AN EXPERIMENTAL INVESTIAGTION ON CHARACTERISTIC PROPERTIES OF PERVIOUS CONCRETE

Submitted in partial fulfillment of the requirements
For the degree of

Bachelor of Engineering

By

AYUB L. MUJAWAR	(12CE43)
MOHD. SIDDIQUE A. SHAIKH	(12CE57)
MOHD. IQBAL G. SIDDIQUI	(12CE59)
NITESHKUMAR D. SINGH	(12CE61)

Under the guidance of

Prof. Dada Patil

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

Plot No. 2/3, Sector – 16, Near Thana Naka, Khanda Gaon,
New Panvel, Navi Mumbai – 41026.

2017-2018

CERTIFICATE

This is to certify that the Project Report entitled "**An Experimental Investigation on Characteristic Properties of Pervious Concrete**" is a bonafide work of **Mr. Shaikh Siddique, Mr. Mujawar Ayub, Mr. Singh Niteshkumar** and **Mr. Siddiqui Iqbal** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

Prof. DADA PATIL

(Supervisor)

Dr. R. B. Magar

(Head of the Department)

Dr. Abdul Razak Honnutagi

(Director, AIKTC)

APPROVAL SHEET

This B. E. Project entitled "**An Experimental Investigation on Characteristic Properties of Pervious Concrete**" by **Mr. Shaikh Siddique, Mr. Mujawar Ayub, Mr. Singh Niteshkumar** and **Mr. Siddiqui Iqbal** is approved for the degree of **"Bachelor of Engineering"** in **"Civil Engineering".**

Examiner

____

Supervisor

____

Date:

Place: Panvel

DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

AYUB L. MUJAWAR	(12CE43)
MOHD. SIDDIQUE A. SHAIKH	(12CE57)
MOHD. IQBAL G. SIDDIQUI	(12CE59)
NITESHKUMAR D. SINGH	(12CE61)

Date:

ABSTRACT

Pervious concrete is a relatively new concept. This concrete can be used for the rural road pavement, with relatively less traffic. As the concrete allows the water to pass through it, this would greatly help in recharging the ground water level. This has multifaceted benefits, including that for agriculture.

Pervious concrete can be introduced in rural areas as a road pavement material. Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater level and minimize storm water runoff. In rural areas, cost consideration is the primary factor which must be kept in mind. In rural areas, storm water management practice is costly. Pervious concrete pavement is unique and effective means to meet growing environmental demands.

In cities also, the pervious concrete pavements can be used for parking areas, garden, etc. It can be advantageously used as a replacement for the paver blocks. By capturing rainwater and allowing it to seep into the ground, this pavement technology creates more efficient land use by eliminating the need for retention ponds, well and other costly storm water management devices. However, the need for pervious concrete is of low grade, as there will not be heavy loads in parking area, garden, etc.

In this project work, an attempt has been made to develop a low grade pervious concrete in the laboratory. The conventional concrete making materials are used for the same. However, the fine aggregates (sand) are not used. Only 10 mm coarse aggregates & 20 mm coarse aggregates are used. The proportion of concrete is 1 cement: 4 aggregates. Due to absence of fine aggregates, the concrete becomes porous in nature. This, in turn, allows the water to pass through it. The strength tests, workability tests & permeability tests are done on concrete to assess its properties & its suitability for the intended purpose.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pervious concrete is a composite material consisting of Portland cement, coarse aggregate, water and limited quantity of fine aggregate. The aggregate usually consists of single size particles and is bonded together at its points of contact by a paste formed by the cement and water. The result is a concrete with a high percentage of interconnected voids that, when functioning correctly, permit the rapid percolation of water through the concrete. Pervious concrete is a special concrete which permits water to percolate through the pavement surface and allows storm water to be eventually absorbed back to soil or evaporate. This overcomes the process of storm water flooding and erosion. They are the best form of storm water management system.

In the recent past due to climatic imbalance, land is drying up causing a serious problem. Not besides the climate change, about 35% to 75% or even more of our construction sites are being covered by paved surfaces and roofs as urban sprawl continues to dominate the landscape. The impervious surfaces block natural water infiltration into soil depleting the ground water source and lowering ground water table. However paved roads, driveways, and parking lots are essential for development. Rather than building city streets with conventional concrete or asphalt, more and more communities, municipalities, and business establishments are switching to pervious concrete or porous pavement, a material that offers the inherent durability and low life cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local watershed systems. Pervious concrete is the panacea for all these problems.

Fig 1: Pervious concrete

Although pervious concrete is widely used throughout the world, there is nowhere accepted mix design similar to normal weight aggregate concrete (ACI 211.1) of ACI and DOE method of UK. Guidelines have been prepared and published by Portland cement Association (PCA) limited of US, Natural Ready Mix Concrete Association (NRMCA) of Canada. The guidelines are too general and there is no specific methodology recommended for design. The study is conducted to give a rational mix design for pervious concrete. The high porosity, unlike conventional concrete, which has a void anywhere from 3-8%, it has a water cement ratio ranging from 0.2 to 0.4, cement content from 275 kg/m^3 to 550kg/m^3, sand content 0% to 35%, and aggregate size from 4.75 mm to 30 mm.

The control factors of pervious concrete are very widely variable and it is this variability which is additionally compounded by the variations, the materials types and characteristics. Besides, the wide range of application from base course, surface course, footpaths, parking lots and driveways have made the evolution of design methodology difficult. Experimentation is absolutely necessary for the purpose. Since experimentation is very costly it is essential to minimize the no of experiments.

To achieve optimum quantity of mix proportions, depending upon control parameters a suitable optimization technique should be adopted.

1.2 Historical development (background)

1. As long as a century ago, designers in Europe recognized the value of porous concrete as structural insulation for buildings.

2. However about 80 years ago in Europe, pervious concrete made its advent in roads as well. It’s only in the last 20 years that porous concrete has gained a foothold for general construction purpose in the United States and worldwide.

3. In the construction industry, concrete technology is heading towards entirely new era by way of using polymers and fibers along with super plasticizer in concrete to achieve high performance levels.

4. Increasing interest is being shown in the area of new materials in the past decade. This is quite understandable because, it is slowly, but increasingly being recognized that economic progress in construction depends more on an intelligent use of the local materials and constant improvement of available materials than on extreme refinements for the purpose of optimizing structural design analysis.

5. While pervious concrete pavement has gained recently much attention, due to increasingly stringent storm water management guidelines that now positions the product as a sustainable building material.

6. Pervious concrete provides the potential for environmentally responsible site use and lowered construction costs in projects ranging from simple sidewalks, to major pedestrian plazas and full-blown multi-acre parking lots for national importance.

7. Pervious concrete pavement can be used as both a parking facility and the storm water treatment system itself. Pervious concrete eliminates the runoff on the parking lot surfaces or other paved areas where it might be applied (sidewalk, plazas) and, via its filtering action, significantly improves the quality of the water passing through.

Advantages

1. Reduces total amount of impervious cover.

2. Reduces peak velocity and volume of storm water runoff delivered to storm sewer system

3. Alleviates flooding and erosion downstream

4. Applicable to all types of sites (residential/commercial/industrial)

5. Recharges groundwater supply

6. Noise reduction

7. Skid resistance

Limitations

1. Low flexural strength due to high porosity.

2. Loading areas with heavy trucks is still not advised.

3. Once paste is hardened, durability of aggregate influences final strength

1.3 Applications of pervious concrete pavements

Pervious concrete is traditionally used in parking areas, areas with light traffic, pedestrian walkways, and greenhouses. It is an important application for sustainable construction. Pervious pavement roadways have been seen wider application in Europe and Japan than in the U.S. properly installed and maintained pervious pavement has a significant life span, and existing systems that are more than twenty years in age continue to function, because water drains through the surface course and into the sub surface bed. Following are the uses of pervious concrete.

1. Low volume pavements
2. Residential roads, alleys, and driveways
3. Low water crossings
4. Sidewalks and pathways
5. Patios
6. Tennis courts
7. Swimming pool decks
8. Pavement edge drains
9. Foundations /floors for greenhouses
10. Fish hatcheries,
11. Aquatic amusement centers
12. Zoos
13. Sub base conventional concrete pavement
14. Slope stabilization
15. Artificial reefs
16. Well linings
17. Hydraulic structures
18. Trees grates in sidewalks
19. Groins and seawalls

Fig 2: Pervious concrete walkways

Pervious concrete pavement has also been used in walkways and sidewalks. These installations typically consist of a shallow (8 in. minimum) aggregate trench that is sloped to follow the surface slope of the path. In The case of relatively mild surface slopes, the aggregate infiltration trench may be "terraced" into level reaches in order to maximize infiltration capacity at the expense of additional aggregate.

Fig 3: Pervious paver blocks

Pervious paver blocks consist of interlocking units (often concrete) that provides some portion of surface area that may be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking area, etc. A number of manufactured products are available, use porous asphalt in parking stalls, and minimize use in parking stalls, and minimize use in high traffic areas.

Fig 4: Play grounds

Using pervious concrete pavement in your parking lot can reduce the need for large detention ponds because the pavement acts as a detention area. Parking lot owners will spend fewer dollars on labor, construction and maintenance of detention ponds, skimmers, pumps, drainage pipes, and other storm water management systems.

Fig 5: Parking lots

Expensive irrigation systems can also be downsized or eliminated a pervious concrete parking lot will help reduce demands upon sewer systems.

An alley or alleyway is a narrow lane found in urban areas, often for pedestrians only, which usually run between or behind buildings. In older cities and towns in Europe, alleys are often what are left of a medieval street network, or a right of way or ancient footpath.

Fig 6: Alleys

1.4 Importance of the topic and need for the study:

1. Pervious concrete has gained wide popularity in the western world and in Japan and other countries.
2. There is no standard mix even though the new edition of ACI 522.11 not gives the mix design and there is no proportioning involved.
3. The mix designs reported in the literature are very specific to the mix but very few have done to Indian material and Indian conditions.
4. However, there is no specified code from ACI and no mix design procedure as in case of conventional concrete e.g. ACI 211.1
5. Guidelines for production and laying also not available.
6. Because of the large no. of parameters and their variability on each size, different approach is needed to account for variability in parameters and performance.
7. Design of experiments provides a convenient means of handling the variability in control factors and in studying the effect on performance parameters.
8. The rain water comes over in 4-5 months to be stored for summer season to fulfill water demand it's one of the best ways is to provide pervious concrete.
9. Now a day's large variety of materials been used for producing conventional concrete. due to shortage of materials aggregate and sand and also growing demand for reducing Portland cement convention and utility of alternate binders.
10. The conventional mix design cannot be directly implied for mix proportioning and design based on experiments seems to be the only recourse.

1.5 Objectives of the study:

1. To prepare pervious concrete suitable for pavement applications by using different W/C ratios, 20 mm coarse aggregate & 10 mm coarse aggregates.
2. To assess the porosity of concrete by passing the water.
3. To obtain the compressive strength & compressive strength of the concrete.

1.6 Scope of the study:

1. Selection of materials cement, fine aggregate and coarse aggregates and their characterization.
2. Identification of mix, control factors, performance parameters and levels of each factors in the mixes.
3. Preliminary mix proportioning of concrete.

CHAPTER 2

LITERATURE REVIEW

2.1. Mix proportions of pervious concrete

Nader Ghafoori, Shivaji Dutta (1) two design procedures, American Association of State Highway and Transportation Officials (AASHTO) and Portland Cement Association (PCA), were used for the thickness evaluation of no-fines concrete parking lots. Test results obtained in the laboratory indicate that, with proper proportioning and densification, no-fines concrete can be successfully utilized as a surface paving material for the construction of parking-lot pavements. The thickness design tables indicate that PCA design procedure is more reasonable for thinner pavements, whereas AASHTO yields a more conservative outcome for thicker pavements. For intermediate traffic categories, both design methods provided similar thickness results.

Jing Yang, Guoliang Jiang (2) Using smaller sized aggregate, silica fume (SF), and super plasticizer (SP) in the previous concrete can enhance the strength of pervious concrete greatly. The pervious pavement materials that composed of a surface layer and a base layer were made.

The compressive strength of the composite can reach 50 MPa and the flexural strength 6 MPa.The water penetration, abrasion resistance, and freezing and thawing durability of the materials are also very good. It can be applied to both the footpath and the vehicle road. It is an environment-friendly pavement material.

C. Lian a, Y. Zhuge (3) Permeable pavement, due to its high porosity and permeability, is considered as an alternative to traditional impervious hard pavements for controlling storm water in an economical and friendly environmental way. Permeable concrete normally made of single-sized aggregate bound together by Portland cement, using restrictedly as a pavement material, because of its insufficient structural strength. Aimed at developing a new type of permeable concrete with enhanced structural strength, various mix designs were attempted and their effects on the compressive strength and permeability of permeable concrete were investigated in this research. The optimum aggregate and mix components design were consequently recommended for enhanced permeable concrete.

Ryan J. Rohne, et al (4) this paper discusses the construction and early performance of a pervious concrete test cell at the MnROAD facility. For mix design aggregate being the major component varied between them. Fly ash content, cement content, and water content varied slightly for each mix design, but the water/cementitious ratio and volume of admixtures remained the same between the three mix designs. Distress observations indicate that poor finishing techniques resulted in raveling and spalling of the pervious driveways surface. The most sever observations of spall/ravel were located in areas that may have been affected by over finishing during placement, the majority of which have occurred in the months after placing the pervious concrete. After further examination, the distress was found to be topical and has not visibly worsened after three years.

Baoshan Huang, et al (5) conducted a laboratory experiment to investigate the permeability and strength characteristics of polymer modified pervious concrete. The basic mix proportion for the control mix is cement: coarse aggregate: water=1:4.5:0.35 by weight. When latex or no fine aggregate were included in the mixture, the solid portion of latex was used to replace 10% cement and natural sand to replace 7 % coarse aggregate by weight. Fiber did not have a significant effect on the strength properties of pervious concrete in this study. This was due to the fact that fiber was not fully dispersed and evenly distributed in the pervious. The preliminary laboratory study on the effect of polymer modification on the performance of pervious concrete with the emphasis on the permeability and strength properties.

Ming-Gin Lee, et al (6) the main purpose of this study is to find the suitable pervious concrete mix for pavement. The laboratory tests included void ratio, unit weight, coefficient of permeability, and compressive strength. The materials including cement crushed gravel, SP and water were used to make the pervious concrete mixture. Pervious concrete mixture has zero inch slump and water to cement ratio. The in place permeability testing method developed for asphalt pavements has been found to work and perform well to pervious concrete pavement. The compression strength of two pervious concrete core specimens exceeds the ordinary concrete structure specification.

Kevern J, Wang K, et al (7) the porosity in PCPC is created by the reduction or elimination of fine aggregate from the concrete mix design. Standard pervious concrete in the U.S is a mixture of a single sized coarse aggregate and cement combined at low water to cement ratios. Results show that PCPC samples with void ratios ranging from 15% to 20%. The conclusions are many methods exits to place and finish PCPC, but little is known about the effect of construction method on long term durability and compaction energy as related to PCPC properties through density can aid in achieving pavements which balance strength and required permeability.

Vernon R. Schaefer, et al (8) carried out investigation mainly to evaluate pervious concrete mix design for wearing courser application. This paper describes the results of research efforts to date, including development of a method to characterize workability, determination of the need for air entertainment and the effect of air entrainment on durability, design mixture proportions for mechanized placement, evaluation of the curing requirements for surface abrasion resistance, and overlay design procedures and development. The results of these studies that effective PCPC Overlays can be designed for wearing course applications.

Wang, K, et al (9) the main aim was for development of mix proportion for functional and durable pervious concrete. Portland cement pervious concrete (PCPC) mixes made with various types and amounts of aggregate, cementitious materials, fibers, and chemical admixtures were evaluated. Porosity, water permeability, strength, and freezing-thawing durability of the concrete were tested the results indicated that the PCPC made with single sized coarse aggregate generally had high permeability but not adequate strength. Addition of a small amount of fine aggregate (approximate 7% by weight of total aggregate) to the mixes significantly improved the concrete strength and freezing-thawing resistance while maintaining adequate water permeability. Addition of a small amount of fiber to the mixes increased the concrete strength, freezing-thawing resistance as well as void content.

L. K. Crouch, et al (10) Tennessee concrete Association sponsored study used a twofold approach to obtain information on pervious PCC split tensile strength, flexural strength, and static modulus of elasticity. In the first approach, existing correlations for traditional PCC were applied to pervious PCC field and laboratory data. Secondly, the impact of effective void content on the previously mentioned properties was determined. The conclusion can be drawn from the above experiment the split tensile strength, flexural strength, and modulus of elasticity of pervious PCC all decrease with an increasingly effective void content.

CHAPTER 3

MATERIALS & METHODOLOGY

3.1 Selection of materials

Fig 7: Cement sample

In the present experimental work, cement of 53 grade was used and the cement sample was tested as per IS-4031-1968 to obtain the following properties.

Table 3.1: Physical properties of cement

Physical Properties	**Specifications according to IS:12269-1987**
Fineness (%)	Not more than 10% as per IS 4013 part 1
Standard Consistency (%)	Not more than 30% as per IS 4031 part 4
Initial setting time in min	Not less than 30 minutes as per IS 4031 part 5
Final setting time in min	Not more than 600 minutes

Table 3.2: Physical properties of 10 mm aggregates

Properties	**Values**
Specific gravity	2.65
Fineness modulus	2.91
Bulk density (Kg/m^3)	1570
Water absorption (%)	1.2

Fig 8: Aggregate sample

3.1.1 Shape test

For the experimental work, locally available crushed stone aggregates from Apcon crushers of size 20 mm down and 10 mm down were used and the various tests carried on the aggregates as per IS 2386-1968 part III are given below.

Table 3.3: Properties of 20 mm aggregates

Properties	Values
Specific gravity	2.7
Bulk density (Kg/m^3)	1640
Water absorption (%)	0.4

Table 3.4: Gradation of coarse aggregates

Sieve size	% passing 20 mm and Down	% passing 10mm and Down	lower limit	upper limit	middle limit
20	90.58	100	95	100	97.5
10	2.61	88.176	25	55	40
4.75	0	3.81	0	10	5

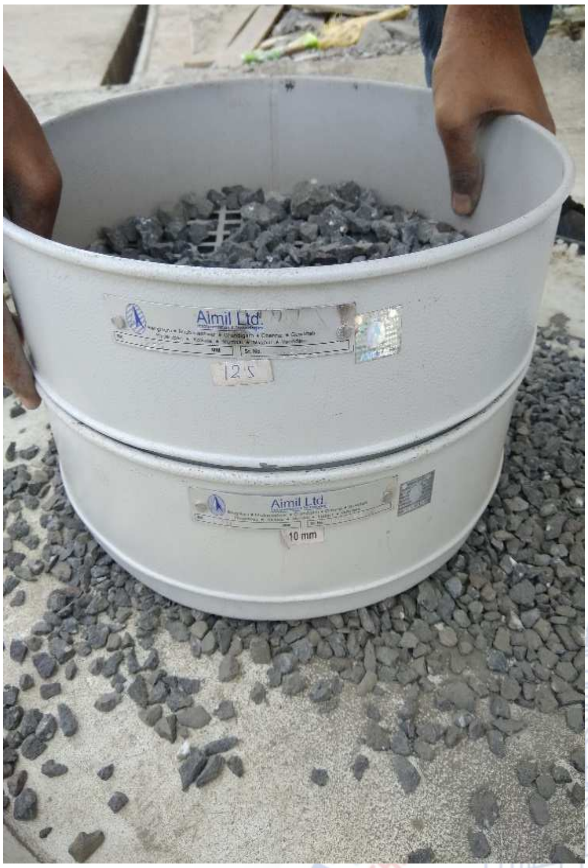


Fig 9(a): Sieve analysis (10 mm)

Fig 9(b): Sieve analysis (20 mm)

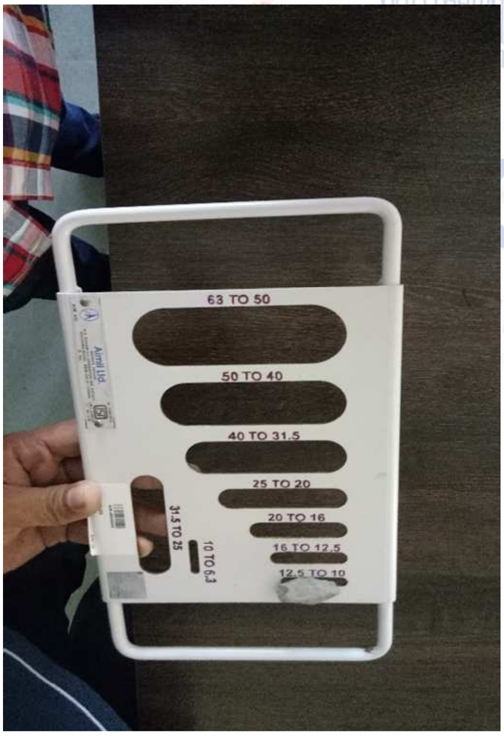


Fig 9(c): Flakiness index (10 mm)

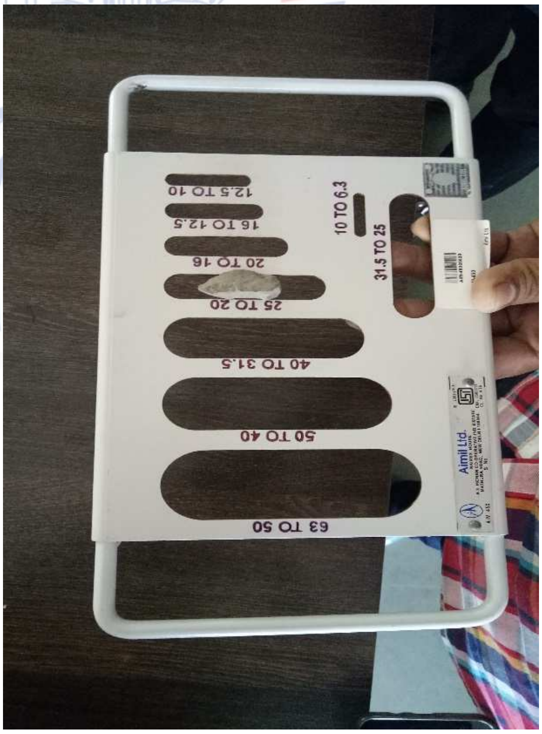


Fig 9(d): Flakiness index (20 mm)

Fig 9(e): Elongation index (10 mm)

Fig 9(f): Elongation index (20 mm)

Fig 9(g): 10 mm & 20 mm Coarse aggregates

3.2 Preparation of Test Specimens

3.2.1 Casting of cubes

Cube specimens of size (150 mm ×150 mm) were cast using steel cube moulds after oiling the inner surface and were placed on vibrating table. 12 cubes were prepared for each mix. Concrete was poured in to the moulds in three layers and compacted using table vibrator. The top surface was finished using trowel. The Compacted specimen were kept in the laboratory and allowed to cure within the moulds for 24 hours. After 24 hours concrete cubes were demoulded and the specimens were kept for curing under water.

3.2.2 Curing of cubes

On completion of 24 hours after casting, all the specimens were cured for 7 and 28 days as per standard procedure. After 24 hrs., concrete specimens were removed from the moulds and kept for curing in water for the required days of curing.

3.2.3 Determination of Workability

Workability of pervious concrete is a complex property. Numerous attempts have been made by many research workers to quantitatively measure the workability but none of the methods are satisfactory for precisely measuring or expressing this property to bring out of its meaning. Some of the tests, measure the parameters very close to workability provide full information.

Slump test is commonly employed to measure workability.

Slump test:

1) Internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test.

2) The mould is placed on a smooth, horizontal, rigid and non-absorbent surface.

3) The mould is then filled in 4 layers, each approximately one fourth of the height of the mould.

4) Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.

5) After the top layer has been roded, the concrete is struck off level with trowel and tamping rod.

6) The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured.

Fig 10(a): Slump cone test **Fig 10(b): Slump cone test**

3.3 Testing of specimens

The specimens were tested for compressive strength, flexural strength, permeability & water absorption. The strength tests were done for 7 & 28 days.

3.3.1 Compressive Strength Test (IS: 516 – 1959)

This test is carried to determine the compressive strength of concrete at 7 and 28 days. At each desired curing period's specimens were taken out of water and kept for surface drying. After surface drying, the cubes were turned by 90 degrees from casting position to have smooth surface contact on the cleaned bearing surface of the testing machine. The axis of the specimen was carefully aligned with the center of the thrust of spherically seated plate. The load was applied without shock and increased continuously until the resistance of specimen to the increasing loads decreases and no greater load could be sustained.

Fig 11 (a): Compression test

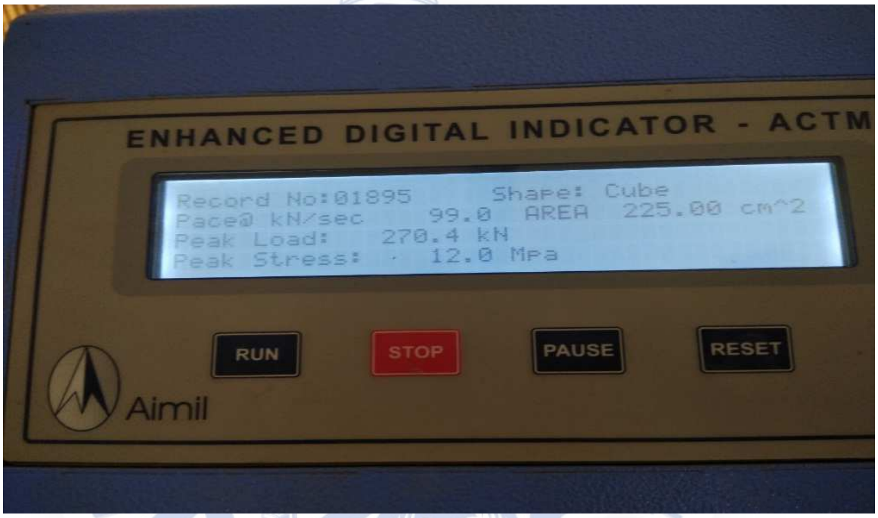


Fig 11 (b): Compression test readings

3.3.2 Coefficient of permeability

Permeability test is done after 28 days of curing of the specimen. The rate of discharge of water under laminar-flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions is defined as Coefficient of permeability.

Fig 12 (a): Permeabilty test on 20 mm agg. concrete block

Fig 12 (b): Permeabilty test on 10 mm agg. concrete block

3.3.3 Flexural strength Test (IS: 10086-1982)

3.3.3.1 Casting of beam specimens for flexural strength test

Beam specimens of size (150 mm×150 mm×750 mm) were cast using steel beam moulds after oiling the inner surface and were placed on vibrating table. 3 beams were prepared for each mix. Concrete was poured in to the moulds in three layers and compacted using table vibrator. The top surface was finished using trowel. The Compacted specimens were kept in the laboratory and allowed to cure within the moulds for 24 hours. After 24 hours, beams were demoulded and the specimens were kept for curing under water.

3.3.3.2 Testing of beams for flexural strength of concrete:

Flexural strength of beam size (150 mm×150 mm×750 mm) was determined using modulus of rupture of the beam tested at 28 days according to (IS: 10086-1982). The flexural strength was measured with the centre-point Method.

Fig 13: Flexure test

3.3.4 Water Absorption Test

3.3.4.1 Casting of cube specimens for water absorption test

Cube specimens of size (150 mm×150 mm) were cast using steel cube moulds after oiling the inner surface and were placed on vibrating table. Concrete was poured in to the moulds in three layers and compacted using table vibrator. The top surface was finished using trowel. The Compacted specimen were kept in the laboratory and allowed to cure within the moulds for 24 hours. After 24 hours concrete cubes were de-moulded and the specimens were kept for curing for 28 days under water.

3.3.4.2 Testing of cube specimens for water absorption of concrete:

Three full size blocks were completely immersed in clean water at room temperature for 24 hours. The blocks were then removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth, the saturated and surface dry blocks immediately weighed. After weighing all blocks shall be dried in a ventilated oven at 105 C for not less than 24 hours and until two successive weighing at intervals of 2 hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen.

The water absorption calculates as given below:

Water Absorption, percent = (A-B)/B * 100

Where, A = wet mass of unit in kg.

B = dry mass of unit in kg.

3.4 List of Figures

Fig 14: Concrete mixing

Fig 15 (a): Filling

Fig 15 (b): Tamping

Fig 16 (a): Moulding for 24 hrs.

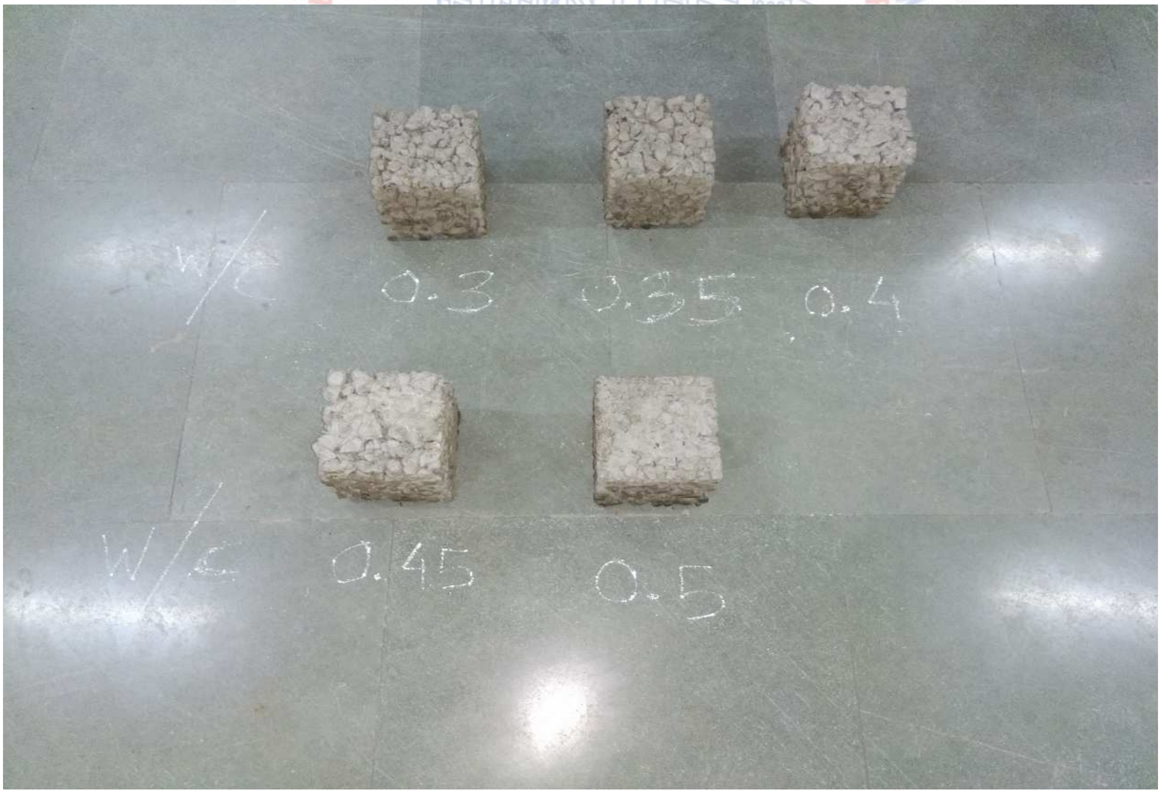


Fig 16 (b): Demoulding after 24 hrs.

Fig 17: Concrete block after compression test

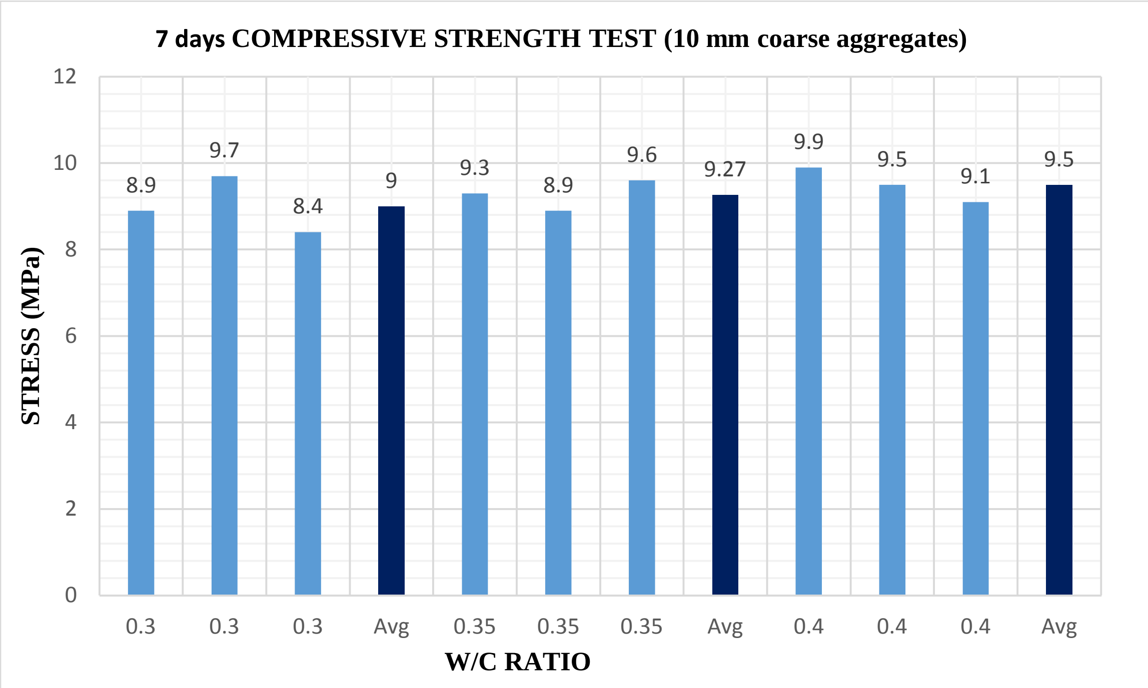
Fig 18: Curing tank

CHAPTER 4

RESULTS & DISCUSSIONS

The mix proportion used is 1 cement: 4 aggregates. In case of combined aggregates of 10 mm & 20 mm, 70% of 10 mm aggregates are used & 30% of 20 mm aggregates are used, in order to improve the strength.

4.1 7 Days Compressive Strength Test (10 mm CA)



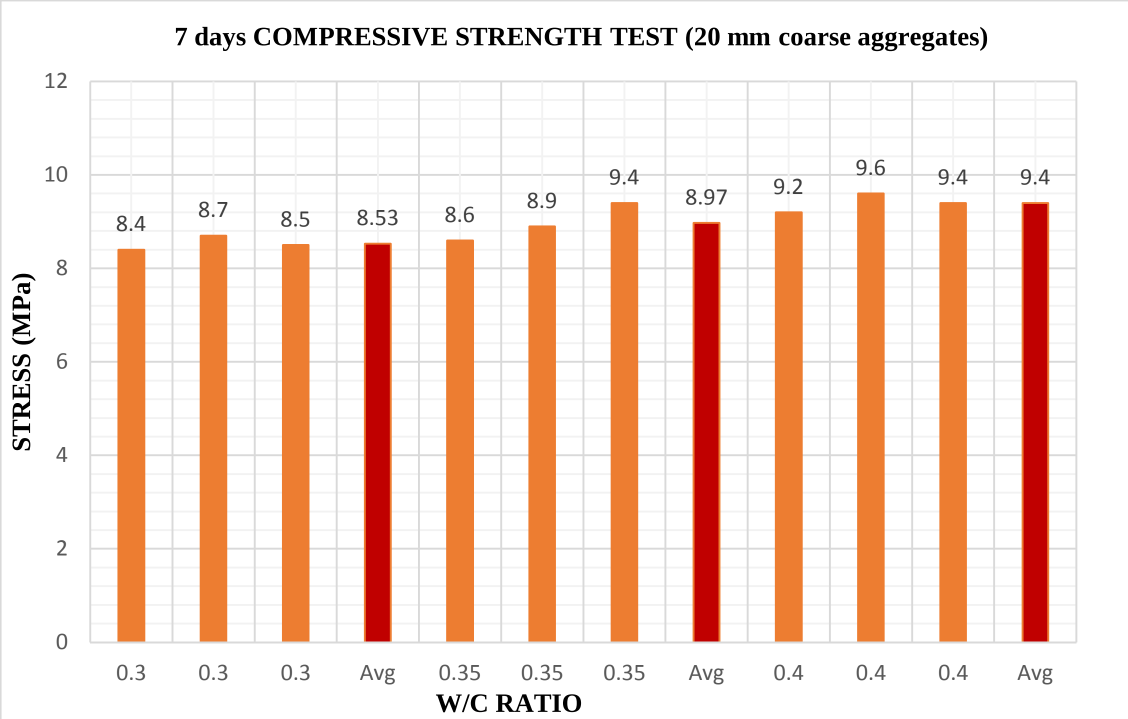
Graph 1: 7 days Compressive strength test

W/C RATIO	STRESS (MPa)
0.3	8.9
0.3	9.7
0.3	8.4
Avg.	9
0.35	9.3
0.35	8.9
0.35	9.6
Avg.	9.27
0.4	9.9
0.4	9.5
0.4	9.1
Avg.	9.5

Table 5: 7 days Compressive strength test

7 day compressive strength is seen to be increasing with the increasing W/C ratio. Usually, as the W//C ratio increases, strength decreases. But, in this case, it seems that the low W/C ratio has not provided adequate bonding between cement & aggregates, thereby resulting in to harsh mix. This might have reduced the strength.

4.2 7 Days Compressive Strength Test (20 mm CA)



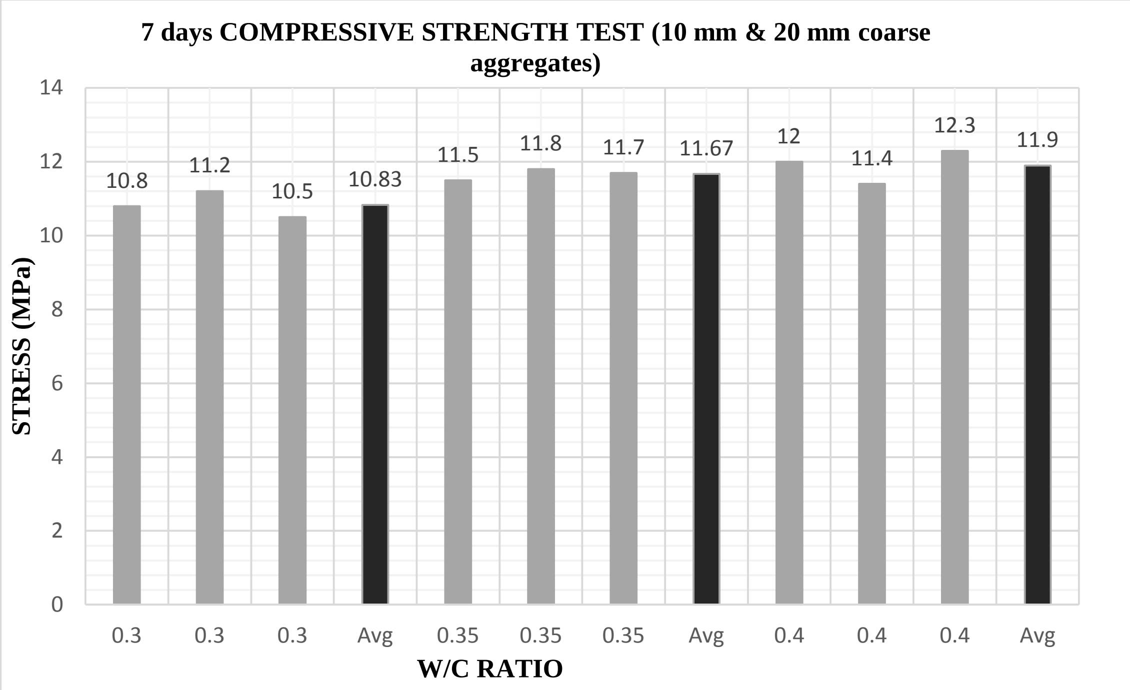
Graph 2: 7 days Compressive strength test

W/C RATIO	STRESSES (MPa)
0.3	8.4
0.3	8.7
0.3	8.5
Avg.	8.53
0.35	8.6
0.35	8.9
0.35	9.4
Avg.	8.97
0.4	9.2
0.4	9.6
0.4	9.4
Avg.	9.4

Table 6: 7 days Compressive strength test

As the W/C ratio is increasing, the compressive strength is seen to have increased. More W/C ratio provides the good bonding between 20 mm aggregates & cement particles. This helps in enhancing the compressive strength.

4.3 7 Days Compressive Strength Test (10 mm & 20 mm CA)



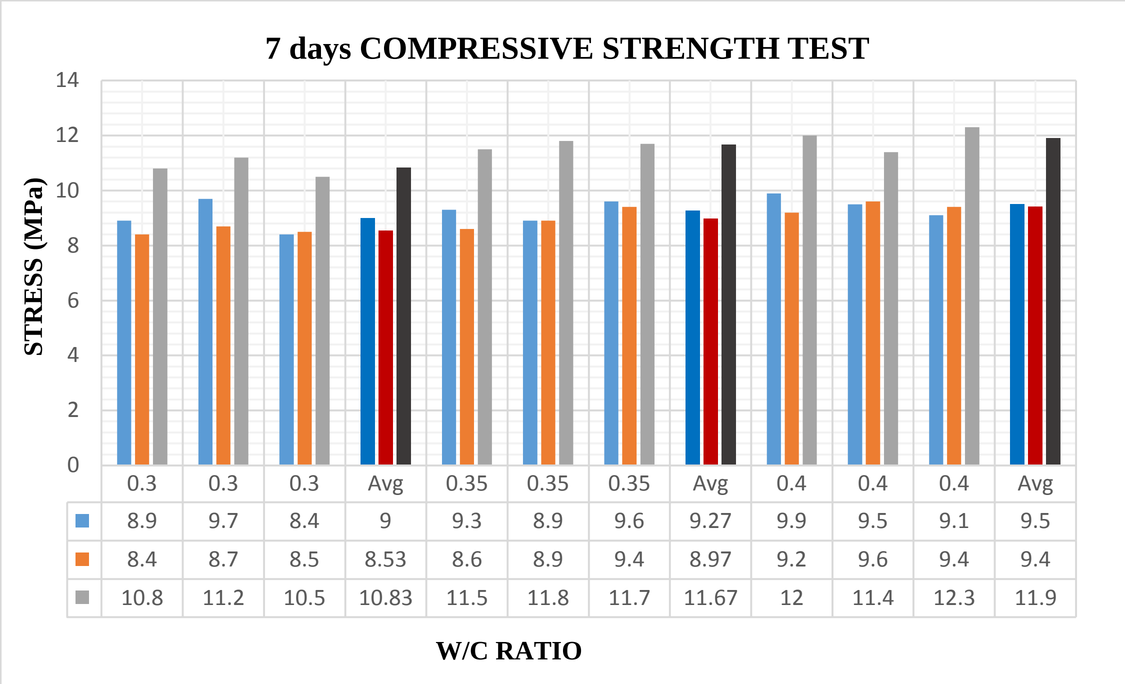
Graph 3: 7 days Compressive strength test (10 mm & 20 mm Coarse aggregates)

W/C RATIO	STRESSES (MPa)
0.3	10.8
0.3	11.2
0.3	10.5
Avg.	10.83
0.35	11.5
0.35	11.8
0.35	11.7
Avg.	11.67
0.4	12
0.4	11.4
0.4	12.3
Avg.	11.9

Table 7: 7 days Compressive strength test

The addition of 70% of 10 mm aggregates & 30% of 20 mm aggregates has resulted in to higher compressive strength at 7 days, as compared to that for concrete with exclusively 10 mm aggregates or 20 mm aggregates. It may be possibly due to the fact that the particle packing is good in case of two different sizes of aggregates.

4.4 Comparison of 7 Days Compressive Strength Test

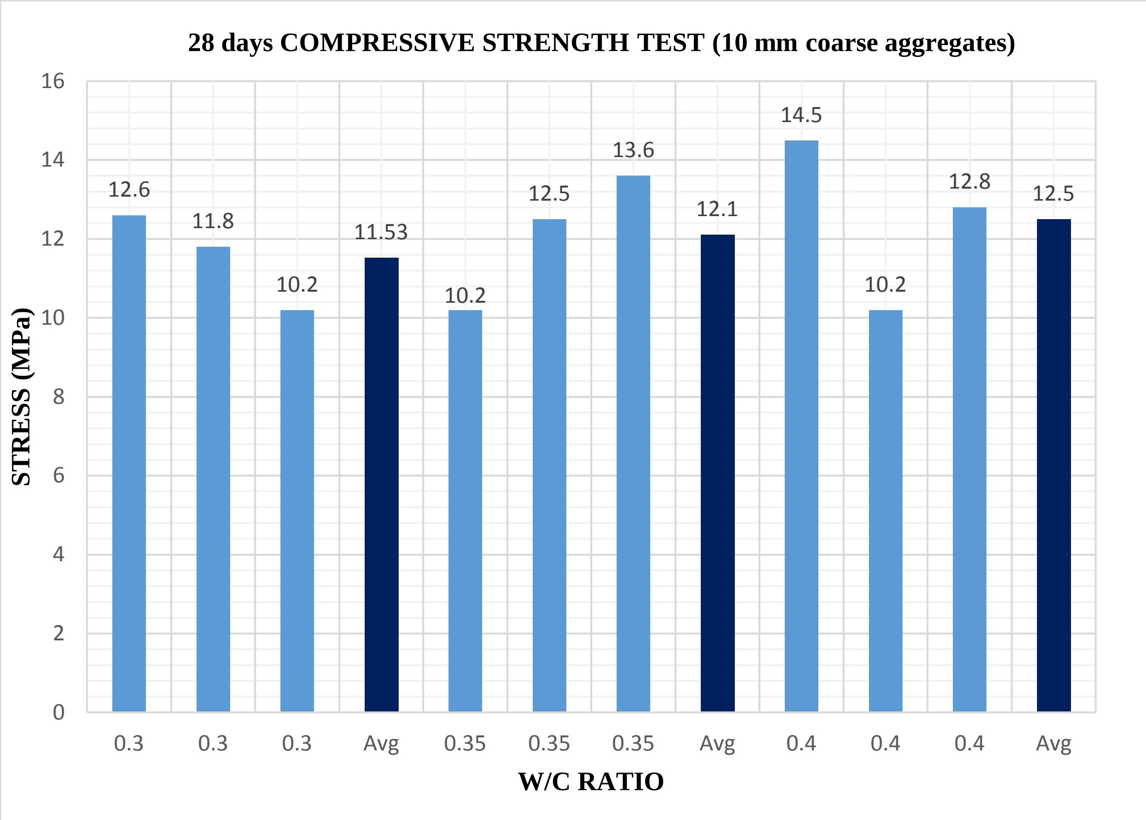


Graph 4: 7 days Compressive strength test

W/C RATIO	STRESS (MPa) FOR 10 mm CA	STRESS (MPa) FOR 20 mm CA	STRESS (MPa) FOR 10 mm & 20 mm agg.
0.3	8.9	8.4	10.8
0.3	9.7	8.7	11.2
0.3	8.4	8.5	10.5
Avg.	9	8.53	10.83
0.35	9.3	8.6	11.5
0.35	8.9	8.9	11.8
0.35	9.6	9.4	11.7
Avg.	9.27	8.97	11.67
0.4	9.9	9.2	12
0.4	9.5	9.6	11.4
0.4	9.1	9.4	12.3
Avg.	9.5	9.4	11.9

Table 8: 7 days Compressive Strength test

4.5 28 Days Compressive Strength Test (10 mm CA)



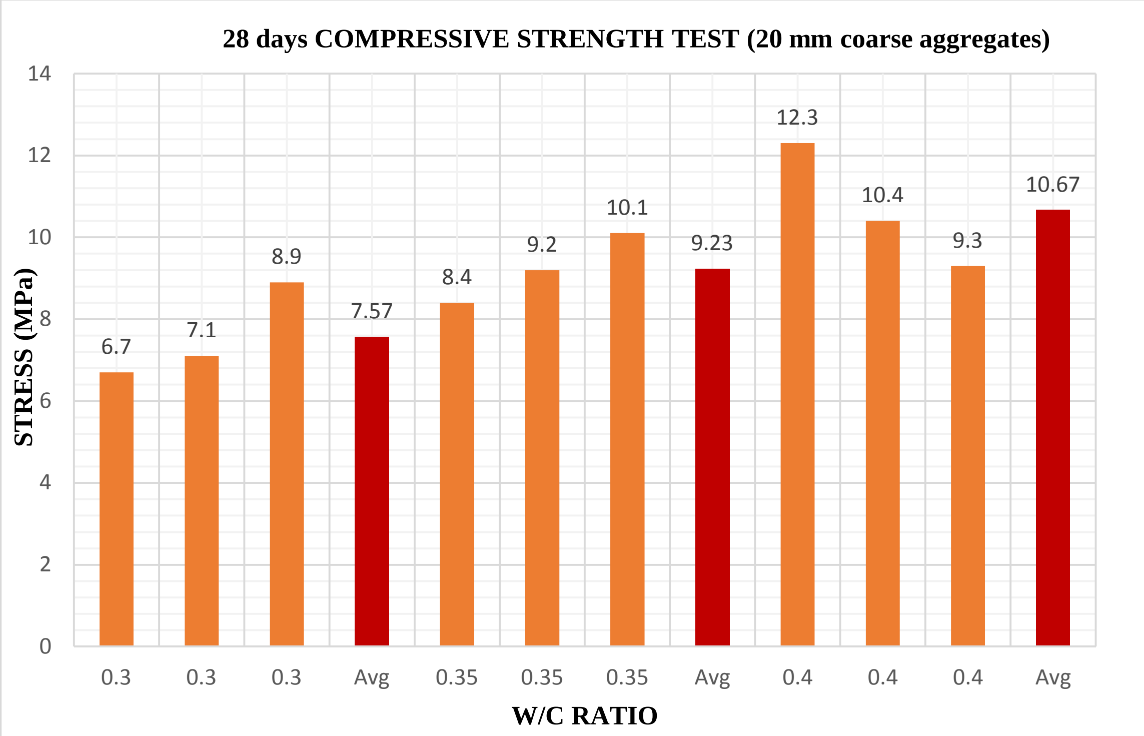
Graph 5: 28 day's Compressive test (10 mm Coarse aggregates)

W/C RATIO	STRESSES (MPa)
0.3	12.6
0.3	11.8
0.3	10.2
Avg.	11.53
0.35	10.2
0.35	12.5
0.35	13.6
Avg.	12.1
0.4	14.5
0.4	10.2
0.4	12.8
Avg.	12.5

Table 9: 28 day's Compressive strength test

As the W/C ratio increases, the compressive strength has shown the increase at 28 days.

4.6 28 Days Compressive Strength Test (20 mm CA)



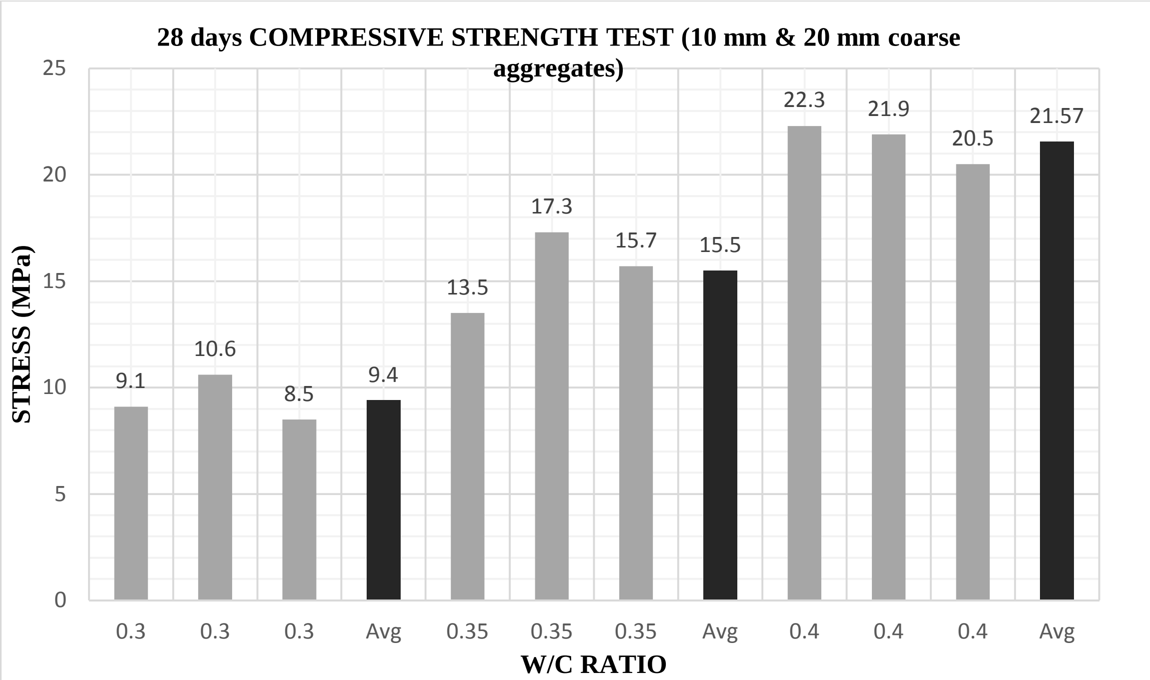
Graph 6: 28 days Compressive strength test (20 mm Coarse aggregates)

W/C RATIO	STRESSES (MPa)
0.3	6.7
0.3	7.1
0.3	8.9
Avg.	7.57
0.35	8.4
0.35	9.2
0.35	10.1
Avg.	9.23
0.4	12.3
0.4	10.4
0.4	9.3
Avg.	10.67

Table 10: 28 days Compressive strength test (20 mm Coarse aggregates)

In this case also, as the W/C ratio is more, the strength obtained is higher.

4.7 28 Days Compressive Strength Test (10 mm & 20 mm CA)



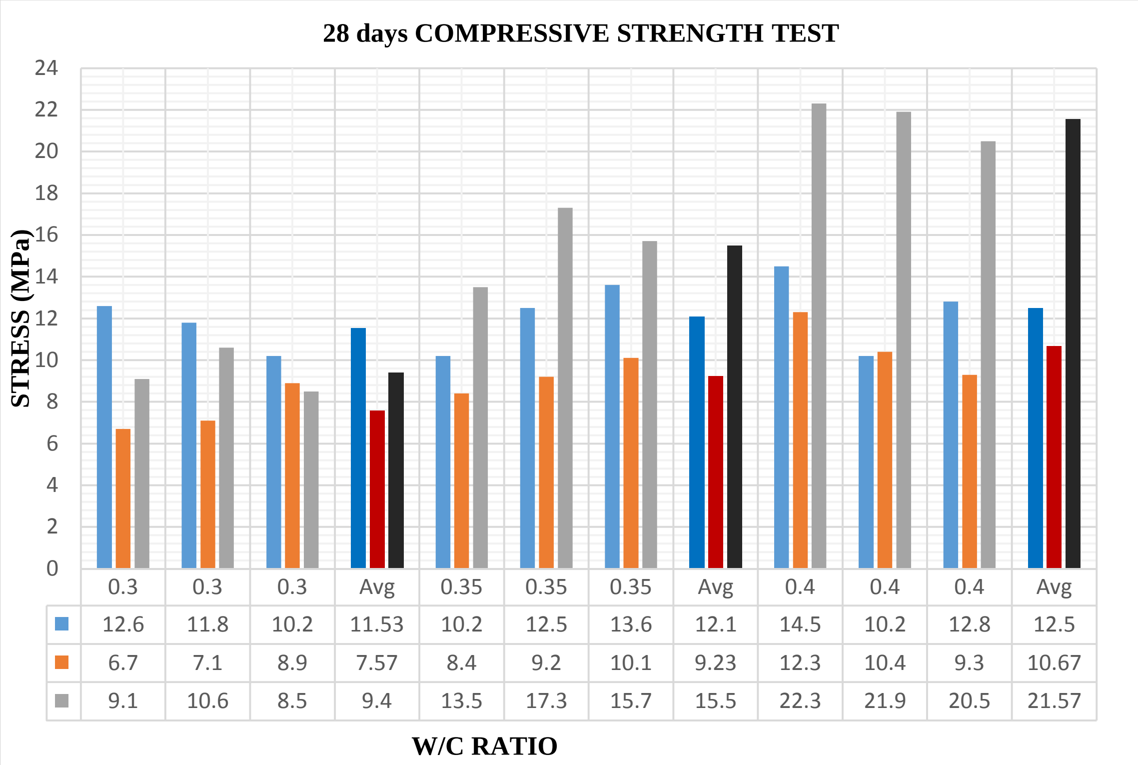
Graph 7: 28 days Compressive strength test (10 mm & 20 mm Coarse aggregates)

W/C RATIO	STRESSES (MPa)
0.3	9.1
0.3	10.6
0.3	8.5
Avg.	9.4
0.35	13.5
0.35	17.3
0.35	15.7
Avg.	15.5
0.4	22.3
0.4	21.9
0.4	20.5
Avg.	21.57

Table 11: 28 days Compression test (10 mm & 20 mm Coarse aggregates)

It can be clearly seen that the combined aggregates of 10 mm & 20 mm give maximum strength of 21.57 MPa. This is due to the good particle packing.

4.8 Comparison of 28 Days Compressive Strength Tests



Graph 8: 28 days Compressive strength tests

W/C RATIO	STRESS (MPa) FOR 10 mm CA	STRESS (MPa) FOR 20 mm CA	STRESS (MPa) FOR (10 mm & 20 mm CA)
0.3	12.6	6.7	9.1
0.3	11.8	7.1	10.6
0.3	10.2	8.9	8.5
Avg.	11.53	7.57	9.4
0.35	10.2	8.4	13.5
0.35	12.5	9.2	17.3
0.35	13.6	10.1	15.7
Avg.	12.1	9.23	15.5
0.4	14.5	12.3	22.3
0.4	10.2	10.4	21.9
0.4	12.8	9.3	20.5
Avg.	12.5	10.67	21.57

Table 12: Comparison of 28 days Compressive strength tests

The table clearly depicts the following facts:

1. For the W/C ratio of 0.3 with 10 mm coarse aggregates, 28 days compressive strength is 11.53 MPa, whereas the strength reduces to 7.57 MPa in case of 20 mm coarse aggregate concrete. For the combination of 70% of 10 mm CA & 30% of 20 mm CA, there is again the increasing trend in the compressive strength. The two different sized aggregates create good particle packing & hence the strength increases.

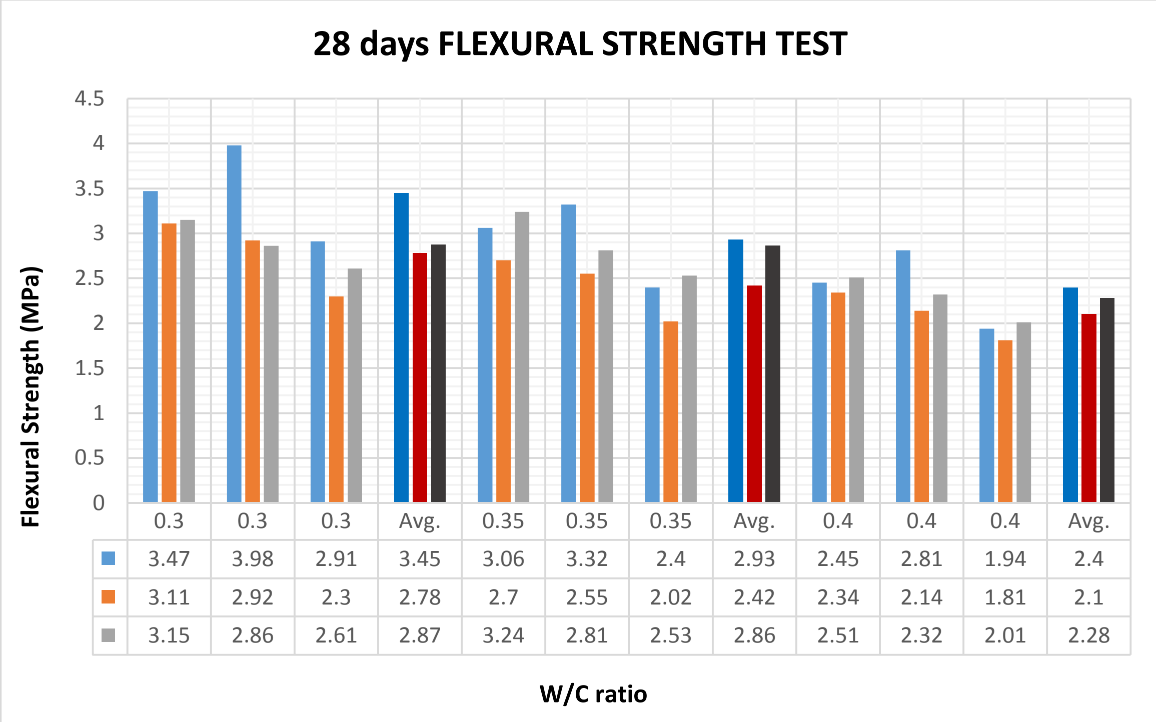
2. In case of 0.35 W/C ratio, the strength follows the same trend as in the first case. But, the noticeable difference here is that the compressive strength for the combined aggregates concrete (15.5 MPa) is more than that for the 10 mm aggregates concrete (12.1 MPa).

3. For the W/C ratio of 0.4, the strength achieved for the combined aggregates concrete is 21.57 MPa. It is showing the strength of M20 concrete.

4. From all the three cases, it can be clearly seen that using large sized aggregates (20 mm) gives lowest compressive strength. The concrete made with 10 mm aggregates gives moderate strength, whereas the concrete produced by combining both the sizes of aggregates gives highest compressive strength.

5. As the W/C ratio goes on increasing, the compressive strength enhances for all the three cases. This is due to the fact that sufficient water helps in lubricating the mix, which, in turn, results in to proper bonding between cement particles & coarse aggregates.

4.9 Comparison of 28 days Flexural Strength Tests



Graph 9: 28 days Flexural strength test

W/C RATIO	STRESS (MPa) FOR 10 mm CA	STRESS (MPa) FOR 20 mm CA	STRESS (MPa) FOR (10 mm + 20 mm CA)
0.3	3.47	3.11	3.15
0.3	3.98	2.92	2.86
0.3	2.91	2.30	2.61
Avg.	3.45	2.78	2.87
0.35	3.06	2.70	3.24
0.35	3.32	2.55	2.81
0.35	2.40	2.02	2.53
Avg.	2.93	2.42	2.86
0.4	2.45	2.34	2.51
0.4	2.81	2.14	2.32
0.4	1.94	1.81	2.01
Avg.	2.4	2.1	2.28

Table 13: 28 day's Flexural strength test

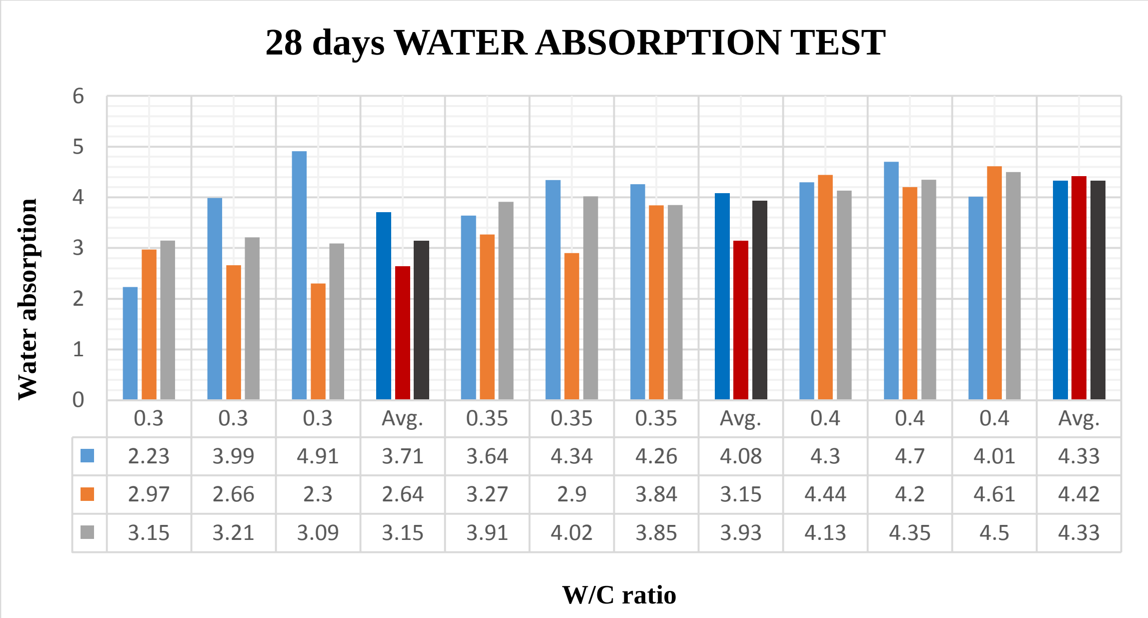
The following inferences can be drawn:

1. Unlike the compressive strength test results, the flexural strength tests show decreasing trend with the increase in W/C ratio.

2. For 10 mm aggregates, the flexural strength has highest value of 3.45 MPa at 0.3 W/C ratio. This may be due to better interlocking property.

3. Though there is a general trend of decrease in flexural strength with increase in W/C ratio for all the three cases, the higher values are obtained in concrete produced with only 10 mm aggregates, for all the W/C ratios.

4.10 Comparison of 28 days Water Absorption Tests



Graph 10: 28 days Water absorption test

W/C RATIO	Water Absorption (%)		
	Concrete with 10 mm CA	**Concrete with 20 mm CA**	**Concrete with (10 mm & 20 mm) CA**
0.3	2.23	2.97	3.15
0.3	3.99	2.66	3.21
0.3	4.91	2.3	3.09
Avg.	3.71	2.64	3.15
0.35	3.64	3.27	3.91
0.35	4.34	2.9	4.02
0.35	4.26	3.84	3.85
Avg.	4.08	3.15	3.93
0.4	4.30	4.44	4.13
0.4	4.70	4.2	4.35
0.4	4.01	4.61	4.5
Avg.	4.33	4.42	4.33

Table 14: 28 days Water Absorption Test

Water absorption is increased with increase in W/C ratio for all the three cases. However, the concrete made with 10 mm CA gives higher values. This may be due to the fact the use of 10 mm aggregates & higher W/C ratio creates more pores in the concrete.

CHAPTER 4

CONCLUSIONS

- The parking areas, gardens, footpaths, etc. do not need high grade concrete, as they do not carry heavy loads. Moreover, the proper drainage in rainy season is one of the important factors to be considered. The porous concrete produced as a part of the project work, can be the answer to this problem.

- The concrete of grade M20 is produced for water/cement ratio of 0.4 using combined aggregates.

- M20 concrete will cater sufficiently to carry the light loads.

- The tests indicated that the water passed through the body of the concrete from one end to the other end. This depicts that the concrete produced is adequately porous to allow the passage of water.

- The pavements, paver blocks, footpaths, etc. are subjected to bending stresses & hence flexural strength tests were carried out. The values obtained are showing good trend.

- The pervious concrete has a dual advantage of supporting the light loads & passing the water through its body. Hence, the development & wide usage of low grade pervious concrete would eliminate the construction of drainage works.

- The water seeped through the concrete would go in to the ground & in turn, would help in enhancing the ground water table, thereby recharging the ground water.

- There is a wide scope in India to adopt the pervious concrete.

CHAPTER 5

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