubber and cement matrix.
- ❖ Using waste tyre rubber in concrete had an adverse effect on the compressive strength. With the increase in the percentage of rubber aggregate, the compressive strength also decreases.
- ❖ From the above results it is found that in concrete cubes with the replacement of 5% natural aggregates the loss in strength is 15.5% for 10% replacement loss in strength is 25.3% and for 20% replacement the loss in strength is 50.8% similarly for RUCFST column with the replacement of 5% loss in strength is 15.34 for 10% replacement loss in strength is 21.78% and for 20% replacement loss in strength is 33.44%. Hence it concludes that by using steel tubes in concrete the loss in strength of concrete is prevented and there is full utilization of strength of concrete.

- Comparing the strength of concrete for M20 28 days strength for CCNAS 0% is 27.50 N/mm2 and for CFST is 69.17 N/mm2 which is 2.52 times greater than cube strength , for CC5RUS(5%) strength is 23.24 and for RUCFST(5%) strength is 58.56 which is 2.51 times greater, for CC10RUS(10%) strength is 20.53 and for RUCFST(10%) strength is 54.10 which is 2.63 times greater, for CC20RUS(20%) strength is 13.53 for RUCFST(20%) strength is 46.04 which is 3.4 times greater than cube strength. From the above results, it is shown that using steel tubes in concrete as the composite column the strength is increased by 2.5 to 3.4 times. This increase in strength is due to the confinement provided by the steel tube section to the concrete.
- Seeing the failure modes, steel section fails by bending and bulging and inner core concrete fails by shear failure from where there are more concentrations of rubber particles.
- The yield point and the ultimate point distance increases with increase in the percentage of rubber aggregate i.e. ductility increases with increase in the percentage of rubber aggregates.

RESULTS

The test results of different experiment conducted are discussed in this section.

5.1 SLUMP TEST RESULTS:

Variations in the slump values of plain and rubberized concrete are shown below in a table. It was observed that with the increased proportions of rubber aggregate the slump values also increase. When the rubber content was increased from 0% to 20% by the coarse aggregate volume, there were variations in slump value by 39%. These results showed that there is a significant effect of rubber on the workability of concrete, which may be due to two reasons. First is that since the rubber particles are softer than the natural aggregate, hence concrete matrix shows more workability than conventional concrete. Second, due to the adhesion between the rubber particles and the concrete paste since the soft rubber surface is smooth and behaves as voids in the concrete mix.

Table1: slump tests results of different proportions of RUC

	Total number of slump conducted=4 (W/C=0.5)	
	Slump Value	**Descriptions**
1	115mm	0%Rubber aggregate (CCNAS)
2	135mm	95% natural aggregate+5%Rubber aggregate (CC5RUS)
3	140mm	90% natural aggregate+10%Rubber aggregate (CC10RUS)
4	160mm	80% natural aggregate+20%Rubber aggregate (CC20RUS)

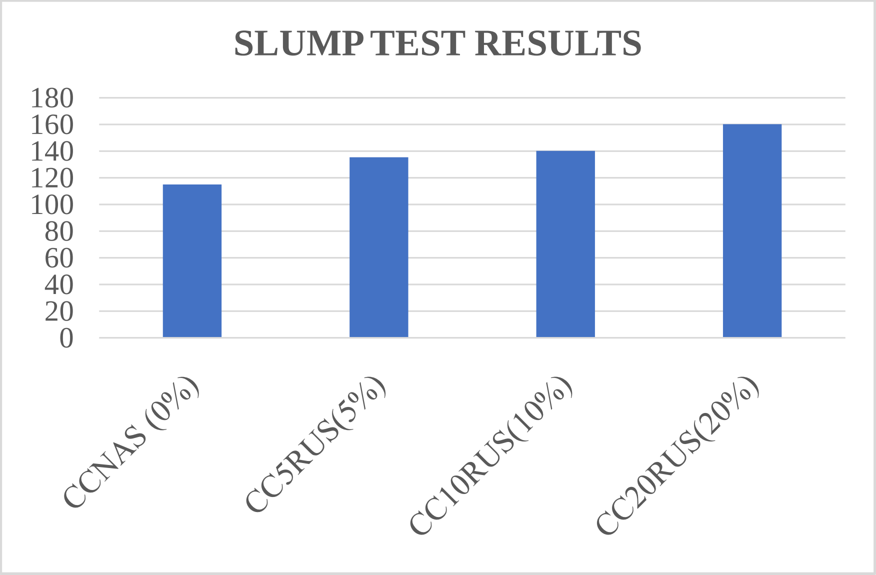

Fig 7: slump value vs % of rubber aggregate in concrete cube

5.2 CUBE TEST RESULTS:

Table 2: Test results For 7 Days Cube Test

S.N	WEIGHT(kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean strength (N/mm2)	Remarks
1	8.37	409.5	18.2	**18.43**	CCNAS (0%)
2	8.41	391.5	17.4		
3	8.5	443.25	19.7		
4	8.22	375.75	16.7	**16.47**	CC5RUS (5%)
5	8.2	380.25	16.9		
6	8.3	384.75	17.1		
7	7.94	346.5	15.4	**15.97**	CC10RUS (10%)
8	8.02	362.25	16.1		
9	8.03	369	16.4		
10	7.6	222.75	9.9	**10.23**	CC20RUS (20%)
11	7.4	229.5	10.2		
12	7.7	238.5	10.6		

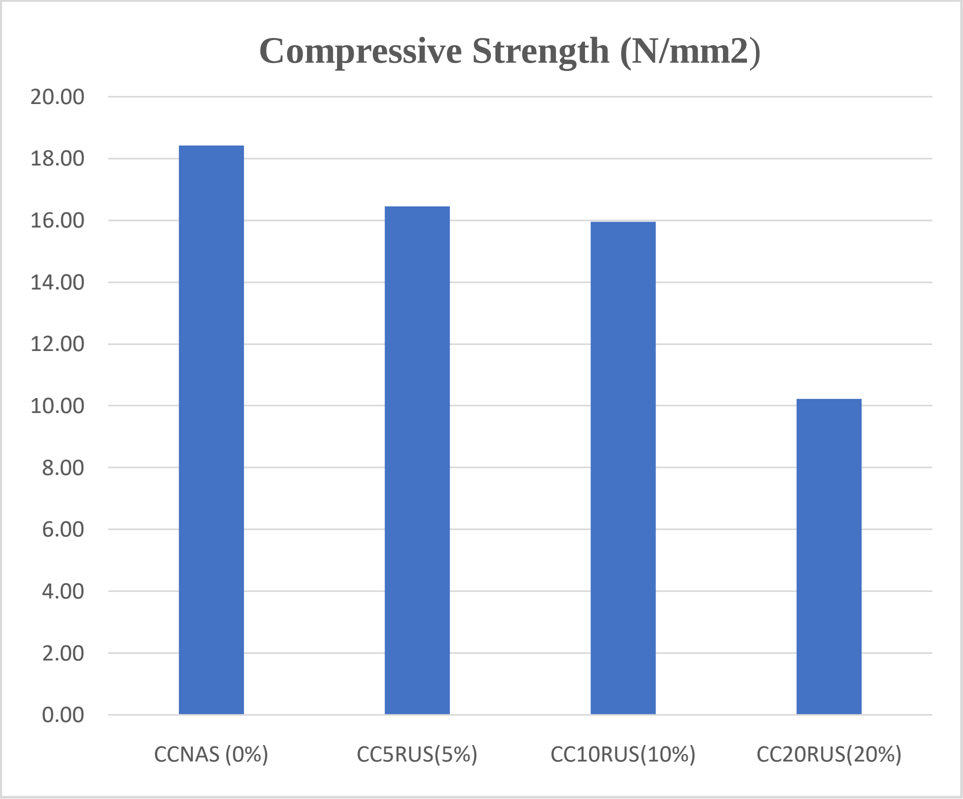

Fig 7: Compressive strength of Cubes at 7 days

Table 3: Test results For 14 Days Cube Test :

S.N	WEIGHT(kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean strength (N/mm2)	Remarks
1	8.4	508.5	22.6	**21.87**	CCNAS (0%)
2	8.32	490.5	21.8		
3	8.26	477	21.2		
4	8.295	468	20.8	**19.87**	CC5RUS (5%)
5	8.26	463.5	20.6		
6	8.11	447.75	19.9		
7	7.8	429.75	19.1	**19.10**	CC10RUS(10%)
8	7.78	434.25	19.3		
9	7.66	425.25	18.9		
10	7.53	290.25	12.9	**12.79**	CC20RUS(20%)
11	7.52	283.5	12.6		
12	7.6	289.8	12.88		

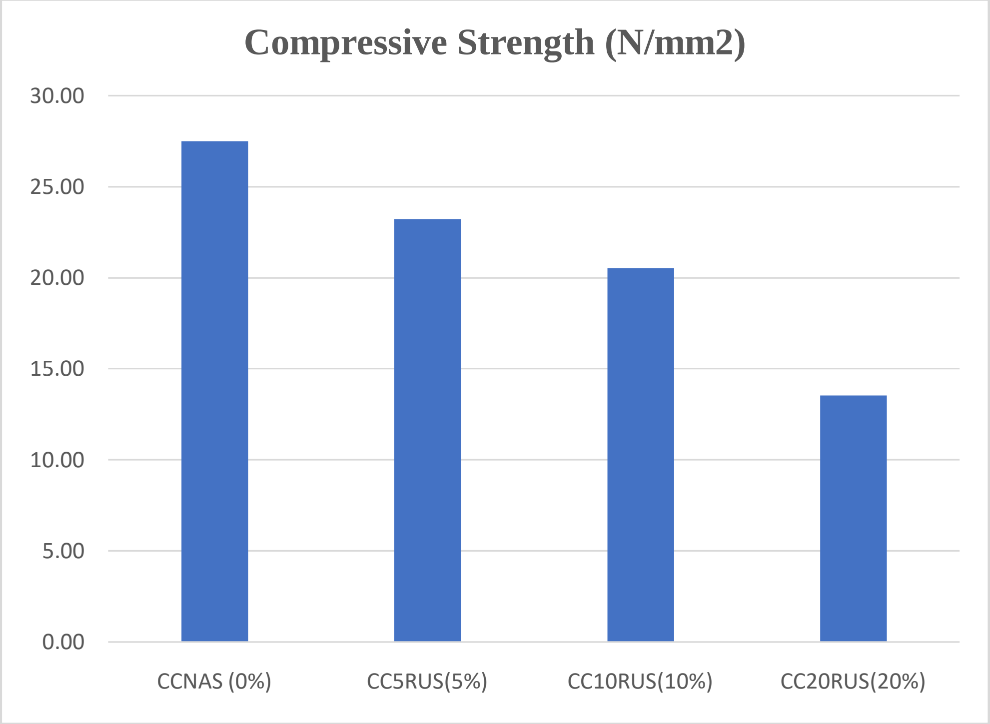

Fig 8: Compressive strength of Cubes at 14 days

Table 4: Test results For 28 Days Cube Test :

S.N	WEIGHT (kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean Strength (N/mm2)	Remarks
1	8.5	633	28.1	27.50	CCNAS (0%)
2	8.38	614.97	27.3		
3	8.3	610.47	27.1		
4	8.1	547.5	24.3	23.24	CC5RUS (5%)
5	8.19	567.79	25.2		
6	8.12	543.45	24.12		
7	7.94	458.12	20.4	20.53	CC10RUS (10%)
8	7.95	446.89	19.9		
9	7.89	478.33	21.3		
10	7.54	320.2	14.2	13.53	CC20RUS (20%)
11	7.4	313.43	13.9		
12	7.55	281.86	12.5		

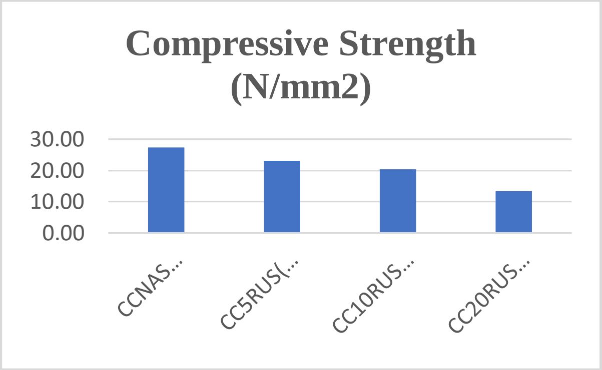

Fig 9: Compressive strength of Cubes at 28 days

Table 5: Comparison table of RUS at 7, 14 and 28 days

Specimen name	**7 Days compressive strength (N/mm^2)**	**14 Days compressive strength (N/mm^2)**	**28 Days compressive strength (N/mm^2)**
CCNAS (0%)	18.43	21.87	27.50
CC5RUS(5%)	16.47	19.87	23.24
CC10RUS(10%)	15.97	19.10	20.53
CC20RUS(20%)	10.23	12.79	13.53

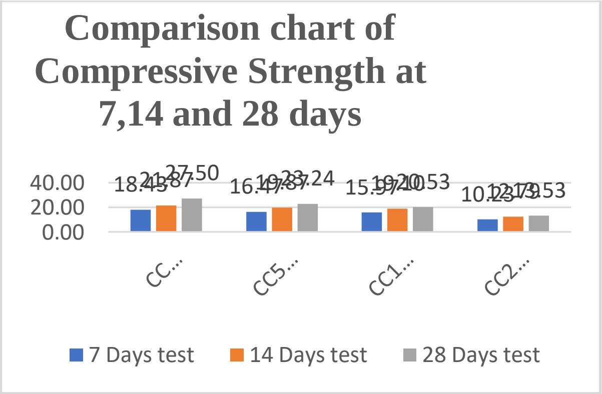

Fig 10: Comparison Chart of RUS Cubes at 7, 14 and 28 days

The experiment concludes that as the percentage of rubber aggregate increases the compressive strength of the concrete decreases. Thus, only by using rubber aggregate as a replacement for coarse aggregate does the strength of concrete decrease. Hence, to enhance the property of rubber aggregate fully in concrete, we provide confinement in concrete by covering the inner core of concrete with steel tube.

5.3 RUCFST TEST RESULTS:

The CFST and RUCFST test was carried out on 7, 14, and 28 days after the concrete was cast in circular tubes. The test was carried out using a UTM machine. The RUCFST sample was kept in the center of the UTM machine. 36 samples of RUCFST columns were tested. The eccentricity of the loading is not considered due to a lack of system availability. The thickness of the plate was used as 5mm. All the data was noted digitally which is given by the UTM machine. The test results obtained at 7, 14, and 28 days are shown below.

Table6: Test results For 7 Days Cylinder Test

S.N	WEIGHT(kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean strength(N/mm2)	Remarks
1	16.6	561.56	59.1	58.94	CFST 0%
2	16.25	547.31	57.6		
3	16.5	571	60.12		
4	16.025	497.9	52.39	53.67	RUCFST 5%
5	16.12	528.75	55.63		
6	16.1	513	54.01		
7	15.7	488.34	51.38	50.66	RUCFST10%
8	15.62	475.13	49.94		
9	15.66	481.73	50.66		
10	14.7	343	36.1	35.76	RUCFST 20%
11	15.21	336.53	35.41		
12	14.9	339	35.755		

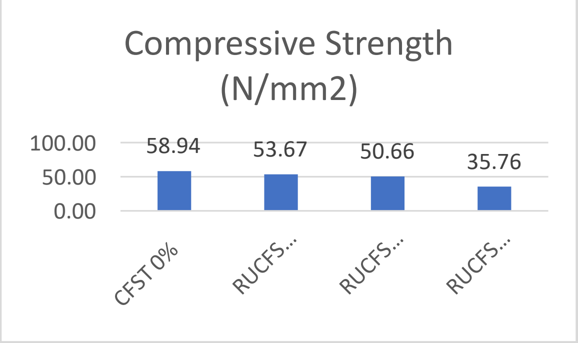

Fig 11: Compressive strength of CFST at 7 days

Table 7: Test results For 14 Days Cylinder Test

S.N	WEIGHT(kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean strength (N/mm2)	Remarks
1	16.6	609.57	64.14	62.85	CFST 0%
2	16.25	597.2	61.3		
3	16.5	602.37	63.1		
4	15.61	539.09	56.76	55.68	RUCFST 5%
5	15.95	568.63	59.87		
6	15.9	522.3	54.99		
7	15.7	495.83	52.17	52.12	RUCFST10%
8	15.62	513.49	54.033		
9	15.66	482.13	50.17		
10	14.7	357.77	37.66	38.69	RUCFST 20%
11	15.21	376.2	39.6		
12	14.9	368.75	38.8		

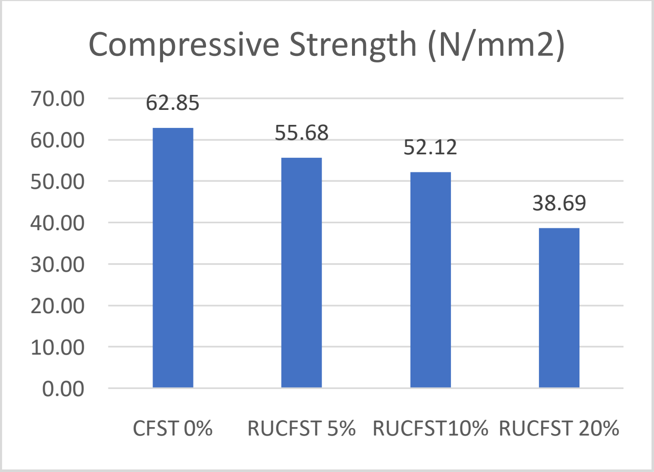

Fig 12 : Compressive strength of RUCFST at 14 days

Table 8: Test results For 28 Days Cylinder Test

S.N	WEIGHT(kg)	Peak Load (KN)	Compressive strength (N/mm2)	Mean strength (N/mm2)	Remarks
1	16.45	663.1	69.77	69.17	CFST 0%

2	16.35	642.62	67.62		
3	16.5	666.42	70.12		
4	16.025	551.03	57.98	58.56	RUCFST 5%
5	16.03	554.98	58.39		
6	16.1	563.62	59.3		
7	15.7	515.121	54.2	54.10	RUCFST10%
8	15.8	501.53	52.77		
9	15.92	525.955	55.34		
10	15.52	421.31	44.33	46.04	RUCFST 20%
11	15.6	461.27	48.53		
12	15.06	430.04	45.25		

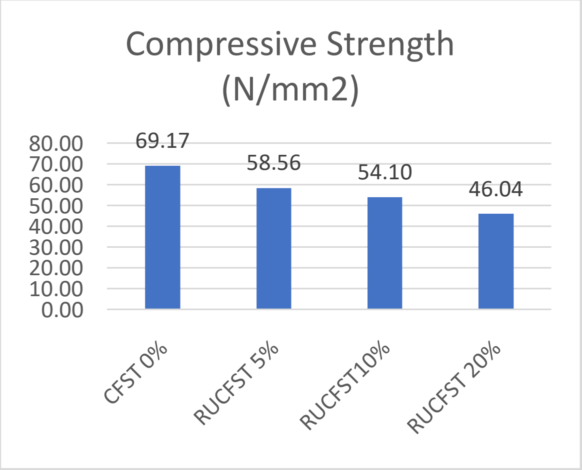

Fig 13: Compressive strength of RUCFST at 28 days

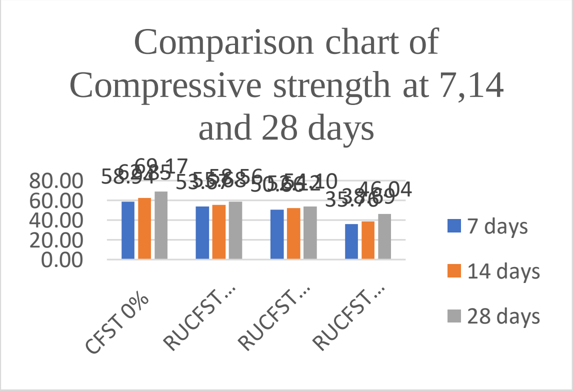

Fig 14: Comparison chart of RUCFST columns at 7, 14 and 28 days

5.4 COMPRESSIVE STRENGTH REDUCTION COMPARASION BETWEEN CONCRETE CUBES AND RUCFST COLUMN:

5.4.1 Comparison of concrete cubes percentage reduction strength at 28 days:

Here, the compressive strength of cubes at 5%,10%, and 20% replacement of natural aggregate with rubber aggregate is compared with the concrete cubes at 100% natural aggregates, and the percentage reduction in strength is computed.

Table 9: Comparison of percentage reduction in strength of cubes

S.N	Mean strength (N/mm2)	Percentage reduction in strength %	Remarks
1	27.5	0.0	CCNAS (0%)
2	23.24	15.5	CC5RUS (5%)
3	20.53	25.3	CC10RUS (10%)
4	13.53	50.8	CC20RUS (20%)

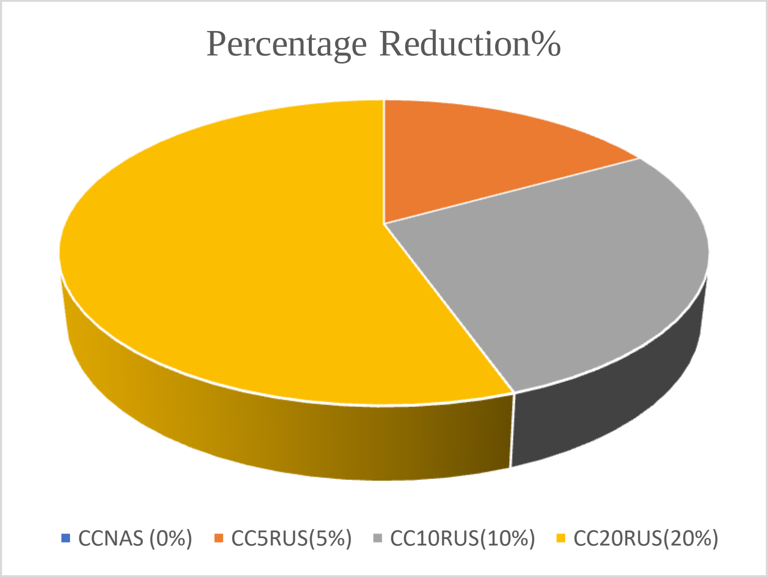

Fig 15: Comparison of percentage reduction of concrete cube at 28 days

5.4.2 Comparison of RUCFST percentage reduction strength at 28 days:

Here, the compressive strength of RUCFST at 5%,10%, and 20% replacement of natural aggregate with rubber aggregate is compared with the CFST at 100% natural aggregates, and the percentage reduction in strength is computed.

Table10: Comparison of percentage reduction in strength of RUCFST column

S.N	Mean strength (N/mm2)	Percentage reduction in strength %	Remarks
1	69.17	0.00	CFST 0%
2	58.56	15.34	RUCFST 5%
3	54.10	21.78	RUCFST10%
4	46.04	33.44	RUCFST 20%

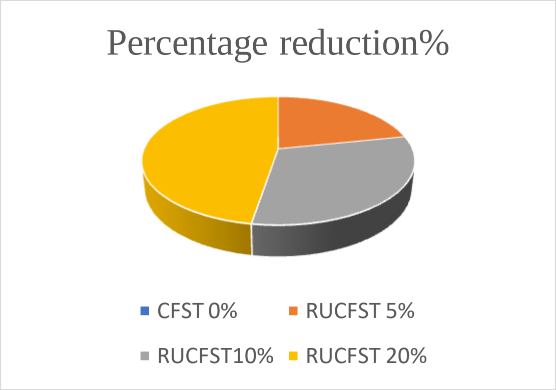

Fig16: Comparison of percentage reduction of RUCFST column at 28 days

5.4.3 Comparison between RUCFST and concrete cube in percentage reduction strength at 28 days:

Table11: Comparison of percentage reduction in strength of RUCFST column and concrete cube

S.N	Mean strength	Percentage reduction	Remarks

	(N/mm2)	in strength %	
1	23.24	15.5	CC5RUS (5%)
2	58.56	15.3	RUCFST 5%
3	20.53	25.3	CC10RUS (10%)
4	54.10	21.8	RUCFST10%
5	13.53	50.8	CC20RUS (20%)
6	46.04	33.4	RUCFST 20%

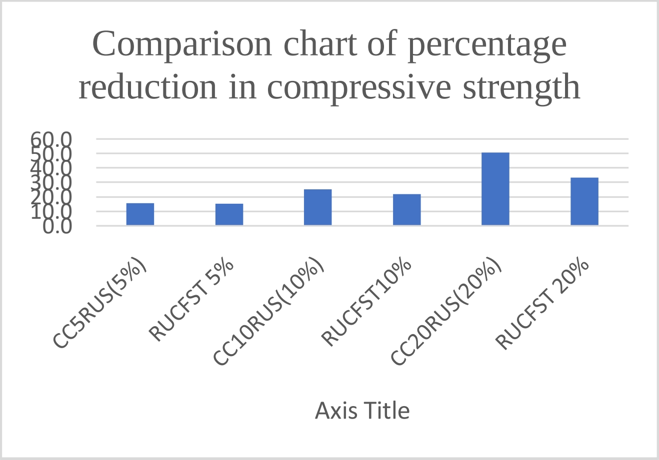

Fig17: Comparison of percentage reduction of compressive strength of RUCFST columns and concrete cubes at 28 days

5.5 Force-displacement and stress strain curve of RUCFST test results:

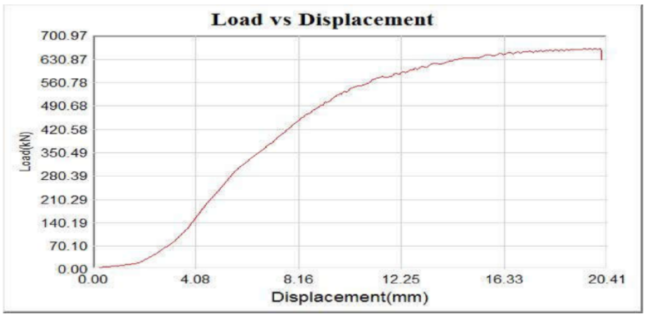

Fig 18 Force-Displacement Curve of Normal Concrete Column (CFST 0%)

Table 12: Normal concrete tube CFST (0%)

Displacement (mm)	Load(KN)	Stress(N/mm2)	Strain	
1.02	7	0.736584688	0.00204	
2.04	24.82	2.611718852	0.00408	
3.06	70.75	7.444766671	0.00612	
4.08	154	16.20486314	0.00816	
5.10	244.41	25.71838052	0.0102	
6.12	322.33	33.91762037	0.01224	
7.14	380	39.98602594	0.01428	
8.16	447.75	47.11511346	0.01632	
9.18	498	52.40273925	0.01836	
10.20	542.58	57.09373145	0.0204	
11.22	573.58	60.35574936	0.02244	
12.24	591.66	62.25824238	0.02448	
13.26	607	63.87241511	0.02652	
14.28	628	66.08216918	0.02856	
15.30	636.25	66.95028685	0.0306	Yield point
16.32	648.25	68.21300346	0.03264	
17.34	654.82	68.9043408	0.03468	
18.36	661.25	69.58094645	0.03672	
19.38	662.33	69.69459094	0.03876	
20.40	663.1	69.77561526	0.0408	Ultimate point

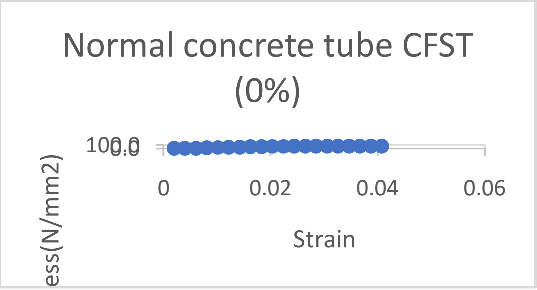

Fig 19. Stress-Strain curve of Normal concrete tube (CFST 0%)

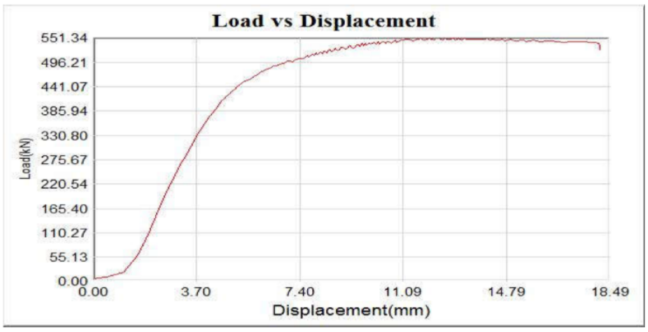

Fig 20 Force-Displacement Curve of Rubber aggregate tube (RUCFST 5%)

Table13: Rubber aggregate concrete tube RUCFST (5%)

Displacement (mm)	**Load(KN)**	**Stress(N/mm2)**	**Strain**	
0.0	**0**	**0.0**	**0**	
0.925	13.66	1.4	0.00185	
1.85	87.82	9.2	0.0037	
2.775	219.16	23.1	0.00555	
3.7	326.5	34.4	0.0074	
4.625	408.56	43.0	0.00925	
5.55	455.5	47.9	0.0111	
6.475	487.82	51.3	0.01295	Yield point
7.4	503	52.9	0.0148	
8.325	512	53.9	0.01665	
9.25	531.16	55.9	0.0185	
10.175	540	56.8	0.02035	
11.1	547	57.6	0.0222	
12.025	551.08	58.0	0.02405	Ultimate point
12.95	550.33	57.9	0.0259	
13.875	549.58	57.8	0.02775	
14.8	551	58.0	0.0296	
15.725	547	57.6	0.03145	
16.65	543	57.1	0.0333	
17.575	543	57.1	0.03515	
18.5	541	56.9	0.037	

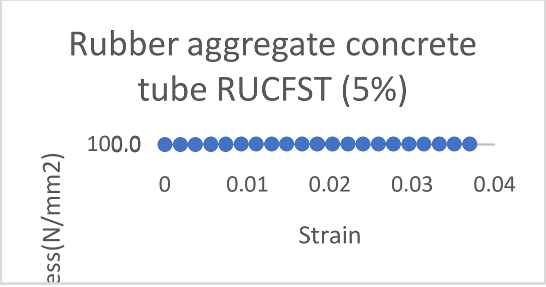

Fig 21. Stress-Strain curve of Normal concrete tube (RUCFST 5%)

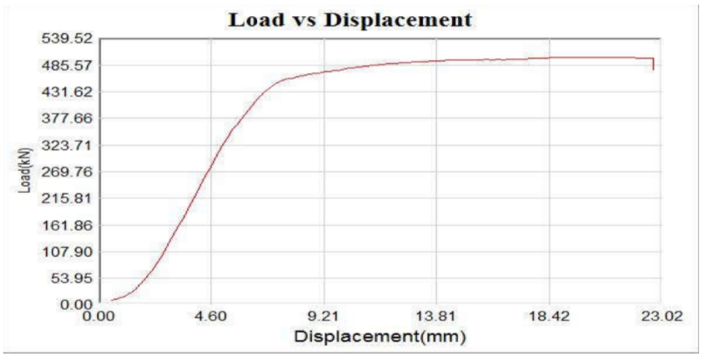

Fig 22 Force-Displacement Curve of Rubber aggregate tube (RUCFST 10%)

Table 14: Rubber aggregate concrete tube RUCFST (10%)

Displacement (mm)	Load(KN)	Stress(N/mm2)	Strain	
1.150	16.75	1.8	0.0023	
2.300	76.66	8.1	0.0046	
3.450	174.5	18.4	0.0069	
4.600	279.56	29.4	0.0092	
5.750	370.41	39.0	0.0115	
6.900	426.91	46.0	0.0138	Yield point
8.050	461.91	48.6	0.0161	
9.200	469.82	49.4	0.0184	
10.350	480.16	50.5	0.0207	
11.500	487.56	51.3	0.023	
12.650	490.91	51.7	0.0253	
13.800	494.82	52.1	0.0276	
14.950	496.66	52.3	0.0299	
16.100	496.75	52.3	0.0322	

17.250	497.41	52.3	0.0345	
18.400	500.91	52.7	0.0368	
19.550	501.5	52.8	0.0391	Ultimate point
20.700	498	52.4	0.0414	
21.850	501.25	52.7	0.0437	
23.000	477.56	50.3	0.046	

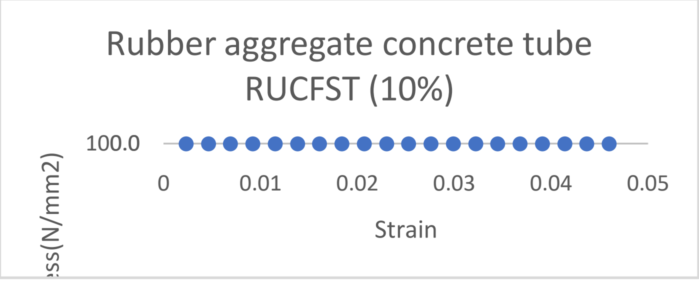

Fig 23Stress-Strain curve of Normal concrete tube (RUCFST 10%)

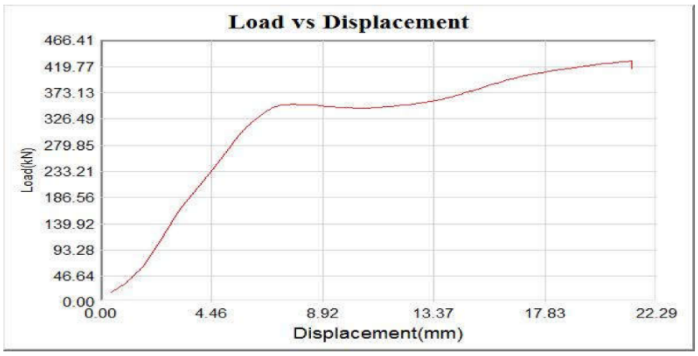

Fig 24 Force-Displacement Curve of Rubber aggregate tube (RUCFST 20%)

Table 5.15: Rubber aggregate concrete tube RUCFST (20%)

Displacement (mm)	Load(KN)	Stress(N/mm2)	Strain	
1.15	36.25	3.8	0.0023	
2.3	94.91	10	0.0046	
3.45	169.91	17.9	0.0069	
4.6	230.25	24.2	0.0092	
5.75	294.75	31	0.0115	Yield point
6.9	339	35.7	0.0138	
8.05	349.82	36.8	0.0161	
9.2	346.5	36.5	0.0184	

10.35	343.66	36.2	0.0207	
11.5	343.91	36.2	0.023	
12.65	349.25	36.8	0.0253	
13.8	356.82	37.5	0.0276	
14.95	367.5	38.7	0.0299	
16.1	384.33	40.4	0.0322	
17.25	397.56	41.8	0.0345	
18.4	407.82	42.9	0.0368	
19.55	414.5	43.6	0.0391	
20.7	421.75	44.4	0.0414	
21.85	425.25	44.7	0.0437	Ultimate point
23	416.75	43.9	0.046	

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