STRESS-STRAIN BEHAVIOUR OF CONFINED NORMAL GRADE CONCRETE

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ABSTRACT: The concrete using in the civil engineering structures generally have low tensile properties compared to the reinforced concrete. In order to attain high strength and properties, here we are going to test the behaviour of the reinforced concrete using hoops.

An experimental investigation into the behaviour of circular, confined, reinforced concrete columns was undertaken. Thirty 150 mm diameter, 300 mm high units were cast with varying amounts of longitudinal and lateral steel.

These were subjected to concentric or eccentric axial loads to failure at slow or dynamic loading rates. Confinement requirements of reinforced concrete columns are discussed and the results and analyses of experimental work presented. Results include an assessment of the significance of loading rate, eccentricity, amount and distribution of longitudinal steel, and the amount of confining steel.

A general stress-strain curve for circular concrete sections loaded at seismic rates is proposed and compared with existing curves based on previous static loading tests.

Knowledge of the stress-strain curve for confined concrete is particularly important for columns with high axial load levels, when the moment curvature characteristics of the column are largely dependent on the concrete compressive strength and the stress strain relationship.

The testing was generally carried out in load controlled testing machines at slow loading rates. Behaviour under these conditions has been used to predict behaviour under seismic conditions, which are characterized by displacement control, rapid loading rates, repeated load application, and eccentricity of loading, recently more realistically sized units have been used but not under simulated seismic conditions.

I. INTRODUCTION

Concrete is a building material in the human history. It consists of Cement, Aggregates and Water. It is no doubt that with the improvement of human civilization concrete will continue to be a governing construction material in the future.

The most widely used construction material in the world is probably the concrete. It is only second to water as the most profoundly consumed substance with about six billion tons being produced every year. There are many types of concrete designed to suit a variety of purposes coupled with a range of compositions and performance characteristics.

The mixture forms a fluid mass when aggregate is mixed together with dry Portland cement and water, then that is easily molded into shape. Often, additives (like super plasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Concrete is poured with reinforcing materials embedded to provide tensile strength, yielding reinforced concrete.

Many types of concrete are available, distinguished by the proportions of the main ingredients below.

Aggregates consists of large chunks of material in a concrete mix, generally a coarse gravel or crushed rocks such as limestone or granite, along with finer materials such as sand.

Cement most commonly Portland cement is associated with the general term "concrete." A range of materials can be used as the cement in concrete.

Water Combining with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely.

Confined concrete:

When concrete is subjected to a uni-axial load (for example in Columns) while having transverse reinforcement like circular hoops or a helical spring then that is called Confined Concrete. So here what you need to know is that the load is perpendicular to the direction of the reinforcement which makes the concrete confined.

Concrete which has closely-spaced special transverse reinforcement, which restrains the concrete in directions perpendicular to the applied stress.

Advantages:

1. The confined concrete has less axial deformation in comparison in the unconfined concrete when subjected to the same amount of load.
2. The failures will initiates from the development of deformation in steel sheet at top and bottom portion of the column of the structure when the ultimate load is applied the deformation initiates in the middle portion.
3. Large span of columns can be adopted
4. High modulus of elasticity for effective long-term reinforcement even in the hardened concrete

Disadvantages:

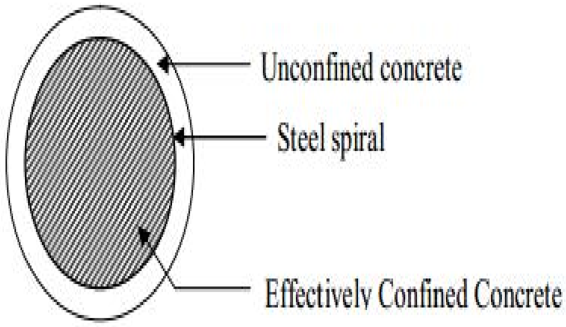
1. Greater reduction of workability
2. High cost of materials
3. Requires skilled labour

Stress-strain curves of concrete members:

The relationship between the stress and strain that a particular material displays is known as that material’s stress-strain curve. This curve is unique for each material and is found by recording the amount of strain or deformation at distinct intervals of stress, with respect to the original specimen’s cross-sectional area and length. These curves reveals the materials important properties such as the modulus of elasticity (E), yield stress (in metallic materials), ultimate strength, and ultimate strain, but more importantly is the fundamental information required for advanced engineering applications, such as moment-curvature analysis which shows an indication of the available flexural strength and ductility.

Circular section

The circular section can be idealized in to the same of effectively confined concrete, steel spiral and unconfined concrete as shown in the below figure.



Rectangular section

In this case, the concrete is longitudinally contracted and laterally expanded with internal micro-cracks as the axial load is increased from the initial stages of loading The transverse reinforcement resists the high expanded pressure, and the effective confinement by the lateral ties leads to the enhancement of the axial load-carrying capacity.

Uses of stress strain behaviour of concrete:

The uses of stress strain behaviour of a concrete are:

1. The stress strain behaviour is used to know the concrete properties like young's modulus or modulus of elasticity of concrete, ductility.
2. It is used to determine the Poisson's ratio.
3. The breaking point load can be determined using the stress strain analysis.
4. The ultimate strains and stresses can be known at different load conditions.

Problem statement:

To study the behaviour of normal or high strength concrete, the appropriate analytic stress-strain models that capture the real (observable) behaviour is one of the most important steps. The better the stress-strain model, the more reliable is the estimate of strength and deformation behaviour of concrete structural members.

Another important characteristic of concrete is that it exhibits different behaviour in its confined and unconfined states. Confined concrete tends to show a much greater ductility when compared to unconfined concrete apart from higher strength. Thus, it becomes important and desirable to have a stress-strain model that differentiates the behaviour of confined and unconfined concrete.

It becomes important to have some guidelines or empirical relations to determine the parameters that are required to establish a representative stress-strain relation, if there is no sufficient data. This study also aims in identifying the most important parameters and establishing empirical relations for these parameters that are required to define generalized stress-strain relations for concrete.

The use of equivalent rectangular stress-block parameters is another important concept in the analysis and design of concrete structures. To define the nominal strength for the designing of reinforced concrete sections, stress-block analysis has been used in hand computations.

However, this concept can be extended for limit states and other strain profiles. From their respective stress-strain relations, it is important to derive the generalized expressions for the equivalent rectangular stress-block parameters for both confined and unconfined concrete. Determining closed form relations for the stress-block parameters for unconfined and confined concrete makes it possible to apply them in both hand and computer analysis to determine a moment-curvature relationship for a specific structural concrete members.

OBJECTIVES OF STUDY:

With a general understanding of the superior stress-strain behavior displayed by active confinement to be obtained, a new and innovative method to confine concrete specimens will be discussed and further investigated within this thesis.

Within this thesis all relative information with regards to the confining potential will be further investigated in great detail, and the following overall primary objectives have been selected.

The precise objectives of the study are as follows:-

To study the stress strain behaviour of concrete using 4mm diameter steel bars confining with hoops at 28 days curing age for different grades of concrete like:

1. M20 grade concrete using 4 mm diameter steel bars of 6 numbers placed in cylinder confining with 3, 4 and 5 hoops of 1.5 mm diameter.
2. M25 grade concrete using 4 mm diameter steel bars of 6 numbers placed in cylinder confining with 3, 4 and 5 hoops of 1.5 mm diameter.
3. M30 grade concrete using 4 mm diameter steel bars of 6 numbers placed in cylinder confining with 3, 4 and 5 hoops of 1.5 mm diameter.

II. LITERATURE REVIEW

Sheikh, Uzumeri and Yeh made analytical and experimental studies on the mechanism of confined concrete. They introduced the concept of the effectively confined concrete area and presented the stress-strain relations of confined concrete. Mander and al proposed a stress-strain relation of confined concrete with according the confinement effects to the various configurations of lateral ties. Heo-Soo and al proposed a stress-strain curve of laterally confined concrete with according the confinement effects to various parameters.

Chan (1955) as part of some other investigations reported the testing of 9 prisms 152 x 152 x 292 mm with bent-in hoops, 7 cylinders 152 mm diameter and 305 mm high with spiral reinforcement, and 7 prisms 152 x 92 x 1321 mm with welded hoops. These were loaded eccentrically or axially with a transverse load at the midpoint. Chan's results for rectangular hoops, when compared with unconfined concrete, showed a strength increase of more than 50%, an increase in ultimate strain of about 500%, and that these increases were only 50% and 70% respectively of those for equivalent spiral reinforcement. To determine the effect of confinement Chan ignored the hoop spacing, and considered only the volumetric ratio of hoop steel.

Roy and Sozen (1963) developed a stress strain relationship for confined concrete by carrying out tests on prisms with about 2% square hoop steel by volume. It concludes that the confined concrete having ductility was closely related to the spacing of hoops provided, size of the lateral ties, and the amount of longitudinal reinforcement had an little effect on properties of concrete. It also concludes that from the test results, the usage of square hoops increases the ductility of the concrete but not the strength of the concrete.

Bertero and Felippa (1964) reported the results of tests performed on 76 x 76 x 305 mm and 114 x 114x 305 mm prisms with square hoop steel and/or longitudinal steel under concentric loading. Increases in concrete strength were found to be 13% to 26%, depending on the hoop steel volume. It was concluded that longitudinal steel alone did not enhance the concrete ductility. Hoops alone however did, and hoops with longitudinal steel provided even greater ductility enhancement.

Vallenas, Bertero and Popov (1977) studied the results of the reinforced concrete columns tested under axial load. The columns with and without longitudinal bars and hoops are tested. In some columns, more than 20% increase in concrete core strength is observed. An increase in ductility is also observed at the point of maximum strength and also at the descending portion of the curve. It was shown that no existing curves predicted the behaviour of their tests by previous researchers such that they suggested improved stress strain relationship for the concrete by using the equations which are dimensionally dependent.

III. MATERIALS PROPERTIES

Concrete materials:

Ordinary Portland cement

Portland cement is the most common type of cement in general usage around the world. It is a basic ingredient of concrete, mortar, and plaster. It developed from other type of hydraulic lime in England in the mid 19th century and usually originates from limestone. It is fine powder produced by heating materials in a kiln to form what is called clinker, grinding the clinker, and adding small amounts of other materials. A number of types of Portland cement are available with the most common being called ordinary Portland cement which is grey in color, but a white Portland cement is also available.

Physical properties of cement

S.NO	PROPERTY		VALUE
1	Specific gravity		3.14
2	Normal Consistency		33%
3	Setting time		
	i)	Initial Setting time	30 min
	ii)	Final setting time	360 min

Water

Water combining with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely.

Less water in the cement paste will yield a stronger, more durable concrete; more water will give a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Fine aggregate

Fine aggregate is normally considered material that will pass through a sieve having 4.75 mm (No.4) mesh. Specifications require washed, natural sand, unless otherwise provided by the Special Provisions. In some instances, fine aggregate of two or three different sizes or from more than one deposit are used.

Properties of fine aggregate

S.NO	PROPERTY	VALUE
1	Specific Gravity	2.75
2	Fineness Modulus	2.8
3	Bulk Density	
	i. Loose State	15.75 KN/mm^3
	ii. Compacted State	17.05 KN/mm^3
4	Grading of Sand	Zone - II

Coarse aggregates

Coarse Aggregates are the pulverized stone is utilized for making concrete. The stone is quarried, pounded and evaluated. A great part of the pounded stone utilized is rock, lime stone and trap rock. Evaluated smashed stone normally comprises of standout sort of rock and is broken with sharp edges. Machine smashed rock softened stone precise up shape was utilized as coarse aggregate was 20 mm and the properties of coarse aggregate are

Properties of coarse aggregates

S.NO	PROPERTY	VALUES
1.	Specific Gravity	2.63
2.	Bulk Density	
	I. Loose State	14.13 KN/mm^3
	II. Compacted State	16.88 KN/mm^3
3.	Water Absorption	0.4%
4.	Fines Modulus	7.2

MIX DESIGN OF CONCRETE

Design stipulations:

Characteristic compressive strength required in the field at 28 days : 20Mpa

Maximum size of aggregate : 20mm

Degree of quality control : Good

Type of exposure : Mild

Tested data for materials:

Specific gravity of cement : 3.14

Comp Strength of cement at 7 days : Satisfies the requirement IS: 269-1989

Specific gravity of Coarse aggregates : 2.63

Specific gravity of Fine aggregates : 2.75

Water absorption of coarse aggregate : 1%

Free moisture in CA & FA : Nil

Mix proportions:

For M20 Grade

Water		Cement		Fine agg.		Coarse agg.
191.58 lit		426kg		583kg		1158kg
0.45	:	1	:	1.37	:	2.71

For M25 Grade:

Water		Cement		Fine agg.		Coarse agg.
191.6 lit		479kg		603kg		1094kg
0.40	:	1	:	1.25	:	2.28

For M30 Grade:

Water		Cement		Fine agg.		Coarse agg.
191.6 lit		497.6kg		580kg		1101kg
0.385	:	1	:	1.16	:	2.21

IV. EXPERIMENTAL INVESTIGATIONS

Concrete mix proportion

As for mix design, material proportions were taken and mixes were prepared for casting a cylinder of 15mm diameter and 30mm height.

For the preparation of a one cylinder the quantities of materials required are calculated on volume basis for different grades of concrete

Using M20 concrete mix, the quantities of materials for casting one cylinder

Cement	Fine aggregate	Coarse aggregate	Water
2.5 kg	3.425 kg	6.775 kg	1.125 lit

Using M25 concrete mix, the quantities of materials for casting one cylinder

Cement	Fine aggregate	Coarse aggregate	Water
2.8 kg	3.51 kg	6.4 kg	1.12 lit

Using M30 concrete mix, the quantities of materials for casting one cylinder

Cement	Fine aggregate	Coarse aggregate	Water
2.92 kg	3.385 kg	6.45 kg	1.12 lit

Casting of test specimens

The hoop reinforcement which is prepared is placed into the standard (150mm x 300mm) cylinder without touching the edges. After the completion of workability tests, the concrete mix has been poured into the cylinder in three layers and compacted about 25 times for each layer. Before putting the solid internal countenances of the mould are covered with the machine oil for simple evacuation of test examples. The solid in the moulds has been vibrated for 30 sec utilizing the table vibrator and the surface of the cubes has been done easily.

Curing of concrete

Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement continues. In all the cases, proper care should take for curing of concrete to achieve the best strength. To increase the strength and fully solidification, the cement requires a moist and prohibited environment. The cement paste hardens over time, at first setting and becomes rigid though very weak and gains the strength in the next weeks. In around four weeks, characteristically over 90% of the final strength is reached, but strengthening may continue for decades. The calcium hydroxide is converted into $CaCO_3$ from absorption of CO_2 over several decades further strengthened the concrete and making it more resilient to damages. However, this reaction, called carbonation, lowers the pH of the cement pore solution and can also cause the reinforcement bars to corrode.

Cylinders after taken from the curing

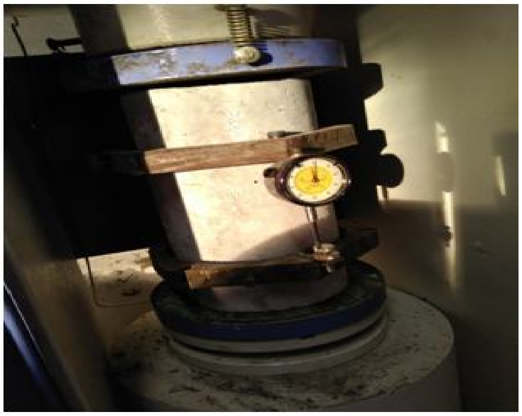
Tests on hardened concrete

Stress strain test:

To determine the stress strain behaviour of a confined concrete, we need the stress strain setup. The cylinder which is placed in the setup is shown in the figure.

Stress-strain setup for cylinder

The dial gauge reading is placed for the setup to take the readings in order to calculate the strain. After the completion of setup, the cylinder is to be placed in the compressive testing machine as shown in the fig.



Placing of cylinder in the compressive testing machine

After placing of cylinder in the testing machine, the load is to be applied gradually and the readings should be noted from the dial gauge corresponding to the load. After increasing the load gradually, the failure of cylinder will occurs. The cylinder at which the failure occurs is noted as the breaking load. At the failure of cylinder, the readings of the dial gauge will increased but the load will decreased.

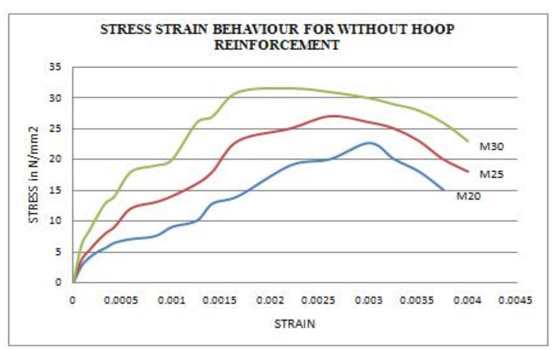
The failure of cylinder under the load is shown in the below figure.

Failures of cylinders

V. TEST RESULTS AND DISCUSSIONS

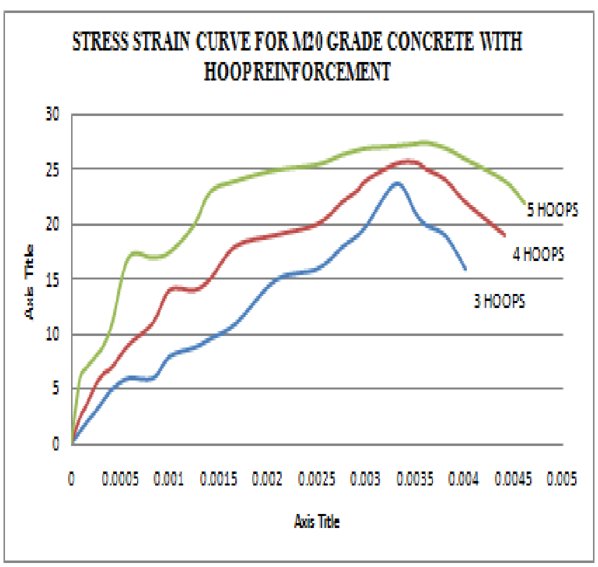
Determination of stress strain test for M20, M25, M30 grade concrete

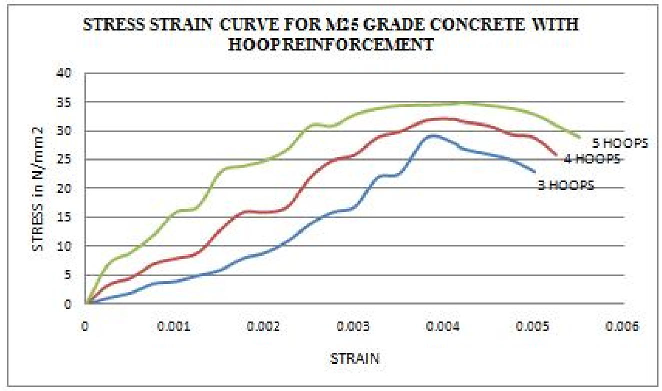
Stress =Load/Area (N/mm2)	Strain=deformation/ original length
0	0
2.829	0.00083
4.527	0.00016
5.658	0.00025
6.2	0.00033
7.92	0.000416
9.62	0.000583
11.317	0.00083
12.449	0.00100
13.60	0.00125
14.712	0.00141
16.976	0.00167
19.805	0.00200
21.503	0.00250
22.635	0.0030

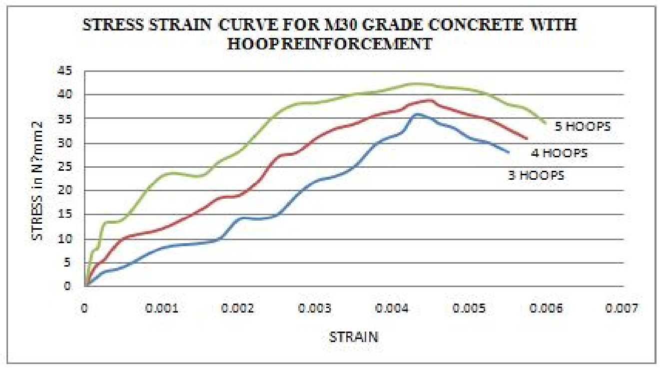


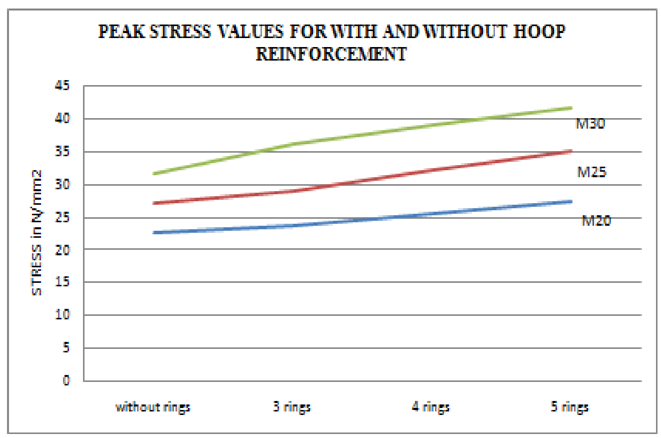
Stress strain test for M20 grade concrete with hoop reinforcement

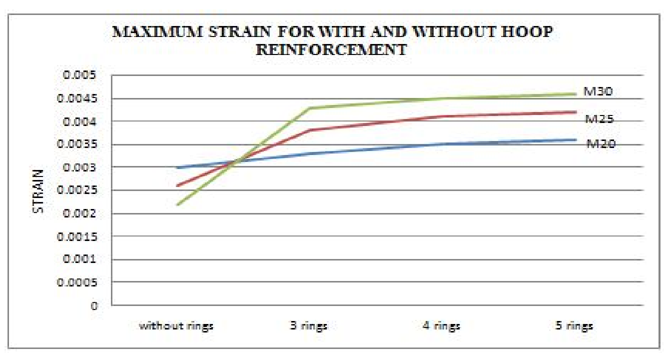
Stress=Load/Area (N/mm2)	Strain=deformation/ original length
0	0
1.1317	0.000083
2.263	0.00016
3.395	0.00025
4.527	0.00033
5.658	0.000416
6.790	0.00050
7.922	0.000583
9.054	0.000670
10.185	0.000750
11.317	0.000830
12.449	0.00100
13.580	0.00108
14.712	0.00125
15.844	0.00150
16.976	0.00183
18.67	0.00200
20.37	0.00225
21.00	0.002416
21.87	0.00267
22.40	0.00291
22.98	0.003
23.8	0.0033











DISCUSSIONS:

ULTIMATE STRESS:

For Plain Concrete:

For M20 grade concrete, the ultimate stress occurs at 22.635 N/mm2.

For M25 grade concrete, the ultimate stress occurs at 27 N/mm2.

For M30 grade concrete, the ultimate stress occurs at 31.6 N/mm2.

For Reinforced Concrete:

For M20 grade concrete using 4 mm diameter bars confining with 3 hoops, we have attained the ultimate stress at 23.8 N/mm2.

Similarly, with 4 hoops the ultimate stress is 25.6 N/mm2 and with 5 hoops the ultimate stress is 27.4 N/mm2

For M25 grade concrete using 3 hoops, we have attained the ultimate stress at 29 N/mm2.

Similarly, with 4 hoops the ultimate stress is 32.2 N/mm2 and with 5 hoops the ultimate stress is 35 N/mm2

For M30 grade concrete using 3 hoops, we have attained the ultimate stress at 36 N/mm2.

Similarly, with 4 hoops the ultimate stress is 39 N/mm2 and with 5 hoops the ultimate stress is 41.6 N/mm2

From the results, we can conclude that by increasing the rings for reinforced concrete the ultimate stress is also increasing.

The ultimate stress for reinforced concrete is increased by around 30% compared to the plain concrete.

YOUNG"S MODULUS:

By finding the slope from the graph, we can obtain the young's modulus.

For Plain Concrete:

The young's modulus for M20 grade concrete is E=40000 N/mm2

The young's modulus for M25 grade concrete is E=42000 N/mm2

The young's modulus for M30 grade concrete is E=44000 N/mm2

For Reinforced Concrete:

The young's modulus for M20 grade concrete with 3 rings is E=48000 N/mm2

The young's modulus for M20 grade concrete with 4 rings is E=50000 N/mm2

The young's modulus for M20 grade concrete with 4 rings is E=52000 N/mm2

The young's modulus for M25 grade concrete with 3 rings is E=54000 N/mm2

The young's modulus for M25 grade concrete with 4 rings is E=56000 N/mm2

The young's modulus for M25 grade concrete with 5 rings is E=58000 N/mm2

The young's modulus for M30 grade concrete with 3 rings is E=60000 N/mm2

The young's modulus for M30 grade concrete with 4 rings is E=62000 N/mm2

The young's modulus for M30 grade concrete with 5 rings is E=64000 N/mm2

The young's modulus for the reinforced concrete is increased by 40% compared to the plain concrete.

MAXIMUM STRAIN:

For Plain concrete:

For M20 grade concrete, the maximum strain is obtained at 0.003

For M25 grade concrete, the maximum strain is obtained at 0.0026

For M30 grade concrete, the maximum strain is obtained at 0.002

For Reinforced Concrete:

For M20 grade concrete using 3 hoops, the maximum strain is obtained at 0.033

Similarly, with 4 hoops the maximum strain is 0.0035 and with 5 hoops the maximum strain is 0.0036

For M25 grade concrete using 3 hoops, the maximum strain is obtained at 0.0038

Similarly, with 4 hoops the maximum strain is 0.0041 and with 5 hoops the maximum strain is 0.0042

For M30 grade concrete using 3 hoops, the maximum strain is obtained at 0.0043

Similarly, with 4 hoops the maximum strain is 0.0045 and with 5 hoops the maximum strain is 0.0046. From the results, we can conclude that the maximum strain for the reinforced concrete is increased by 50% compared to the plain concrete.

Stress strain behaviour:

The pattern of stress-strain behavior for medium strength conventional concretes (M20, M25 and M30 grades) is approximately same except the small variations in the peak stresses and strains corresponding to the peak stress values.

When the hoop reinforcement is used for M20, M25 and M30 grades, the pattern of stress-strain behavior is similar to the conventional concrete of medium grades except the increase in peak stress values and increase in strain corresponding to the peak stress values.

VI. CONCLUSIONS

1. From the results, we have studied the stress strain behaviour of a plain concrete and confined normal grade concrete with hoops under axial compressive load.
2. The results shows that the stress-strain behaviour in the case of using hoops shows a similar pattern except in increase in the peak stress values compared to the normal plain concrete.
3. The circular columns confined with hoop reinforcement generally performed better than the normal rectangular and square columns.
4. The load taking on to the concrete using hoops gives breaking load of more than 30% compared to the normal plain concrete.
5. From the results, we have attained the young's modulus of more than 40% for the reinforced concrete compared to the plain concrete.
6. From the results, we have obtained the maximum strain increased by almost 50% in case of reinforced concrete than the normal plain concrete.

7. By increasing the number of hoops to the reinforced concrete, the compressive stresses are also increased slightly by almost 10%.

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