STRUCTURAL RETROFITTING OF RC COLUMNS USING GLASS FIBER-REINFORCED POLYMER MATERIALS

Submitted in partial fulfillment of the requirements

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MASTER OF TECHNOLOGY

in

CIVIL ENGINEERING

by

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Transforming Education Transforming India

School of Civil Engineering

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

2017

CERTIFICATE

This is to certify that this dissertation report entitled, "**STRUCTURAL RETROFITTING OF RC COLUMNS USING GLASS FIBER-REINFORCED POLYMER MATERIALS"** is a bonafide work done by "**Imaad Majid, Reg. No.:- 11615664"** Student of Civil Engineering Department, Lovely Professional University, Phagwara, Punjab in partial fulfillment of the requirement for the Degree of Master Of Technology in Structural Engineering. This report has not been submitted to any other university or an institution for the award of any degree.

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DECLARATION

I, Imaad Majid (11615664), hereby declare that the dissertation report entitled, **"STRUCTURAL RETROFITTING OF RC COLUMNS USING GLASS FIBER-REINFORCED POLYMER MATERIALS"** is a bonafide and genuine research work carried out by myself under the guidance of **Mr. R.Navaneethan, Assistant Professor; Department of Civil Engineering, Lovely Professional University**, **Phagwara.**

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Signature of Student

ABSTRACT

There are various strengthening and rehabilitation techniques to improve the performance, durability, load carrying capacity and life span of structure. Retrofitting of the damaged or week structure is the best way to improve the strength of that structure. In recent years, FRPs have been used for the purpose of retrofitting. In this experimental study, 12 number of rectangular columns will be casted and the size of each specimen will be 700mm × 150mm. Testing of columns will be done on Universal Testing Machine (UTM). Also the columns will be tested for 7 days, 28 days, 56 days and 90 days compressive strength.

After the failure of the columns or when cracks will be formed, columns will be wrapped with GFRP laminates. First epoxy resin will be applied on the surface of columns and then the wrapping of the GFRP laminates on the column surface. Epoxy resin will act as a adhesive for wrapping of GFRP laminates tightly. Wrapping of laminates will be done on the damaged portions or on the week spots. Also the retrofitting will be done on the edges of columns and on the centre portion. After binding, the strength of columns will be tested again and their strength will be evaluated.

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CA	Coarse aggregates
FA	Fine aggregates
FRP	Fiber reinforced polymer
GFRP	Glass fiber reinforced polymer
CFRP	Carbon fiber reinforced polymer
PPC	Pozzolana Portland cement
Min	Minutes
mm	Millimetre
Sec	Second
^{o}C	Degree Celsius
ml	Millilitre
kg	Kilogram
%	Percent
kg/m^3	Kilogram per metre cube

CHAPTER 1

INTRODUCTION

1.1 General

All the loads that are acting on the structure whether they are lateral loads, gravity loads, longitudinal loads, etc are transferred from beam to column and column then transfers it to the foundation. So the columns are very important in any structure for its stability and durability. Whenever there are higher loads acting on the structure, or there is an earthquake, structure gets damaged partially or fully and the structure loses its original strength. To regain its original strength, retrofitting is the best way chosen so far to improve the strength of that damaged structure.

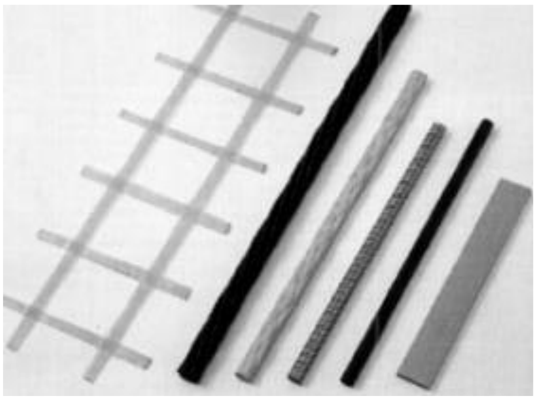
Retrofitting means improvements in strength to an existing structure. There are a lot of RC buildings and bridges and various RC structures that are in need of re-strengthening and therefore there is a need of retrofitting.[1] There are a number of reasons that lead to retrofitting which are: seismic activity, higher load demand, higher strength demand, constructional errors, deterioration caused by environmental factors, change in use of the structures, etc. Micro cracks are also developed in concrete due to thermal variations. Due to the formation of micro cracks, there is a decrease in strength of a structure. So it regain its strength, a structure needs to be retrofitted.[2] So to sum up, retrofitting is modification of existing structures to make them more resistant towards external loadings.

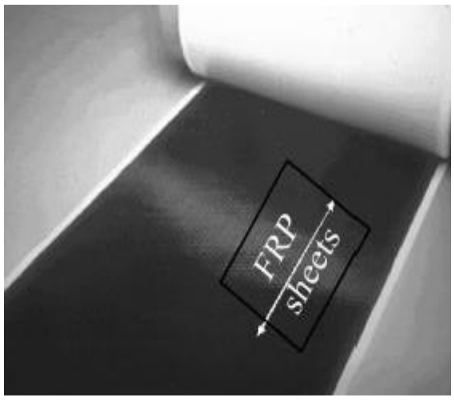
In past years, significant research work has been done to make various strengthening and retrofitting techniques to enhance the strength, load carrying capacity and lifespan of a structure. Some of the strengthening methods that has been applied in the past are steel plate bonding, jacketing, external post tensioning, addition of new structural elements, etc and these methods were successful. Among all the methods, retrofitting with Fibre Reinforced Polymers (FRP) materials has lead to a various achievements in the field of civil engineering in past one or two decades. Fiber-reinforced polymers (FRP) are light weight in nature, easy for implementation and have high tensile strength and also are corrosion resistance. Due to these reasons, FRP composites are preferred solutions for strengthening method of various reinforced concrete structural elements and are now extensively being used all over the world.[3]

FRP composites may be of various types:

- Carbon fiber-reinforced polymer (CFRP)
- Glass fiber-reinforced polymer (GFRP)
- Aramid fiber-reinforced polymer (AFRP)

In FRP's, the main load bearing component are the fibers. FRP products that are used in retrofitting of structures can be in the form of strips, sheets and laminates.


(a)



(b)

Figure 1: FRP products for structural retrofitting, (a) FRP Strips and (b) FRP Sheets

1.2. Fiber reinforced polymer:

FRP is a material made up of two or more materials to form a composite material which possess various combinations of properties. FRPs are widely used these days for retrofitting of damaged or weak structures. There are various advantages of fiber reinforced polymers (FRP) like they are light in weight, they bear high mechanical properties and they also are corrosion resistant.[4] Physical properties and mechanical properties of FRPs are governed by its basic properties and the structure at micro level. Before wrapping of FRP to the structural element, there should be proper analysis and design of FRP. FRPs are anisotropic in nature. In our experimental study, FRP provides strength and stiffness to the structural component on which it will be wrapped.

1.3 Methods of strengthening and retrofitting:

Various techniques are:

- Jacketing of steel to structural elements.
- External pre stressing for the bridge girders.
- Use of FRP composites wrapped to the surface of concrete.
- Chemical methods i.e filling up of cracks with some adhesives or cracks.

Retrofitting technologies for structures are at the research stage. So following figure shows us various types of methods for retrofitting which have been developed and are beneficial for the performance of the structure.[5]

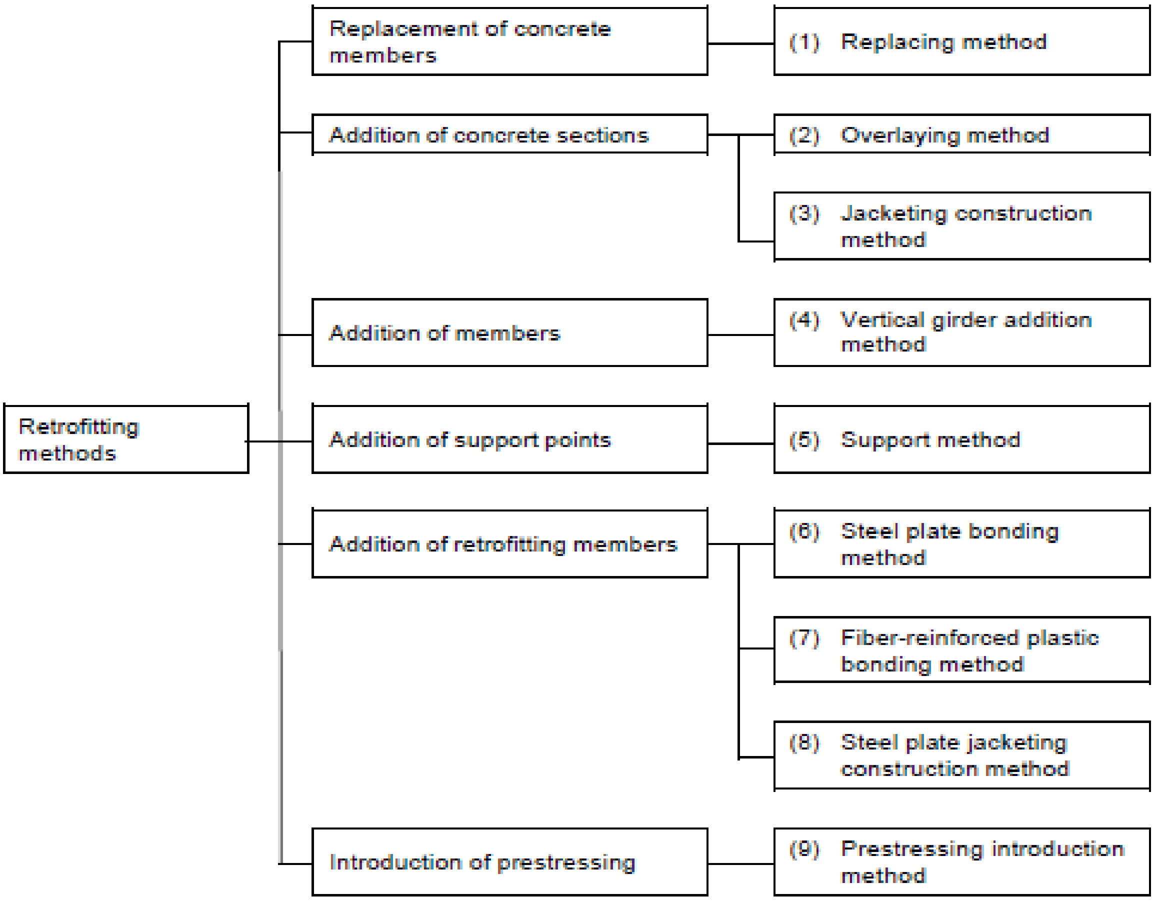


Figure 2: Methods of retrofitting

1.4 Advantages of FRP materials:

For repairing, retrofitting and re-strengthening of various structural elements, FRP is mostly used in place of steel. Various advantages of FRP materials are;

1. High strength;
2. High stiffness;
3. High corrosion resistance[6];
4. Convenient in handling;
5. Ease of implementation;
6. Resistance to high temperature;
7. Resistance to mechanical as well as environmental conditions.;

8. High tensile strength;
9. Light in weight;
10. Low cost of maintenance and repair.

1.5 Disadvantages of FRP composites:

1. Low compressive strength as compared to tensile strength.
2. Unstable at high temperature;
3. Anisotropic material i.e, it doesn't have same properties in all directions.
4. Very high cost of some of the fibers like carbon fibers.
5. FRPs are not good resistant of fire.
6. Up to yield point, stress strain curve is linear but after that mode of failure is brittle.

1.6 Objective of the Project

Main objectives of our experimental study are:-

1) TO determine the elastic properties of the columns after retrofitting. The elastic properties to be determined are stiffness, flexural strength.
2) Improve in the moment carrying capacity of the column after retrofitting.
3) To determine the durable properties.
4) To make retrofit technique easy, practical and economic.
5) To detect and repair damage easily.
6) To find failure mode and cracking pattern.
7) Increase in failure load of the column in compression which is retrofitted.

1.7 Scope of the project:

There are a lot of RC buildings and bridges and various RC structures that are in need of re-strengthening and therefore there is a need of retrofitting. There are a number of reasons that lead to retrofitting which are: seismic activity, higher load demand, higher strength demand, constructional errors, deterioration caused by environmental factors, change in use of the structures, etc.[8] Micro cracks are also developed in concrete due to thermal variations. Due to the formation of micro cracks, there is a decrease in strength of a structure. So to regain its strength, a structure needs to be retrofitted.

CHAPTER 2

LITERATURE REVIEW

1. Antonio De Fabio Matta and Antonio Nanni "structural evaluation of full scale FRP confined reinforced concrete columns"

The well known technique for retrofitting and strengthening purposes for various damaged RC columns is by externally wrapped FRP laminates or sheets. In this paper, there is experimental study on various FRP materials like blast glass fiber laminates and glass fiber sheets on rectangular and square RC columns. These columns are tested under eccentric loading and axial loading and the design of columns was also done for the two loading conditions: axial loading and eccentric loading by referring ACI 318 code. This study was conducted to determine how FRP sheets effect on peak axial strength and deformation under the centric loading for FRP wrapped column. After studying this whole experimental program, it was concluded that the strength was increased in compression.

2. Yu-Fei Wul, Tao Liu and Seric J. Oehlers "Fundamental principles that govern retrofitting of RC columns by steel and FRP jacketing" 2015

In this experimental program, different retrofitting techniques were demonstrated and it was determined that which technique in particular is effective for enhancement in the structural performance of the columns. This study identifies the key factors that affect the effectiveness and deficiencies of different retrofitting methods. various results were determined from this study, some of them are as follows:

1. Retrofitting by steel or FRP jacketing is very effective for circular as well as rectangular columns.
2. For axial retrofitting, circular shaped jackets can offer a reliable performance that can be both qualitatively and quantitatively found out and for flexural retrofitting, circular jackets can also be very effective for both lap splice failure and concrete crush failure.

3. G Promis, E. Ferrier, P. Hamelin. "Effect of external FRP retrofitting on short columns for seismic strengthening" 2013

In this experimental program, the main aim is to check the CFRP's contribution to the improvement in the strength and load carrying capacity of short columns. The columns were tested under the combined effect of compressive and flexural loading. Total number of 8 columns were casted in this study, which are having longitudinal reinforcement higher than then the transverse reinforcement. Each of the 8 columns was wrapped with CFRP or GFRP sheets. After studying this whole experimentation, it was found out that Use of FRP has a good influence on ductility, stiffness and dissipated energy.

4. K.Galala, A. Arafa, A.Ghobarah "RETROFIT OF RC SQUARE COLUMNS" 2008

During seismic activity, RC short columns are most likely to undergo shear failure. Therefore study of the behaviour of short columns is very important and also retrofitting of the short columns is important. In this paper, short reinforced columns were reinforced with transverse reinforcement and then they were retrofitted by using fibre reinforced polymer composites. Design of seven short RC columns was done and then they were tested under axial load. CFRP or GFRP was used for the purpose of retrofitting. From this experimental study, I can say that increase in the number of FRP layers in RC short column decreases the strains in both the transverse ties and fibre materials used. By retrofitting of CFRP sheets, shear force was improved and energy dissipating capacity was also improved.

5. Minho Kwon, Jinsup Kim, Wooyoung Jung, Hyunsu Seo, "Design procedure of GFRP-infill panels to improve the strength of steel-frame structures." 2011

GFRP-infill panels (GIPs) were designed for use in steel frame structures. The objective of this designing was to increase the strength of the steel structure and to give support to the week steel frames under seismic activity. After the studying of the test results, there was an increase in the strength of frames made up of steel structures. Also design procedure for GIPs can be used to improve the strength and durability of a frame made up of infill-steel structure.

6. Dr. Gopal Rai and Yogesh Indoliia "Fiber reinforced polymer, a novel way for strengthening for structures." 2006

New innovative construction materials are being used now-a-days to meet the requirements of any structure in advance. The use of FRP in strengthening of the structure are proven quite useful and also are used in various other applications. FRP can be used by applying epoxy on the laminates and that can be wrapped around the beams, slabs and columns to improve their strength in weak regions or damaged areas. Direction of application of FRP laminates or strips are parallel to the high tensile stresses. Therefore the compound of FRP are finding ways to test its affect on the structure and economical time.

7. Pedram Sadeghian, Ali R Rahai and Mohammad R Ehsani "Experimental study of rectangular RC columns strengthened with CFRP composites under eccentric loading" 2013

In recent years, different studies on FRP confined column strengthened had been tested under concentrated loads. However most of the columns crack when there is eccentric loading with the combinations of axial compressive loads and bending moment. This study is done by experimenting tests on RC columns reinforced with carbon fibers and were being tested under axial force and bending moment. In this paper, & number of specimens with cross section of 200mm × 300mm were casted and tested under eccentric loading. FRP was applied in two, three and five layers on the columns. On determining the results, it was shown that increase in eccentricity decreases the moment carrying capability of the column. Also CFRP composites increases the load carrying capacity of column. FRP jacketing can enhance or improve the ductility of the columns.

8. Raafat El Hacha, Mark F Green and Gordon R Wright "Effect of sever environmental exposure on CFRP wrapped concrete"

The deterioration of concrete structures by corrosion of reinforcements and rebars is due to sever environment conditions such as cold zones and coastal area zones. The main motive of this study is to enhance the effectiveness of concrete cylinders when it is exposed to extreme temperature differences. In this experimental paper, 36 plain cement concrete cylinders were tested and they were wrapped by 2 number of layers of unidirectional CFRP plates. These specimens were subjected to temperature differences of 23ºC and 45ºC heating and cooling and later these specimens were put to cyclic freeze thaw cycles. Some of the specimens were completely submerged into water. Then the specimens were subjected to the loading for failure under uni-axial compressive stress and axial and lateral deformations were calculated. Based upon the test results, 74% strength was increased in the cylinder which was made up of 43 cement grade and was wrapped by unidirectional carbon fibers. Significant strength was also increased in those samples which were subjected to temperature fluctuations. Axial load carrying capability of cylinder was increased upto 4 times.

9. Eslami and H. R. Ranogh "Experimental investigation of an appropriate anchorage system for flange bonded carbon fiber reinforced polymers in retrofitted RC beam column joints."

In past years, there has been a lot of research in the field of retrofitting on a column beam joint arrangement by using fiber reinforced polymers (FRP) by various researchers. Most of the researchers have said that FRP jacketing should be done on the web of the beam column arrangement and corners which are fixed i.e, crossbeams and central slabs should be wrapped with FRP laminates in slabs because maximum strain has been determined in these portions only. In this paper, 9 no. of beam-column test specimens were castes in which two were control beams and rest were retrofitted. Cyclic loading were applied to the beam-column joint to check the effect of the seismic forces on these specimens. Various properties were determined like, moment carrying capacity, stiffness, displacement, ductility and dissipated energy and these were compared with the test results from the control mix beam-column joints and hence it was proved that the efficiency of new system of anchorage is beneficial in beam-column joints.

10. Dhanu M. N. Revathy D. Lijina Rasheed, Shanavas. "Experimental and numerical study of retrofitted RC beams using FRP."

In this study, experimental and numerical study was done by retrofitting of FRP laminates on the RC beams. Main motive of this paper is to check the improvement in the strength of RC beams by applying adhesive on the surface of the beam and then wrap it with the FRP laminate. FRP used in this experimental study is GFRP and coir fibers. After the wrapping of FRPs, moment carrying capacity and crack pattern were determined. The same model of the beam was made in ANSYS software and both the results were compared. It was concluded that the GFRP and coir fiber retrofitting increases the resisitance of structure towards seismic forces.

11. Okan Ozcan, Baris Binici, Guney Ozcebe "Seismic strengthening of rectangular reinforced concrete columns using fiber reinforced polymers"

In this research paper, rectangular RC columns were casted and they were retrofitted with CFRP anchorages. Only 5 rectangular Rc columns were casted with poor transverse rebars and also the strength of concrete was kept low. These columns were subjected to cyclic displacements and axial forces. Also wrapping was done on the surface of the columns by CFRP laminates and they were fixed with some adhesive so that laminates can be tightly wrapped. It was found out that an increase in the ratio of FRP laminates is very beneficial.

12. Mohammad R. Irshidat, Mohammed H. Al-Saleh, Mahmoud Al-Shoubaki. "Using carbon nanotubes to improve strengthening efficiency of carbon fiber/epoxy composites confined RC columns."

In this experimental study, carbon nanotubes (CNTs) were used to improve the strength of RC columns confined by carbon fibers/epoxy composites. Total number of 14 rectangular RC columns were casted and tested under concentric axial loading. Carbon fibers were coated with epoxy resins which were enriched with CNTs. For the experimentation, RC columns were tested with fully wrapped carbon fibers and partially wrapped carbon fibers. Different properties were determined like failure modes, axial load-displacement responses, etc. from the tests, it was proven that the axial load carrying capability and toughness of columns wrapped with carbon fibers was increased by 12% and 19% respectively.

CHAPTER 3

METHODOLOGY ADOPTED

3.1 MATERIAL USED:

For the casting of columns, various construction materials are used like cement, fine aggregates and coarse aggregates and water. GFRP laminates will be used for the purpose of retrofitting.

- **Cement**: Portland pozzolana cement (PPC) was used for the casting of the columns. The cement has been checked for various properties and they are accurate taking IS:4031-1968 into consideration.
- **Coarse aggregates:** Size of the aggregates which will be used in the making of concrete are 10mm and 20mm. This material has to satisfy IS:383-1970. Locally available aggregates and some basalt stone chips will be used in this study.
- **Fine aggregates**: Locally available riverbed sand will be used and it should be confirming some zone which depends upon the sieve analysis of the sand.
- **Fiber:** The main role of the fibers is to carry load, provide stiffness, increase strength and give thermal stability to the structure. Fibers are made up of long filaments. There are basically three general types of fibers which are being mostly used in retrofitting i.e, glass fiber, carbon fiber and aramid fibers.
- **Glass fibers:** These fibers are generally made up of silicon. Their main property is high strength. After retrofitting, glass fibers enhance various properties of the structure.

3.2 Tests performed:

Various tests were performed on the cement and the aggregates. These tests were done in the laboratory under the supervision of our mentor. Various properties were determined with the help of these tests. These all tests were performed keeping IS 383:1970 in consideration.

3.3 Tests performed on the cement:

Various tests were performed on the cement to check its various properties and the calculated results are discussed below:

I. Consistency
II. Soundness test
III. Initial setting time

IV. Final setting time

V. Fineness of cement

VI. Specific gravity test

3.3.1 Consistency test:

Objective: To determine the standard consistency of cement paste.

Theory: The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger (consistency apparatus) to penetrate to a depth of 33-35 mm from the top of the mould. Normally standard consistency is used to determine the quantity of water required to be added to cement to make it in the form of paste.

Apparatus required:

1. Vicat apparatus.
2. Balance.
3. Measuring cylinder.
4. Tray.
5. Glass plate.

Environmental conditions:

Table no. 4- Environmental conditions for consistency test.

Temperature	25^oC to 27^oC
Humidity	60^oC to 70^oC

Calculations:

Standard consistency is the ratio of quantity of water added (W) to the quantity of cement used(C).

Mathematically, consistency is represented as:

$$\mathbf{P} = \frac{W}{C} \times 100$$

Figure 6: consistency test

Result:

Table no. 5: calculation of standard consistency.

S.No	Weight of cement (gms)	Percentage by water of dry cement (%)	Penetration (mm) (from the bottom of the mould)
1	300	25	41 mm
2	300	27	34 mm
3	300	29	31 mm
4	300	30.5	23 mm
5	300	32.5	11 mm
6	300	34.5	7 mm

Therefore the standard consistency for the cement is **34.5%**.

Test standard reference

The IS code used for the consistency of cement is IS:4031-PART 4-1988

3.3.2 Soundness of cement

Objective: To calculate the soundness of cement by Le- Chateliers method.

Theory: certain cements undergo large expansion after setting that causes failure in the structure. So the cement after setting should not have any expansion or there should be no change in the volume of the cement. Soundness of cement is determined to detect any expansion in the cement by boiling a hardened cement paste for a fixed time. The capability to resist any volume expansion is called as soundness of that material.

Apparatus:

1. Le-Chatelier test apparatus.
2. Water bath (100^0C).
3. Caliper.
4. Balance.
5. Trowel.
6. Tray.

Figure 7: le-chatelier's test apparatus.

Environmental conditions:

Table no. 6: Environmental condition for soundness test

Temperature	25^oC to 27^oC
Humidity	60^oC to 70^oC

Calculations:

L_1= Distance separating the two indicator points submerged in water bath at normal temperature for 24 hours.

L_2= Distance between the two indicator points submerged in water bath at 100^oC for three hours.

Soundness or expansion= **L_2-L_1**

Table no.7: Result for soundness test.

s.no	L_1 (mm)	L_2 (mm)	Soundness (mm)
SAMPLE 1	1.5	1.9	0.4
SAMPLE 2	1.5	1.85	0.35
SAMPLE 3	1.5	1.75	0.25

The soundness is calculated by taking the mean of the three samples and it comes out to be **0.33mm.**

Conclusion:

According to IS:1489-1991 (part 1), the expansion limit for Portland pozzolana cement is 10mm. Therefore, the given cement is said to be sound as the soundness or expansion is only 0.33 mm.

3.3.3 Initial setting time of cement.

Objective: To determine the initial setting time of the cement.

Theory:

Initial setting time: It is the time when the water is added to the cement to the time the cement paste starts losing its plasticity.

Final setting time: it is defined as the time when water is added to the cement to the time when the cement has completely lost its plasticity and has attained some firmness to resist any external load or pressure.

Apparatus:

Vicat apparatus.

Balance

Trowel

Tray

Water

Stop watch

Figure 8: Vicat apparatus

Figure 9: Assembly of test apparatus and test block

Calculations:

1. Weight of dry cement is 300 gm.

2. The standard consistency of cement is 34.5%.

3. Volume of water added = 0.85P

$0.85 \times 34.5 = 29.325\%$

∴ volume of water added = $29.325 \times (\frac{300}{100}) = 87.97$ ml

Initial setting time= $T_2 - T_1$.

Table no 8: Result of initial setting time test.

Sample	T_1 (min)	T_2 (mins)	Setting time (T_2-T_1)
Sample 1	10:15	10:52	37
Sample 2	11:05	11:39	34
Sample 3	12:02	12:33	31

The initial setting is calculated by taking the average of the three reading and is equal to 34 minutes

The final setting time is taken as the average of the 3 samples and is 590 minutes.

Test standard reference

According to IS:1489 - part 1, the initial and final setting time of PPC should be 30 minutes and 600 minutes respectively. According to our test, the initial and final setting time is 34 minutes.

3.3.4 Fineness of cement

Objective: To find out the fineness of Portland pozzolana cement by dry sieving.

Theory: Fineness is determined by sieving of dry cement on the standard sieve and the size of grains whose size is larger than the specified sieve size is determined. The fineness of cement has a good affect on the rate of hydration. Finer the cement more will be the rate of hydration and thus there will be increase in the strength.

Apparatus required:

90 micron sieve

Balance

Tray

Lid

Figure 10: 90 micron sieve

Calculations:

The fineness of cement is calculated by taking the average of the three samples.

Table no. 9: calculation of fineness of cement

Sample	**Weight of dry cement (g)**	**Weight retained on the 90 micron sieve (g)**	**Fineness (%)** $(X/200) \times 100$
Sample 1	200	11.5	5.75
Sample 2	200	10.9	5.45
Sample 3	200	10.7	5.35

Therefore the fineness of cement is calculated by taking the average of the three samples and is equal to 5.5%.

Test standard preference:

According to IS:4031-1996 (part 1) the fineness of PPC should not be more than 10%. So our sample is fine in nature as its fineness is 5.5%.

3.3.5 Specific gravity test

Objective: To find out the specific gravity of dry cement using Le-Chatelier's flask,

Theory: The specific gravity is defined as the ratio of the weight of a given volume of material and weight of an equal volume of water. Kerosene or diesel is used to determine the specific gravity of cement.

Apparatus :

Le-Chatelier's flask

Balance

Diesel

Dry cement.

Figure 11: Le-Chatelier's flask

Calculation:

The difference between the two readings represents the volume of liquid displaced by the equal amount of cement.

W= weight of cement.

W_1= weight of diesel in the flask.

W_2= weight of diesel and cement in the flask.

Specific gravity of cement = $\frac{W}{W-\{(W2-W1)\times 0.85\}}$

Specific gravity of diesel = 0.85

Here, W=50 gm

W_1= 240.35 gm

W_2= 279.352 gm

Therefore, specific gravity of cement = 2.967.

Reference:

According to IS:4031-1988(part 11), the specific gravity of Portland pozzolana cement is around 3.10.

3.4 Tests performed on the coarse aggregates and fine aggregates.

3.4.1 Sieve analysis of coarse aggregates and fine aggregates.

Theory: Sieve analysis is commonly known as gradation test. The sieve analysis helps us in determining the gradation of particles i.e, the distribution of aggregate particles by size.

A). **Determination of sieve analysis for coarse aggregates:**

Objective: To determine the fineness modulus of coarse aggregates.

Apparatus: Sieves of size 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, Balance

Figure 12: coarse aggregate test

Calculation:

Weight of coarse aggregates taken= 5kg.

Table no. 10: fineness modulus of coarse aggregates.

S.NO	Sieve size (mm)	Weight retained (kg)	% weight retained	Cumulative % weight retained (X)	Cumulative percent passing
1.	80	0	0	0	100
2.	40	0	0	0	100
3.	20	0.400	8	8	92
4.	10	2.850	57	65	35
5.	4.75	1.480	29.6	94.6	5.4
6.	2.36	0.270	5.4	100	0
Total		5.000 kg		267.6	

Result:

Therefore, the fineness modulus of coarse aggregates = $\frac{X}{100} = \frac{267.6}{100}$ = 2.676.

Also the given sample of coarse aggregates belong to graded aggregates taking IS:383:1970 into consideration (grading limits for coarse aggregates).

Standard reference:

IS : 2386 (Part I) – 1963,

IS: 383-1970,

IS : 460-1962

B). Determination of sieve analysis for fine aggregates.

Objective: to determine the fineness modulus of fine aggregates by sieve analysis.

Theory: With the help of fineness modulus, we can determine the fineness of sand, whether it is coarse sand, medium sand or fine sand.

Table no 11: types of fine aggregates and their range

Fine aggregate	Fineness modulus
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Fine aggregates having fineness modulus more than 3.2 will be unsuitable for preparing concrete.

Apparatus:

Test Sieves conforming to IS : 460-1962 having specification of 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron, 150 micron,

Balance, Gauging Trowel, Stop Watch, etc.

Calculation:

Weight of fine aggregate taken = 1kg

Table no. 12: Fineness modulus of fine aggregates

S.NO	Sieve size	Weight retained (kg)	% weight retained	Cumulative % weight retained (kg)	% weight passing (kg)
1.	4.75 mm	0.02	2	2	98
2.	2.36mm	0.045	4.5	6.5	93.5
3.	1.18mm	0.092	9.2	15.7	84.3

4.	600 μm	0.177	17.7	33.4	66.6
5.	300 μm	0.492	49.2	82.6	17.4
6.	150μm	0.161	16.1	98.7	1.3
7.	Pan	0.013	1.3	100	0
Total		1 kg		X=238.9	

Result:

Therefore, the fineness modulus of the fine aggregates = $\frac{X}{100} = \frac{238.9}{100} = 2.389$

Also the given sample of fine aggregates belong to the Grading zone *III* taking IS:383:1970 into consideration (grading limit for fine aggregates).

3.4.2 Determination of specific gravity and water absorption of coarse aggregates.

Objective: to determine the specific gravity and water absorption of coarse aggregates.

Apparatus:

Wire basket,

Oven

Container for filling water and suspending the basket.

Air tight container

Balance

Tray and absorbent clothes.

Calculations:

W_1= weight of saturated dry sample.

W_2= weight of wire basket in water.

W_3= weight of wire basket + sample in water.

W_4= weight of oven dried sample.

Table no. 13: specific gravity and water absorption of CA

SAMPLE	W_1 (kg)	W_2 (kg)	W_3 (kg)	W_4 (kg)
Sample 1	2	0.108	1.382	1.991

Sample 2	2.	0.637	1.910	1.995
Sample 3	2	0.177	1.432	1.994
Average	2	0.307	1.574	1.993

Average specific gravity= $\frac{W4}{W4-(W3-W2)} = \frac{1.993}{1.993-(1.574-0.307)}$=**2.74.**

Water absorption percentage= $\frac{W1-W4}{W4} \times 100$= $\frac{2.000-1.993}{1.993} \times 100$= **0.7%**

Result:

The average specific gravity of coarse aggregate is 2.74

The water absorption percentage is 0.7%.

Test reference:

IS : 2386-1963 (part III).

3.4.3 Specific gravity and water absorption of fine aggregates:

Objective: to determine the specific gravity and water absorption of a given sample of fine aggregates.

Apparatus:

Pycnometer,

1000-ml measuring cylinder,

oven,

Taping rod, Filter papers and funnel, balance, etc.

Figure 13: Pycnometer.

Calculations:

Table no 14: specific gravity and water absorption of fine aggregates

Sample	Weight (g)
Weight of saturates and dry aggregates (W)	500
Weight of pycnometer, sample and water (W_1)	1896
Weight of pycnometer and water (W_2)	1584
Weight of oven dry sample (W_3)	494

Result:

Specific gravity = $\frac{W3}{W-(W1-W2)} = \frac{494}{500-(1896-1584)}$ = 2.62

Water absorption = $\frac{W-W4}{W4} \times 100 = \frac{500-494}{494} \times 100$ = 1.1 %

Test reference:

IS : 2386-1963 (PART III)

3.5 MIX DESIGN M20

Design mix is done by taking IS:10262-2009 into consideration.

Stipulation for proportionating:

I. Grade of concrete = M20

II. Type of cement = PPC 43 Grade.

III. Maximum size of coarse aggregates = 20mm

IV. Exposure condition = mild

V. Maximum cement content = 450 kg/m^3

VI. Type of aggregate = crushed.

Test data for material: All the data is based on the test results which were done in laboratory.

1. specific gravity of cement = 2.967
2. specific gravity of coarse aggregates = 2.74
3. specific gravity of fine aggregates = 2.626
4. Water absorption of CA = 0.7%
5. Water absorption of FA = 1.1%
6. Fineness modulus of FA = 2.389
7. Consistency of cement = 34.5 %
8. Initial and final setting time of cement = 34 minutes and 602 minutes respectively.

- **Mix design**

1. Target strength for mix design

$\mathbf{F_{ck} = f_{ck} + (t \times s)}$

Where "F_{ck}" is target average compressive strength at 28 days and "f_{ck}" is the characteristic at 28 days, "s" is standard deviation and "t" is a statistic variable depending upon the accepted proportion of low results and the no. of tests.

[Table 1 IS:10262-2009]

$\mathbf{F_{ck} = 20 + (1.65 \times 4.6) = 27.59\ N/mm^2}$

2. Selection of water cement ratio

W/C ratio for corresponding F_{ck} value from IS:10262-2009 = 0.48

For mild exposure = 0.6

Take the min. water cement ratio = 0.48

[Table 5 IS:10262-2009]

3. Air content:

For maximum size of 20 mm aggregates, the entrapped air is 2% of the volume of concrete.

4. Water content and fine aggregate to total aggregate ratio

For nominal maximum size of 20 mm aggregates and concrete grade of M20, the water and sand content obtained are 186 kg/m^3 and 35% of total aggregate volume respectively.

Water content = 186 kg/m^3.

5. Adjustments of values in water content and sand percentages

No corrections are required since aggregates used are not rounded and there is no increase or decrease in w/c ratio and compaction factor.

6. Determination of cement content

W/C ratio = 0.48

Water content = 186 kg/m^3

Cement content = $\frac{186}{0.48} = 387.5$ kg/m^3

7. Check for minimum and maximum cement content

The calculated cement content of 387.5 kg/m^3 is adequate as per IS: 456:1978

8. Determination of coarse and fine aggregate content

Fine aggregates:

$$V = \left(W + \frac{C}{Sc} + \frac{1}{p} \times \frac{\mathbf{fa}}{Sfa}\right) \times \frac{1}{1000}$$

$$0.98 = \left(186 + \frac{387.5}{2.967} + \frac{1}{0.35} \times \frac{\mathbf{fa}}{2.622}\right) \times \frac{1}{1000}$$

Fa = 608.79 kg

Coarse aggregates:

V= $(W + \frac{C}{Sc} + \frac{1}{p} \times \frac{\mathbf{Ca}}{Sca}) \times \frac{1}{1000}$

$0.98 = (186 + \frac{387.5}{2.967} + \frac{1}{1-0.35} \times \frac{\mathbf{Ca}}{2.740}) \times \frac{1}{1000}$

Ca = 1181.50 kg.

10. Total quantities of ingredients and mix proportions

Table no. 15: proportion for mix design M20

Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (kg/m^3)
387.5	608.79	1181.50	186
1	1.570	3.049	0.48

Therefore ratio of mix = 1 : 1.570 :3.049.

CHAPTER 4

EXPECTED OUTCOMES

Following are the outcomes from my research project:

- First of all the column will be subjected to axial compressive loads and then their failure will be achieved. After the formation of crack pattern, column will be wrapped with GFRP laminates at the weak spots or where the damage has been done. After retrofitting, we will check the strength of column again and it should be improved.
- By the definition of retrofitting, there should be re-strengthening in the structure. Same will be the condition with the columns, when the GFRP sheets will be binded to the damaged column, it will increase its strength.
- We will also learn the technique to do retrofitting. Mainly GFRP sheets are applied on the centre of the column, but in this project, sheets will be applied on the top and bottom portions of column also. GFRP sheets will be binded also in helical nature.
- Flexure strength and compressive strength will be determined.
- Crack pattern will be checked also.

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