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EXPERIMENTAL STUDY OF PERVIOUS CONCRETE DESIGN USING DEMOLISHED AGGREGATE AND GLASS FIBER UNDER CYCLIC LOADING

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Abstract
Special concrete has been widely used in the construction industry. Pervious concrete is such concrete in which the fine aggregate is omitted. In the manufacturing of any type of concrete, the optimum dosage of all the materials must be known. This study aims to find out the optimum dosage of demolished aggregate and glass fiber and study their behavior on fresh and hardened properties of pervious concrete. The result of the study shows that the grading of aggregate has significant effect on the strength of pervious concrete. We have used the ratio of 60:40 of the 20mm and 10mm respectively. The use of demolished aggregate up to 40% has shown increase in compressive strength of pervious concrete. The strength is increased up to 30% by using demolished aggregate. With the use of glass fiber as a replacement of cement the strength is increased up to 10% at 1% replacement. Use of both glass fiber and demolished aggregate result in increasing the compressive strength of pervious concrete up to 20%, 14%, 5%, for the aggregate-binder ratio of 5, 4.1, and 3.9 respectively. Demolished Aggregate and Glass fiber also increase the split tensile strength and flexural strength by 15% and 5% respectively. Use of demolished aggregate and glass fiber shows better result in the cyclic loading as compare to control mix specimen.

Keywords: Cyclic Loading, Demolished Aggregate, Glass Fiber, Pervious Concrete,

1. Introduction

Today in the present world we are very much fond of sustainable and eco-friendly means of Construction. Particularly in a country like India where flooding and waterlogging problems are the Major environmental issues sustainable development has become a necessity. Various sustainable and eco-friendly means are being implemented to tackle these problems where pervious concrete pavement is one among them. Working on the “rain-drain” concept Pervious concrete allows a significant amount of stormwater to seep into the ground, thereby recharging the groundwater and reducing the stormwater runoff. Pervious Concrete is lightweight concrete produced by omitting the fines from conventional concrete. The recent emphasis on sustainability issues in construction has increased the interest in exploring possible further uses of no-fines concrete.

Currently, Indian conditions have not fully adopted pervious concrete specifications but have been gathering various types of research on the subject and have developed a draft specification based on the ACI 522 specification. While numerous states have created such a document, the unique weather conditions in Indian conditions have not been evaluated and tested. Several admixtures in conjunction with typical aggregates found in Indian conditions state projects were included in the design mixtures for this project. The need to design-performing pervious concrete specifications for Indian conditions was the basis of this report. Several admixtures were tested along with regional materials often used in road projects. Structural and durability characteristics.

Figure 1: Pervious Concrete Cube

2. **Material Used**

a. **Cement**

OPC 53 confirming to IS 8112:2013 is used in this research to make pervious concrete. All the physical test is performed as per Indian standard specification.

Table 4.1 Physical Properties of Cement

S. NO.	Test conducted	Results obtained	Requirement as per IS 8112
1.	Fineness	325 m^2/kg	Min 225 m^2/kg
2.	Initial setting time	120 minutes	Should not be lesser than 30 min
3.	Final setting time	360 minutes	Should not be lesser than 30 min
4.	Specific gravity	3.15	3.1-3.15
5.	Compressive strength	55.2 MPa	53 Pa (minimum)

b. **Natural Aggregate**

The Natural gravel of size 4.75mm-20mm selected for the study. The grading has been done as per IS 383:2016.

Table 2 Physical Properties of Natural Aggregate

S. No.	Properties	Unit	Results
1.	Bulk density	Kg/m^3	1470
2.	24h water absorption	%	0.7
3.	Specific gravity	-	2.74
4.	Fineness modulus	-	5.23
5.	Los Angeles abrasion loss	%	31

c. **Demolished Aggregate**

Demolished Concrete Aggregate was used as coarse aggregate as a replacement of Natural coarse aggregate. It was brought from waste found in the institute laboratories and used as recycled materials. To produce aggregate from the demolished concrete, the following procedure was followed:

- The demolished concrete was crushed into smaller sizes manually by a hammer and put into sieve to obtain the required sizes.
- The crushed old concrete was sieved on a standard sieve according to IS 383:1970, to produce aggregate with 20mm maximum size, single and grading similar to that of natural aggregate used in this study.

Table 3 Physical Properties of Demolished Aggregate

Properties	Unit	Demolished Aggregate (DA)
Bulk density	Kg/m^3	1252.1
24h water absorption	%	5.05
Specific gravity	-	2.47
Fineness modulus	-	5.87
Los Angeles abrasion loss	%	40

d. Glass Fiber

Glass fiber is a material that has very fine fibers of glass. It has a high percentage of silica and other components like calcium, and aluminium. The glass fiber used in this study have length of 6-12mm and filament diameter of 14 microns. It has high thermal, electric, sound, and high-strength fabric and is also corrosion-resistant. It is used in concrete to minimize shrinkage cracking and reduce permeability.

Table 4 Properties of Glass Fiber

Property	Result*
Type of material	Alkali-resistant Glass Fiber
length (mm)	6–15
Filament diameter (microns)	13
Moisture	0.5%
Chemical resistance	Very high
Modulus of elasticity (GPa)	72
Tensile strength (MPa)	>1720
Specific gravity	2.62
Dry rodded density (kg/m^3)	840

***Properties are taken from the research paper of Megha N Belagal**

3. Methadology

A total of 3 specimens were tested under each type of loading and the mean of the result is noted. The behavior of pervious concrete is checked under uniaxial compressive loading & cyclic loading.
Firstly, the optimum dosage of Demolished aggregate and glass fiber is obtained using compressive strength test on the cube specimen.
For the cyclic loading test cylinders are designed of pervious concrete with different replacement are tested under monotonic loading for M1, M2 and M3 to check the maximum strength of under gradually varying load. After getting the stresses of the test specimen cycle has been decided. In the second stage cyclic loading has been performed on the cylinder specimen of grade M1, M2 and M3 and load and deflection are noted digitally with the help of load cell, data logger, and LVDT. And using these load and deflection values we have plotted the common point curve and stability point curve. To develop an SN curve repeated loading is applied on the cylinder specimen under the maximum and minimum values of ultimate load. The cycle is determined on the range of 90-50%, 65-45%, 85-45% of the maximum load and it helps to determine the strength under various repeating loads cycles.

4. Experimental Programme

4.1 Seive Analysis of 20mm Aggregate

Table 5 Seive Analysis of 20mm Aggregate

IS Sieve	weight retained in grams	Percentage weight retained	Cumulative Percentage weight retained	Cumulative percentage passing
40 mm	0	0	0	100

20 mm	1470	14.70	14.70	85.30
10 mm	7757	77.57	92.27	8.27
4.75 mm	827	8.27	100	0
Pan	0	0	100	0
TOTAL	10000		306.97	

4.2 Sieve Analysis of 10mm Aggregate

Table 6 Seive Analysis of 10mm Aggregate

IS Sieve	Weight retained in grams	Percentage weight retained	Cumulative Percentage weight retained	Cumulative percentage passing
20 mm	38	0.38	0.38	99.62
10 mm	937	9.37	9.75	90.25
4.75 mm	8477	84.77	94.52	5.48
2.36 mm	548	5.48	100	0
Pan	0	0	100	0
TOTAL	10000		304.65	

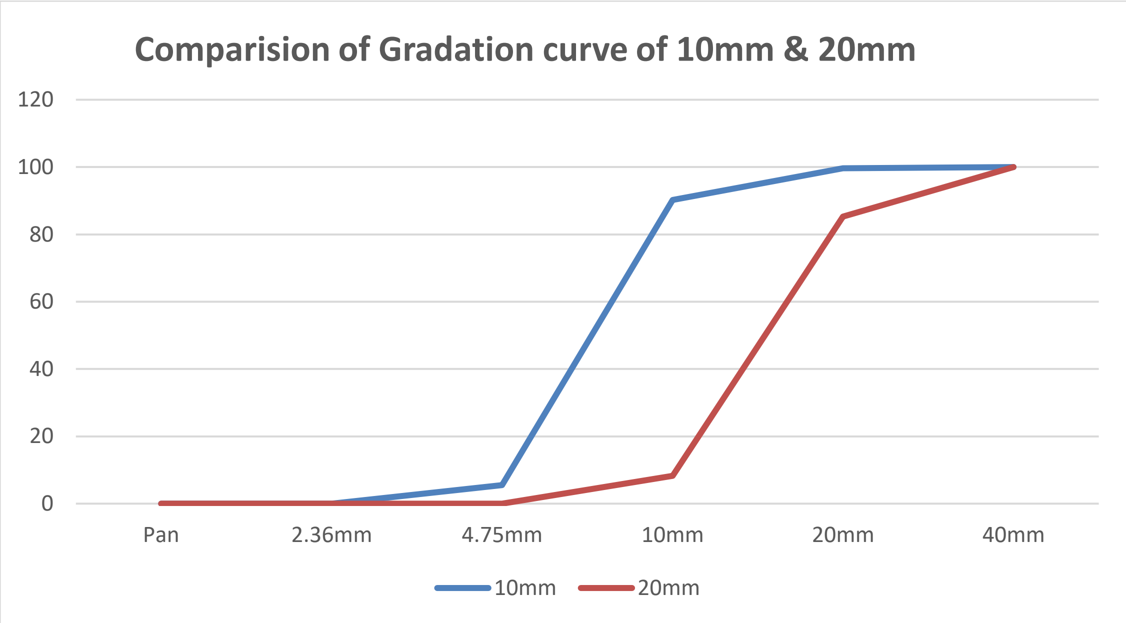

Figure 2 Gradation Curve of 10mm and 20mm Aggregate

4.3 Details of Mix Design

Table 6 Details of Mix Proportions

Mix	Cement (kg/m^3)	Natural Coarse Aggregate (kg/m^3)		Water (kg/m^3)	Demolished Aggregate kg/m^3)		GF (kg/m^3)
		10mm	20mm		10mm	20mm	
CM1	385	650	1280	142.5	-		-
DM1 (40%DA, 1%GF)	381.15	390	768	142.5	260	512	3.85
CM2	464	673.3	1232.45	148.5	-		-
DM2	459.36	403.98	739.47	148.5	269.32	492.98	4.64

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(40%DA, 1%GF)							
CM3	487.3	644.61	1255.86	136.44	-		-
DM3 (40%DA, 1%GF)	482.27	386.76	753.51	143	257.84	502.344	71.55

5. Result and Discussion

5.1 Result of Optimum dosage of Demolished Aggregate

For the optimum dosage of demolished aggregate, the cubes of size 150mm x150mm x 150mm is prepared and the compressive strength test is done to obtain the optimum dosage of demolished aggregate.

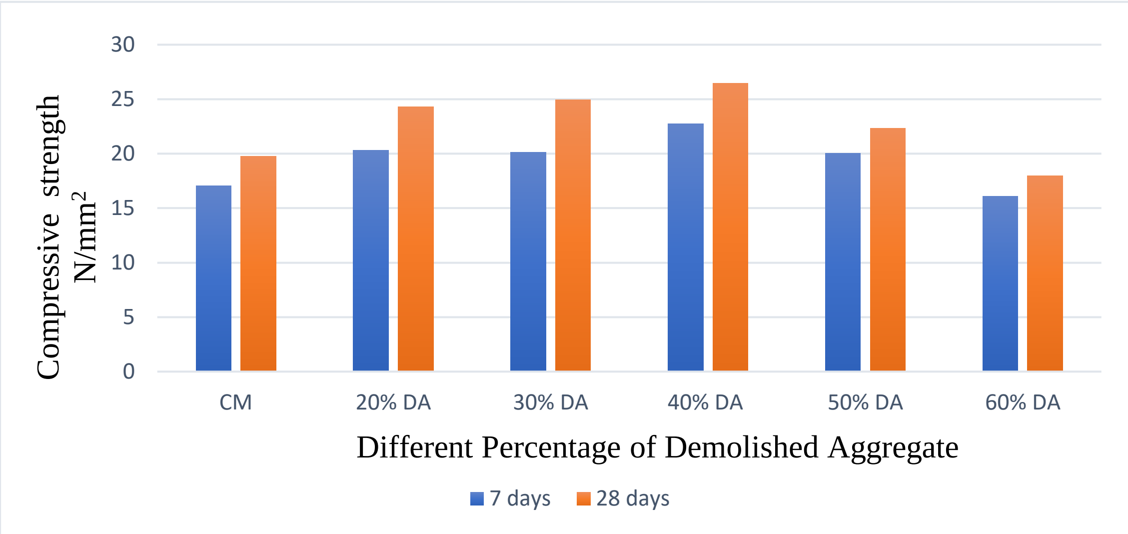

Figure 3 Comparison of Result of compressive strength test of different % of DA

***CM- Control Mix, DA- Demolished Aggregate**

5.2 Result of optimum dosage of Glass Fiber

For the optimum dosage of glass fiber, the mortar cubes of size 70.6mm x 70.6mm x 70.6mm is prepared and the compressive strength test is done to obtain the optimum dosage of glass fiber.

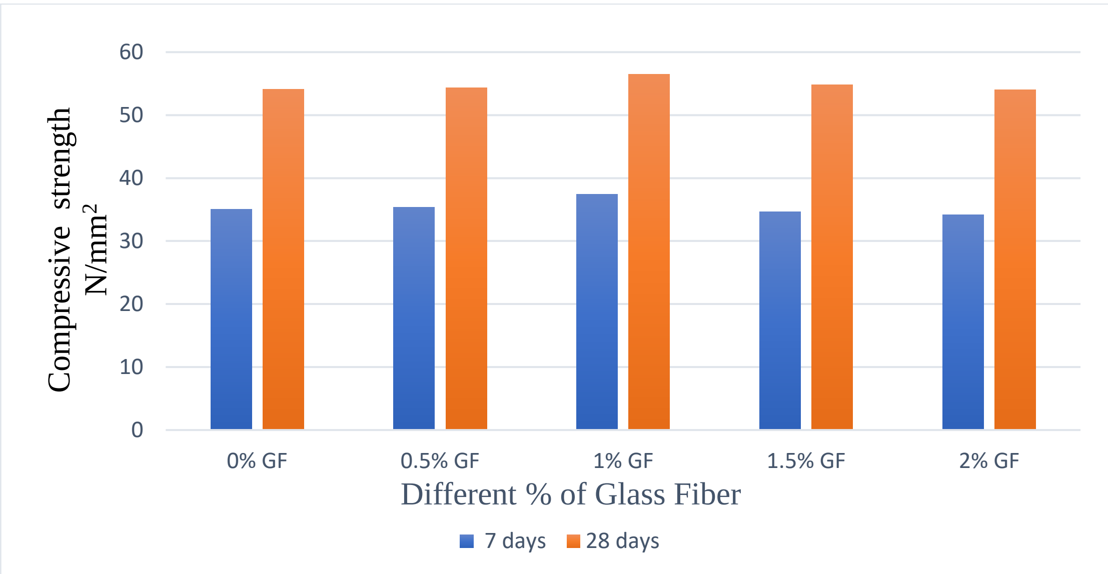

Figure 4 Comparison of Compressive strength result for different dosage of GF

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5.3 Result of Void Ratio and Porosity

Table 7 Result of Void Ratio and Porosity of different Mix

Mix	Void Ratio (%)	Porosity (%)
CM1	28.8	22.3
DMI	26.4	20.8
CM2	25.7	20.4
DM2	23.85	19.25
CM3	23.4	18.9
DM3	18.8	15.8

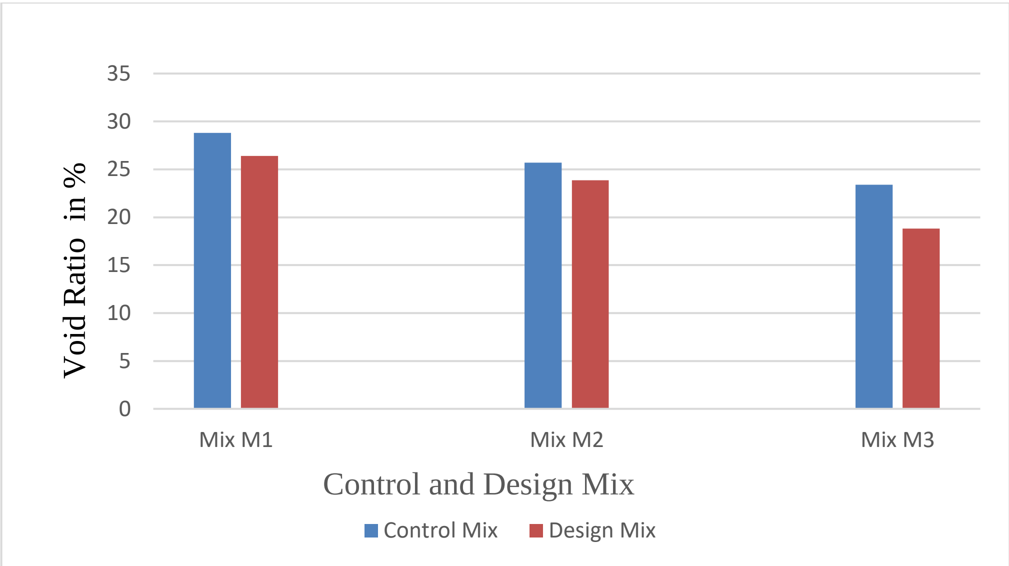

Figure 5 Comparison of Void Ratio of Different Mix

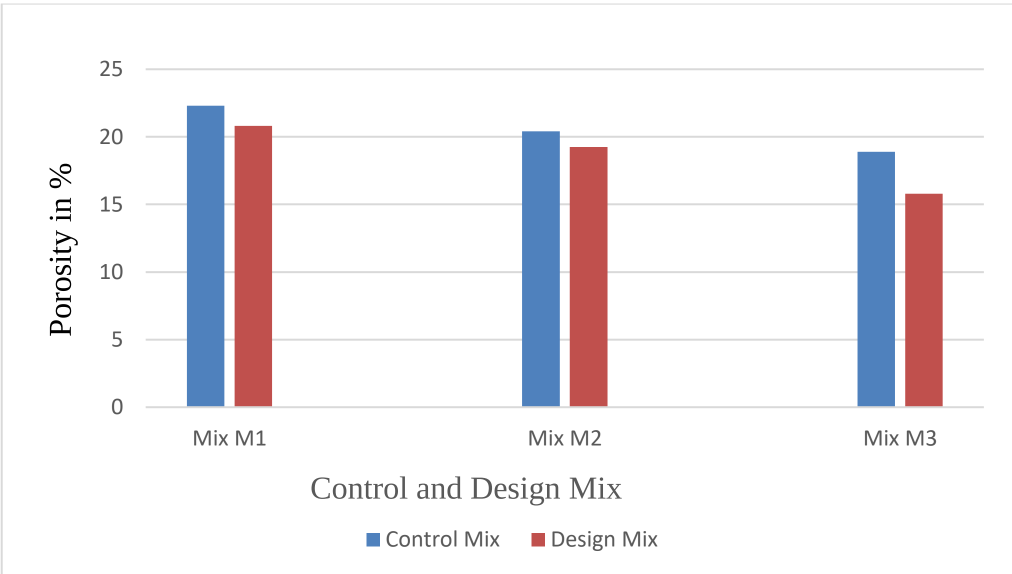

Figure 6 Comparison of Void Ratio of Different Mix

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5.4 Result of Compressive Strength

Table 8 Result of Compressive strength test of cube

Mix	7-days	28-days
CM1	20.97	24.31
DMI	26.31	29.87
CM2	27.08	31.25
DM2	29.47	33.18
CM3	29.12	35.38
DM3	34.33	36.33

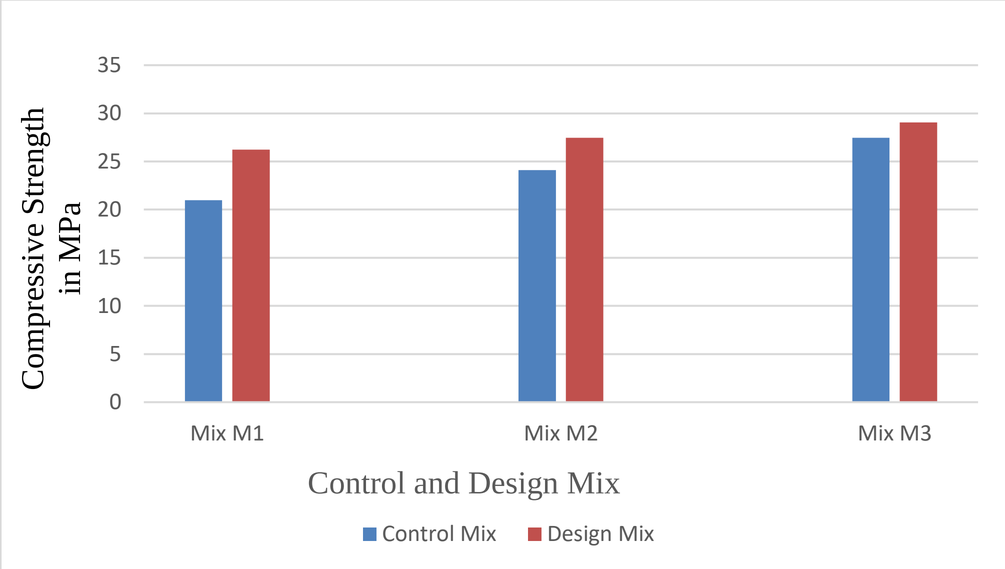

Figure 7 Comparison of 7-days Compressive Strength Different Mix

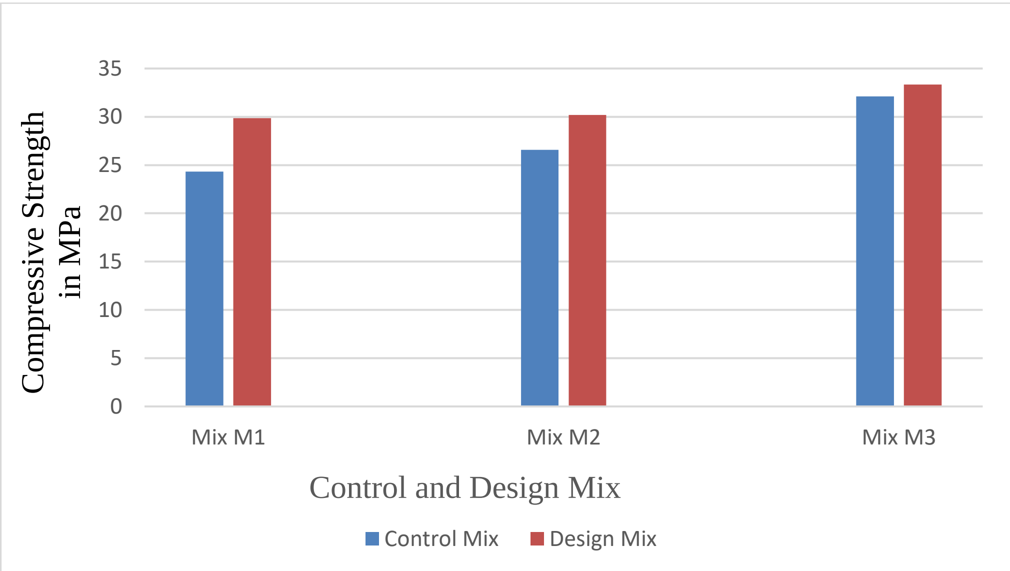

Figure 8 Comparison of 28-days Compressive Strength Different Mix

5.5 Result of Flexural Strength of beam

The beam of size 500mm x 100mm x 100mm are tested for flexural strength (f_b) as per IS 516:1959. Since we got the distance between the line of fracture and the nearer support (a) more than 13.3 cm, so we use the formula $f_b = P.l/b.d^2$ (kg/cm^2) where,

p = maximum load in kg applied to the specimen,

l = length in cm of the span on which the specimen was supported,

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure.

Table 9 Result of Flexural strength test of beam

Z	Load in kg	Flexural Strength in MPa
CM1	443	1.77
DM1	474	1.89
CM2	490	1.96
DM2	514	2.05
CM3	540	2.16
DM3	577	2.30

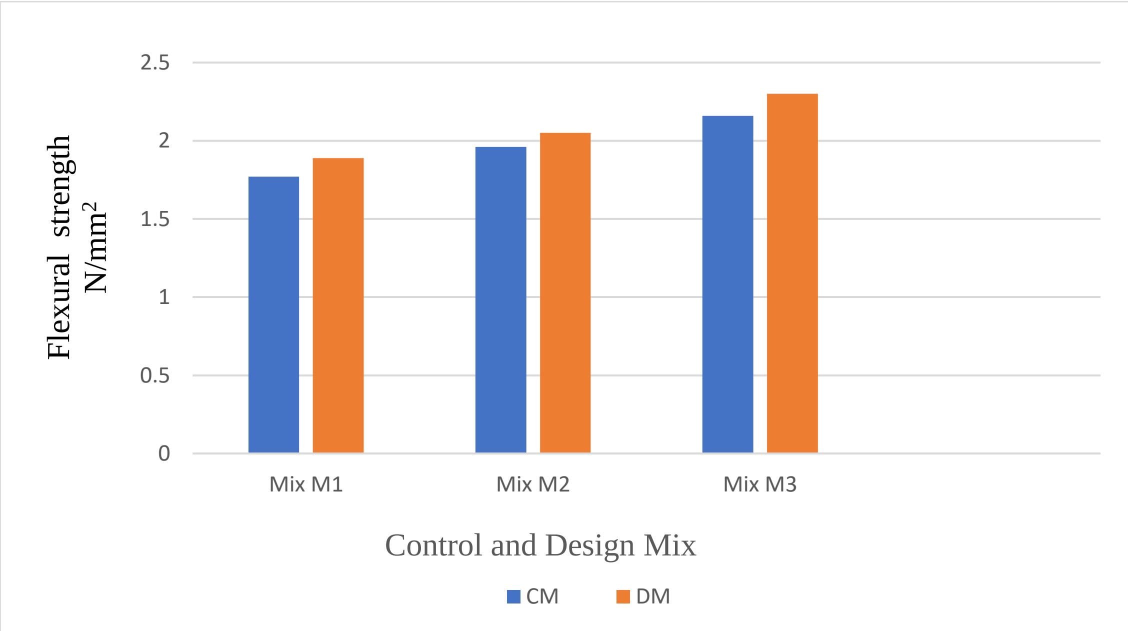

Figure 9 Comparison of Flexural Strength of Beam

5.6 Result of Split tensile strength of Cylinders

Table 10 Result of Flexural strength test of cylinders

Mix	7-days	28-days
CM1	0.68	1.12

DMI	0.88	1.28
CM2	1.11	1.72
DM2	1.44	2.04
CM3	1.3	2.03
DM3	1.60	2.36

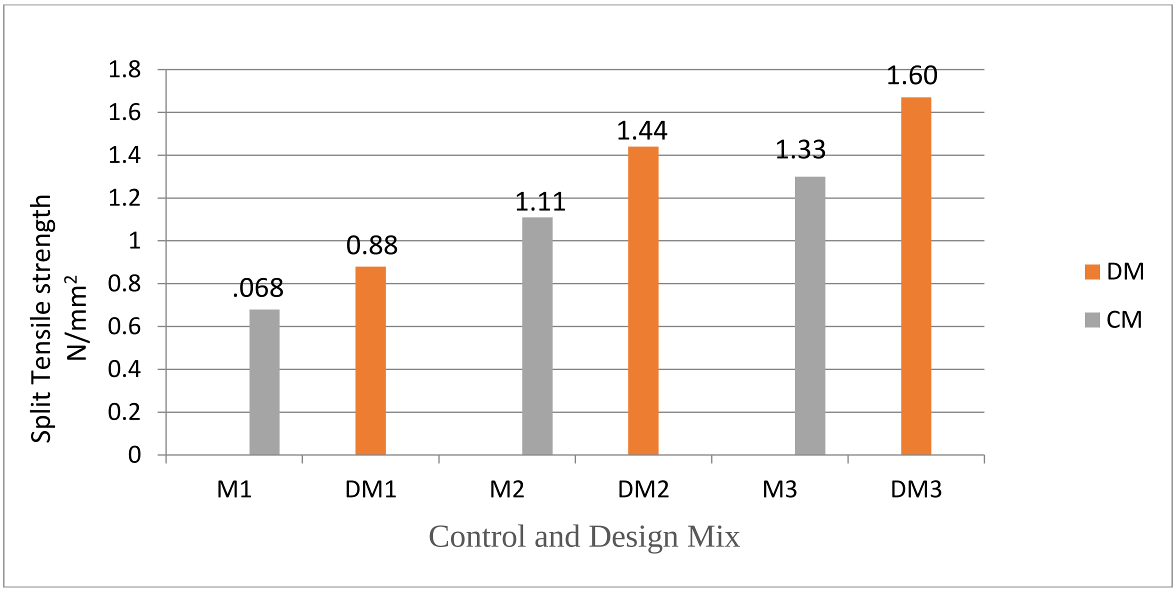

Figure 10 Comparison of Split Tensile Strength of Cylinder After 7days

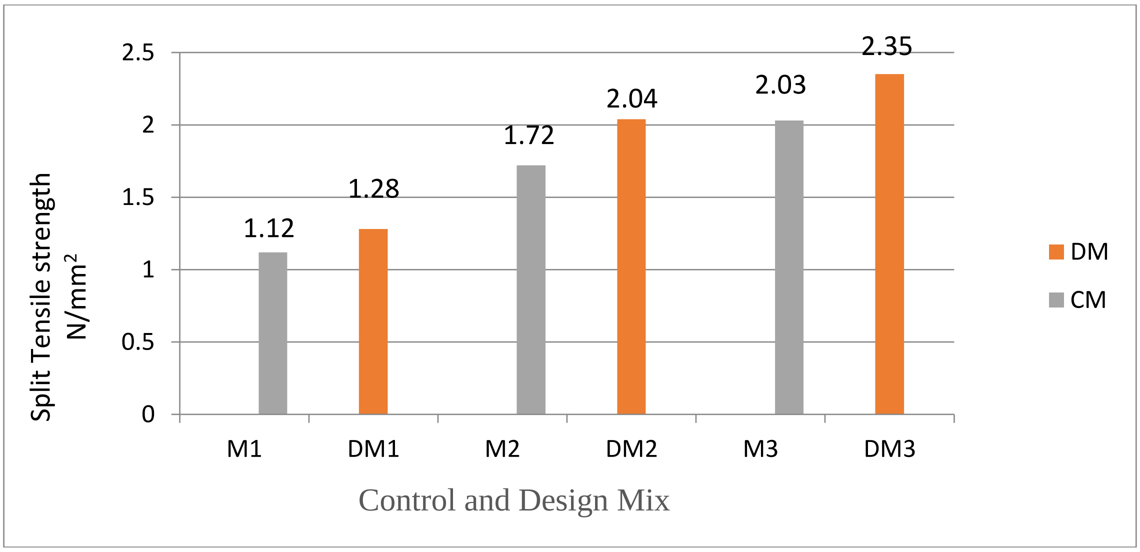

Figure 11 Comparison of Split Tensile Strength of Cylinder After 7days

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5.7 Result of Cyclic Loading on Cylinder Specimen

5.7.1 Behavior under Monotonic Loading

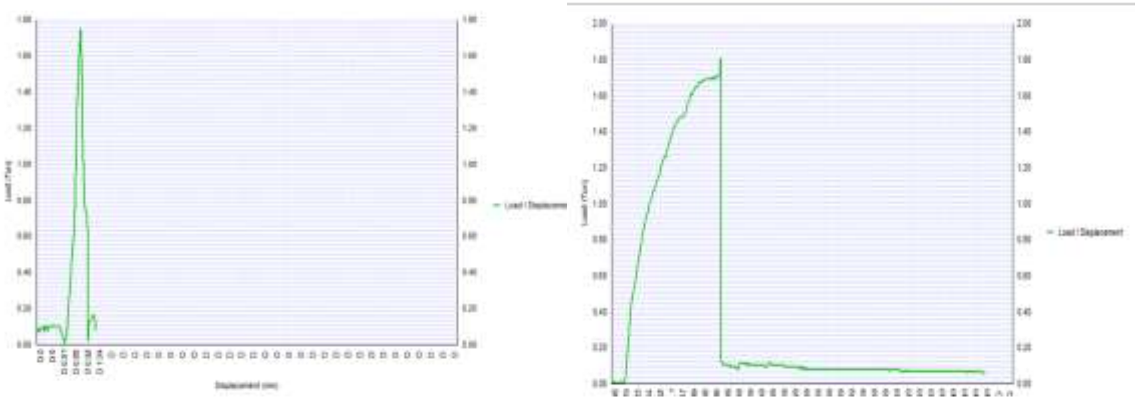

Figure11 Behavior of Mix M1 grade under Monotonic loading

Figure 11 shows the comparison of monotonic load on Control mix M2 and Design mix DM2. M2 achieve a load of 2.20 ton while the DM2 fails at a load of 2.75 ton under the monotonic loading.

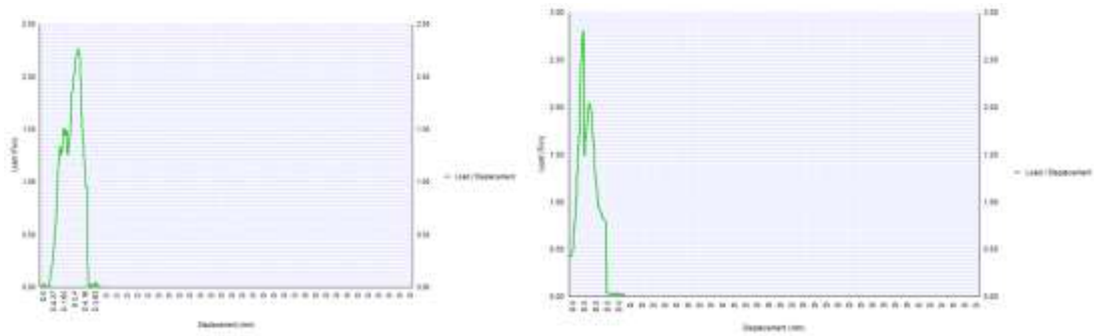

Figure 12 Behavior of Mix M2 grade under Monotonic loading

Figure 12 shows the comparison of monotonic load on Control mix M2 and Design mix DM2. M2 achieve a load of 2.20 ton while the DM2 fails at a load of 2.75 ton under the monotonic loading.

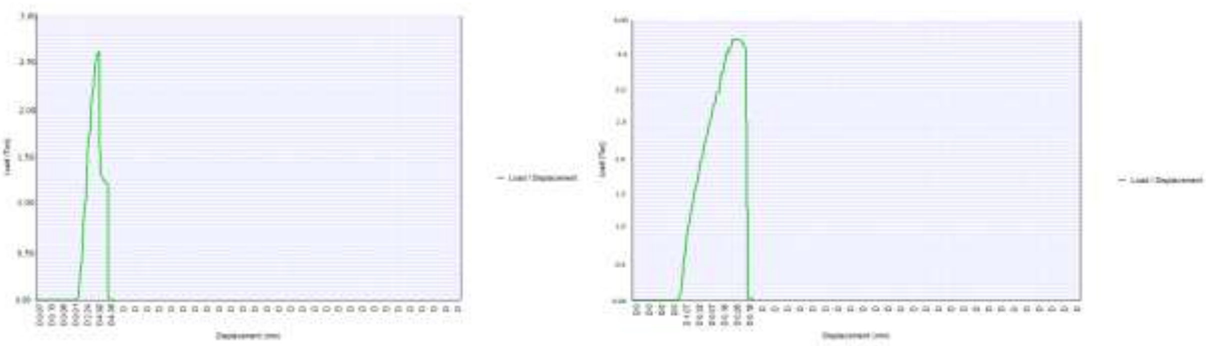

Figure 13 Behavior of Mix M3 grade under Monotonic loading

Figure 13 shows the comparison of monotonic load on Control mix M3 and Design mix DM3. M3 achieve a load of 2.60 tons while the DM3 fails at a load of 3.7 ton under the monotonic loading.

5.7.2 Behavior under Cyclic Loading

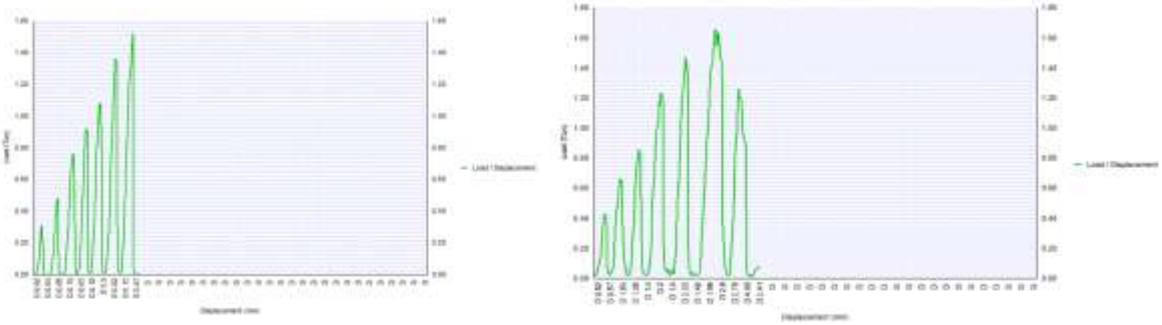

Figure 14 Behavior of Mix M1 grade under Cyclic loading

Above fig. shows the comparison of cyclic load on Control mix M1 and Design mix DM1. M1 achieve the load of 1.5 ton while the DM1 fails at the load of 1.67 ton under the cyclic loading.

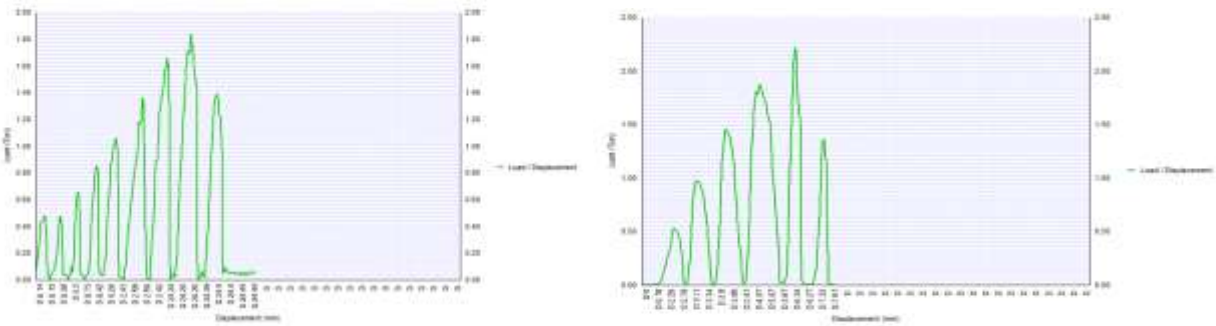

Figure 15 Behavior of Mix M2 grade under Cyclic loading

Above fig. shows the comparison of cyclic load on Control mix M2 and Design mix DM2. M2 achieve the load of 1.9 ton while the DM2 fails at the load of 2.25 ton under the cyclic loading.

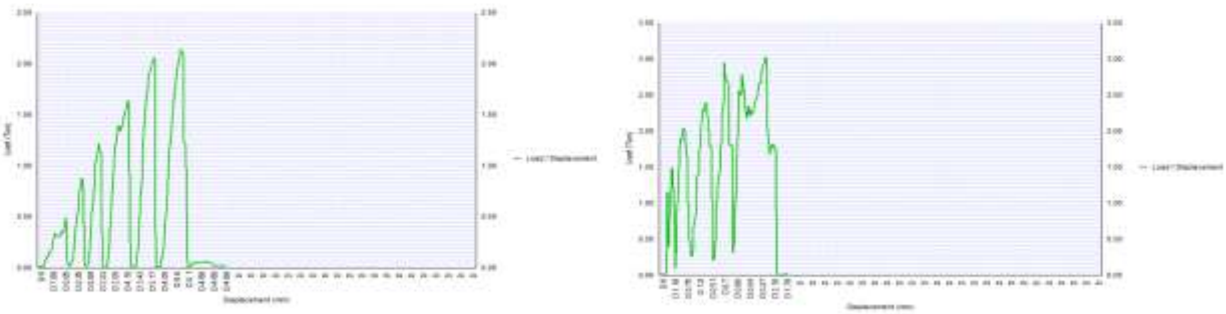

Figure 16 Behavior of Mix DM3 grade under Cyclic loading

Above shows the comparison of cyclic load on Control mix M3 and Design mix DM3. M3 achieve the load of 2.2 ton while the DM3 fails at the load of 3 ton under the cyclic loading.

5.8 Behavior of beam under Cyclic loading

A total of 8 beams of size 200mm x 230mm x 1700mm were casted in 2 groups. One group contains 4 beams of Mix DM2 & the other group also contains 4 beams of mix DM3. These beams were tested under cyclic loading. Results obtained from the test are shown below.

5.8.1 Behavior of DM2 beam

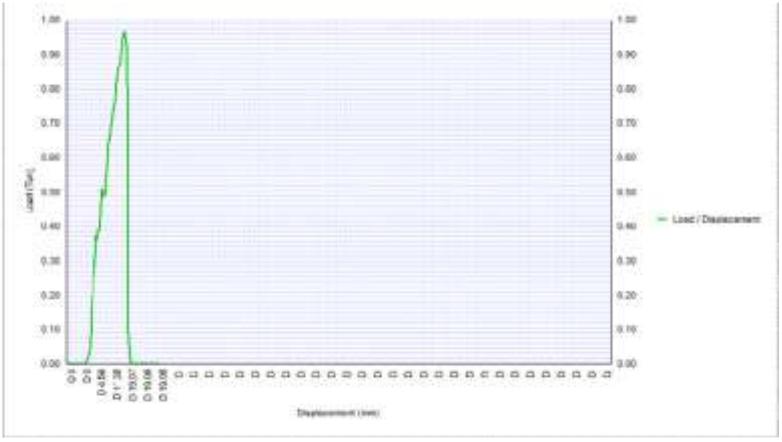

Figure 17 Behavior of DM2 Beam under Monotonic Loading

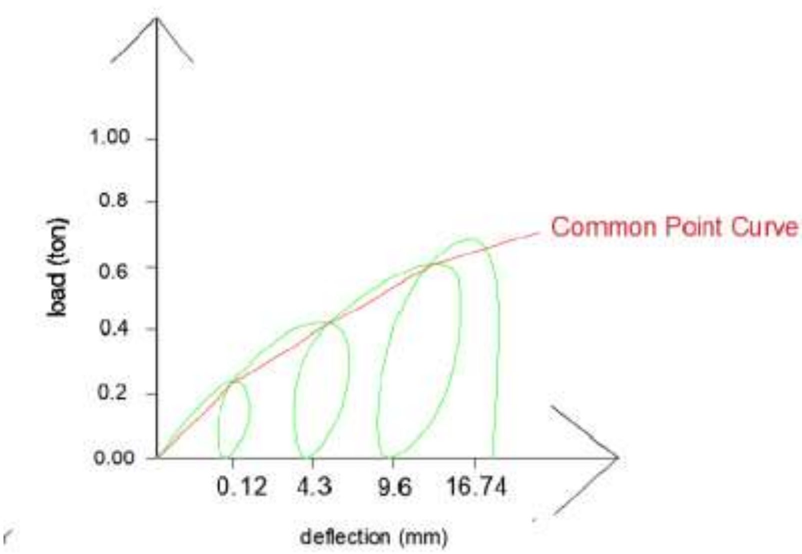

Figure 18 Behavior of DM2 Beam under Cyclic Loading

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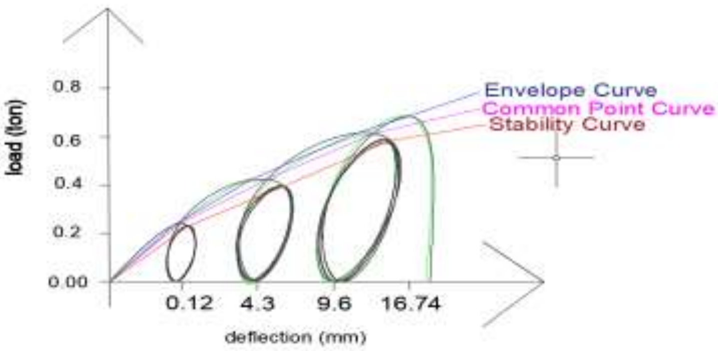

Figure 19 Behavior of DM2 Beam under Stability Loading

Above figure shows the behavior of beam monotonic, cyclic and stability loading condition. The beam get the maximum strength of 1 ton under monotonic loading, 0.75 ton under cyclic loading, and 0.65 ton under stability loading.

5.8.2 Behavior of DM3 Beam

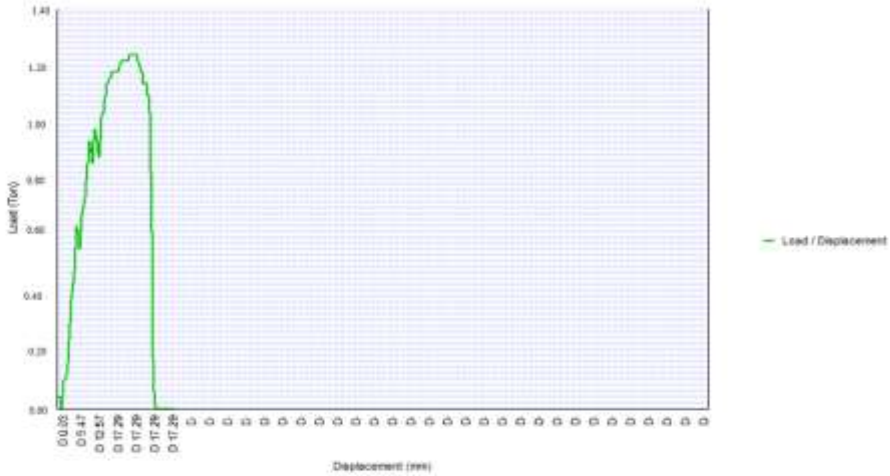

Figure 20 Behavior of DM3 Beam under Monotonic Loading

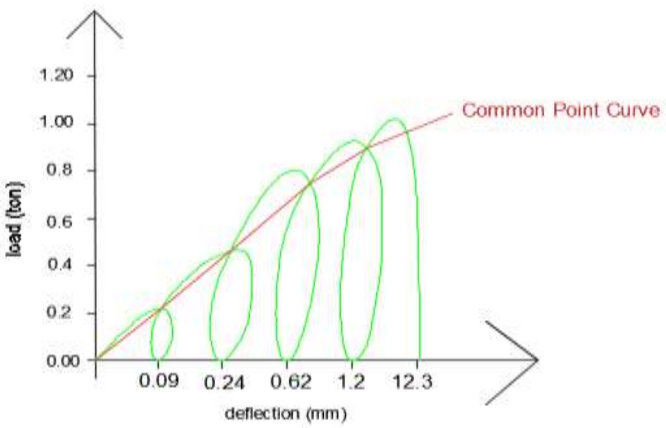

Figure 20 Behavior of DM3 Beam under Cyclic Loading

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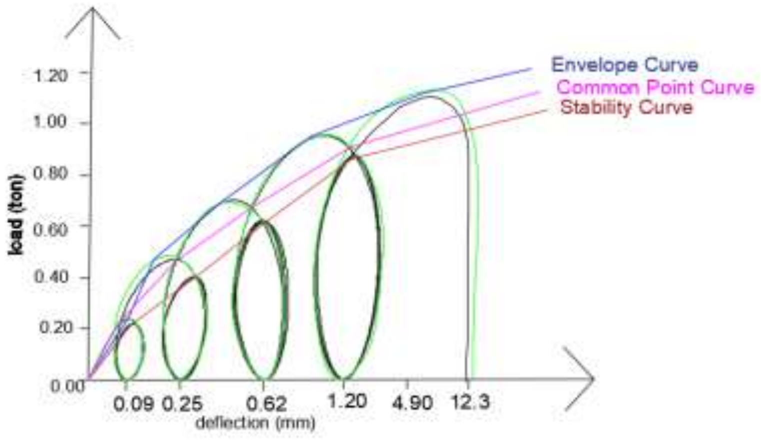

Figure 21 Behavior of DM3 Beam under Stability Loading

Above figure shows the behavior of DM3 beam monotonic, cyclic and stability loading condition. The beam get the maximum strength of 1.25 ton under monotonic loading, 1.05 ton under cyclic loading, and 1 ton under stability loading condition.

6. Study of Failure Pattern

Figure 22 Failure pattern of pervious concrete cube under CTM

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Figure 23 Failure pattern of pervious concrete Cylinder under cyclic loading

Figure 24 Failure Pattern under Split Tensile Strength test

Figure 25 Failure Pattern of Beam under Flexural Strength test

Figure 25 Failure Pattern of Beam under Cyclic Loading test

7. Conclusion

Based on the result of this study following conclusion may be drawn:

- The replacement of natural aggregate with demolished aggregate in pervious concrete has shown increase in strength.
- With 40% replace of NA with DA the strength is increased up to 30% after 28 days of curing.
- The 1% replacement of cement with glass fiber increases the strength up to 6% at 7 days and up to 4% at 28 days.
- We found that with the grading of coarse aggregate, the strength of pervious concrete increases.
- For the aggregate-binder ratio of 5 (Mix M1) the compressive strength is increased up to 30% for 7 days and 20% for 28 days of curing.
- For the aggregate-binder ratio of 4.1 (Mix M2) the compressive strength is increased up to 14% for 7 days and 12% for 28 days of curing.
- For the aggregate-binder ratio of 3.88 (Mix M3) the compressive strength is increased up to 5% for 7 days and 4% for 28 days of curing.
- We get the maximum compressive strength up to 33.33 MPa at aggregate-binder ratio of 3.8.
- Void ratio and porosity increases as the aggregate binder ratio increases.

- Void ratio and porosity is decreased for the DM up to 10% when compare with the CM.
- The flexural strength is increases up to 5% for the DM when compare with the CM.
- The split tensile strength is up to 25% at 7 days and up to 15% at 28 days of curing for the DM.
- For the monotonic and cyclic loading DM shows increase in strength up to 5%, 20%, 25% for the mix M1, M2, and M3 respectively.
- Under cyclic loading the specimen of different mix fails in the range of 75-90% of monotonic loading.

Scope for further studies

- The conclusions of this study are drawn from the test results using limited specimens. Therefore, additional experimental and analytical studies are necessary to generalize these conclusions under various design conditions.
- Study the behavior of pervious concrete using different types of fiber and check its property.
- Check the behavior of pervious concrete using different supplementary cementious material.
- Check the behavior of pervious concrete by adding some % of fine aggregate.

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