



ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2015; 1(10): 676-681
www.allresearchjournal.com
Received: 28-07-2015
Accepted: 29-08-2105

Sai Sindhu K
M. Tech student, IV semester,
Visvodaya Engineering
College, Kavali

Dr. Suresh Babu T
Professor and Head,
Department of Civil
Engineering, Visvodaya
Engineering College, Kavali

International Journal of Applied Research

Study and Comparison of Mechanical Properties, Durability and Permeability of M₁₅, M₂₀, M₂₅ Grades of Pervious Concrete with Conventional Concrete

Sai Sindhu K, Suresh Babu T

Abstract

Pervious concrete is a special type of concrete with high porosity. It is used for concrete flatworks application that allow the water to pass through it, thereby reducing the runoff from a site and allowing ground water recharge. The high porosity is attained by a highly interconnected void content. Typically pervious concrete has water to cementitious material ratio of 0.28 to 0.4. The mixture is composed of cementitious materials, coarse aggregates and water with little to no fine aggregates. Addition of a small amount of fine aggregates will generally reduce the void content and increase the strength. The present project deals with the study and comparison of mechanical properties, workability density and permeability of different grades of pervious concrete (M₁₅, M₂₀, M₂₅).

Keywords: pervious concrete, no fines, hyper plasticizer, permeability, Sulphate attack.

1. Introduction

One of the disadvantages of concrete is the high self weight of concrete. Density of normal concrete is in the order of 2200 to 2600 kg/m³. This heavy self weight will make it to some extent an uneconomical structural material. Attempts have been made in the past to reduce the self weight of concrete to increase the efficiency of concrete as a structural material. The light weight concrete density varies from 300 to 1850 kg/m³.

Light weight concrete has become more popular in recent years and have more advantages over the conventional concrete.

Pervious concrete is nothing but no fines concrete, which is also known as porous, gap graded or permeable concrete mainly consists of normal Portland cement, CA, water. In which FA are not existent or present in very small amount i.e < 10% by weight of the total aggregates.

In general, for making porous concrete, we will use the aggregates of size which passes through 12.5mm sieve and retained on 10mm sieve. In this project we have taken single size aggregates i.e 12.5mm. the single size aggregates make a good no-fines concrete, which addition to having large voids and hence light in weight, also offers architecturally attractive look.



Fig 1: test specimens

Correspondence
Sai Sindhu K
M. Tech student, IV semester,
Visvodaya Engineering
College, Kavali

Common applications for pervious concrete are parking lots, side walls, path ways, tennis courts, slope stabilization, swimming pool decks, green house floors, drains, highway pavements. Generally which is not used for concrete pavements for high traffic and heavy wheel loads. structural advantages.

2. Aim and Objectives

The aim of the research is to study the strength, durability and permeability of pervious concrete for different grades (M15, M20, M25). The objectives include

- To study the workability of concrete.
- To study the density of concrete.
- To study the mechanical properties such as compressive, tensile and flexural strength of concrete.
- To study the durability of concrete by sulphate attack (by using MgSO₄ curing).
- To study the permeability of concrete.

3. Materials

The present investigation the following materials were used:

- Ordinary Portland Cement of 53 Grade cement conforming to IS: 169-1989
- Fine aggregate and coarse aggregate conforming to IS: 2386-1963.
- Water.
- Hyper plasticizer (ECMASHP-902)

3.1 Cement

Ordinary Portland Cement of 53 Grade of brand name Ultra Tech Company, available in the local market was used for the investigation. Care has been taken to see that the procurement was made from single batching in air tight containers to prevent it from being effected by atmospheric conditions. The cement thus procured was tested for physical requirements in accordance with IS: 169-1989 and for chemical requirement in accordance IS: 4032-1988. The physical properties of the cement are listed in Table –

Table 1: Properties of cement

Sl. No	Properties	Test results	IS: 169-1989
1.	Normal consistency	0.32	
2.	Initial setting time	60min	Minimum of 30min
3.	Final setting time	320min	Maximum of 600min
4.	Specific gravity (a)	3.14	

3.2 Fine Aggregates

River sand locally available in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS: 2386-1963. The sand was surface dried before use.

Table 2: Properties of Fine Aggregates

Fineness modulus	2.4
Specific Gravity of fine aggregate	2.55
Free moisture	2%

3.3 Coarse Aggregates

Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their

physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386-1963. The individual aggregates were mixed to induce the required combined grading. the particular gravity and water absorption of the mixture are given in table.

Table 3: Properties of coarse aggregates

Specific Gravity of coarse aggregate	2.60
Water absorption	1%

3.4 Water

Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

3.5 Hyper Plasticizers

Hyper plasticizers are standard chemical admixtures for concrete employed in the reduction of water to cement quantitative relation while not moving workability, and to avoid particle saggregation within the concrete mixture. These are called high vary water reducers (HRWR), fluidifiers, and dispersants as these are capable of reducing water to cement quantitative relation by forty.0%. These chemical admixtures are additional within the concrete simply before the concrete is placed. These admixtures facilitate to enhance strength and flow characteristics of the concrete. In this project we used ECMASHP-902 as admixture with an amount of 0.2% by weight of cement.

Mix proportions as Per ACI 211.1-91

Table 4: Mix proportions for M15 grade of concrete

materials	Proportions for Conventional (kg/m ³)	Proportions for No fines concrete (kg/m ³)
Cement	277.7	277.7
Fine aggregates	642.04	0
Coarse aggregates	1193.94	1193.94
Water cement ratio by mass	0.3	0.3
Admixture(ml)	55.54	55.54

Table 5: Mix proportions for M20 grade of concrete

materials	Proportions for Conventional (kg/m ³)	Proportions for No fines concrete (kg/m ³)
Cement	380	380
Fine aggregates	563.06	0
Coarse aggregates	1113.75	1113.75
Water cement ratio by mass	0.3	0.3
Admixture(ml)	76	76

Table 6: Mix proportions for M25 grade of concrete

materials	Proportions for Conventional (kg/m ³)	Proportions for No fines concrete (kg/m ³)
Cement	452.38	452.38
Fine aggregates	503.2	0
Coarse aggregates	1113.75	1113.75
Water cement ratio by mass	0.3	0.3
Admixture(ml)	90.47	90.47

4 Sulphate Attack

To determine the resistance of various concrete mixtures to sulphate attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% of Magnesium sulphate (MgSO₄) by weight of water was found. The concrete cubes which were cured in MgSO₄ were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken.. The resistance of concrete to sulphate attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersion of concrete cubes in 3-5% magnesium sulphate water.

5 Experimental Results

5.1 Workability: Results obtained from compaction factor test showing that the workability of concrete

Table 7: Compaction factor for conventional concrete and No fines concrete

Grades Of Concrete	Compaction Factor	
	Conventional Concrete	No Fines Concrete
M15	0.8	0.85
M20	0.84	0.89
M25	0.87	0.92

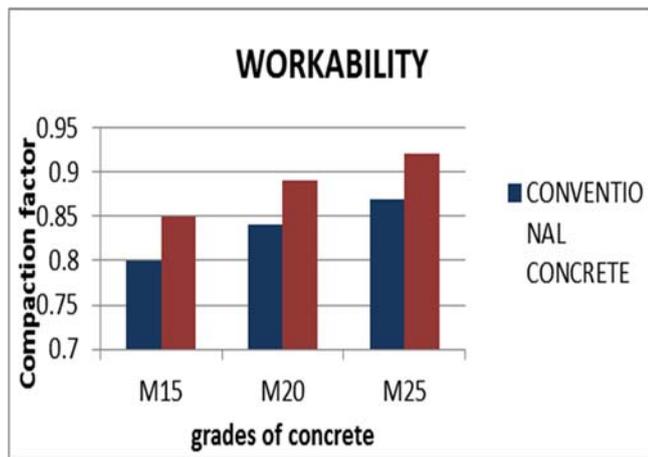


Fig 2: Workability variation of conventional and pervious concrete for different grades

5.2 Compressive Strength

These results are obtained by testing the total 6 specimens for 7 days and 28 days and by considering the average of the test results and that are tabulated in table

Table 8: compression strength of No fines concrete cubes cured in water and cured in MgSO₄.

Grades Of Concrete	Compressive Strength(N/mm ²)			
	Cured In Water		Cured In MgSO ₄	
	7 Days	28 Days	7 Days	28 Days
M15	11.02	16.32	8.96	15.1
M20	14.98	20.79	12.82	18.74
M25	19.86	24.4	17.2	25.53

Table 9: compression strength of conventional concrete cubes cured in water and cured in MgSO₄.

Grades Of Concrete	Compressive Strength(N/MM ²)			
	Cured In Water		Cured In MgSO ₄	
	7 Days	28 Days	7 Days	28 Days
M15	14.6	19.1	13.03	18.8
M20	17.26	25.44	15.6	24.03
M25	21.3	30.88	19.3	28.87

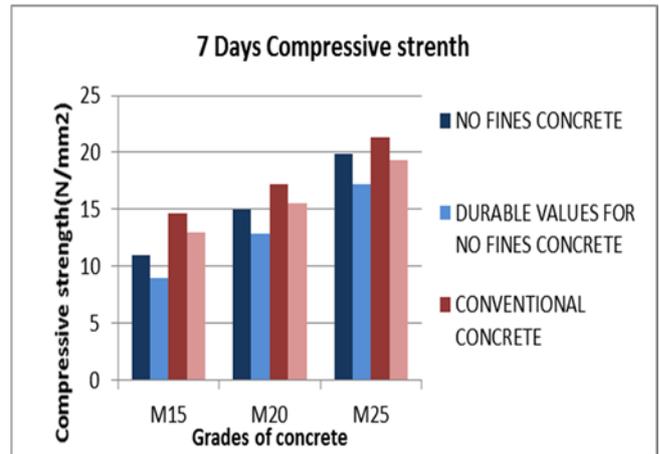


Fig 3: Seven days compressive strength variation of conventional and No fines concrete cured in water and cured in MgSO₄.

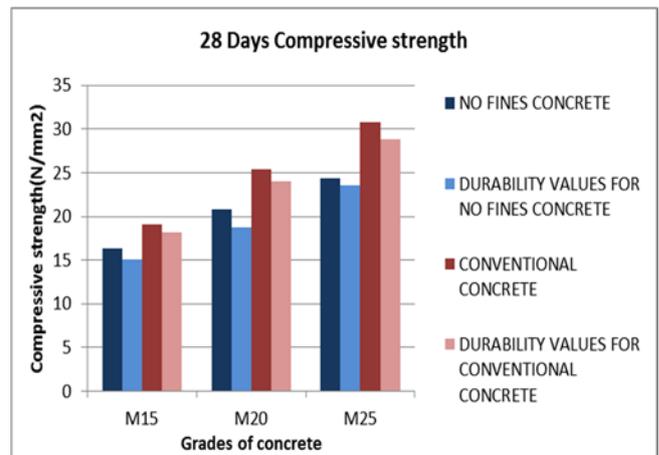


Fig 4: Twenty eight days compressive strength variation of conventional And No fines concrete cured in water and cured in MgSO₄.

Split Tensile Strength:

These results are obtained by testing the total 6 specimens for 7 days and 28 days and by considering the average of the test results that are tabulated in table

Table 10: Split tensile strength of No fines concrete cylinders cured in water and cured in MgSO₄.

Grades Of Concrete	Split Tensile Strength(N/mm ²)			
	Cured In Water		Cured In MgSO ₄	
	7 Days	28 Days	7 Days	28 Days
M15	0.98	1.22	0.84	1.08
M20	1.17	1.57	1.04	1.39
M25	1.41	2.05	1.29	1.82

Table 11: Split tensile strength of conventional concrete cylinders cured in water and cured in MgSO₄.

Grades Of Concrete	Split Tensile Strength(N/mm ²)			
	Cured In Water		Cured In MgSO ₄	
	7 Days	28 Days	7 Days	28 Days
M15	2.11	3.26	1.65	2.92
M20	3.19	4.7	2.93	3.99
M25	4.04	5.2	3.11	4.82

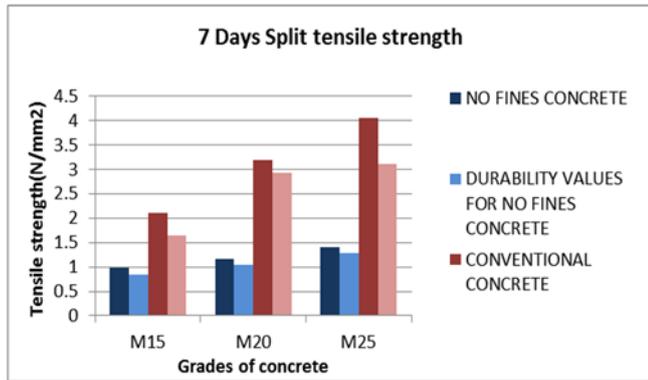


Fig 5: Seven days split tensile strength variation of conventional And No fines concrete cured in water and cured in MgSo4.

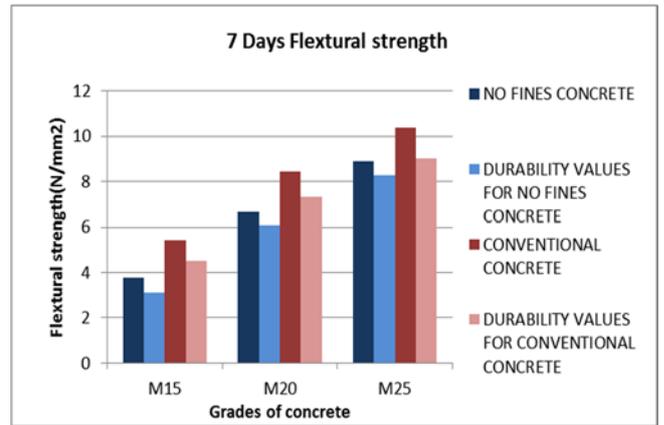


Fig 7: Seven days flextural strength variation of conventional And No fines concrete cured in water and cured in MgSo4.

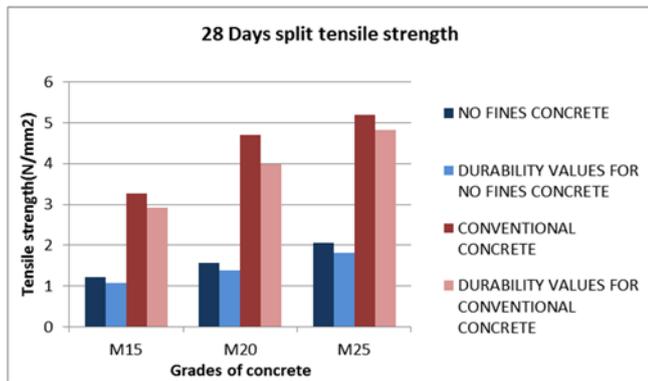


Fig 6: Twenty eight days split tensile strength variation of conventional And No fines concrete cured in water and cured in MgSo4.

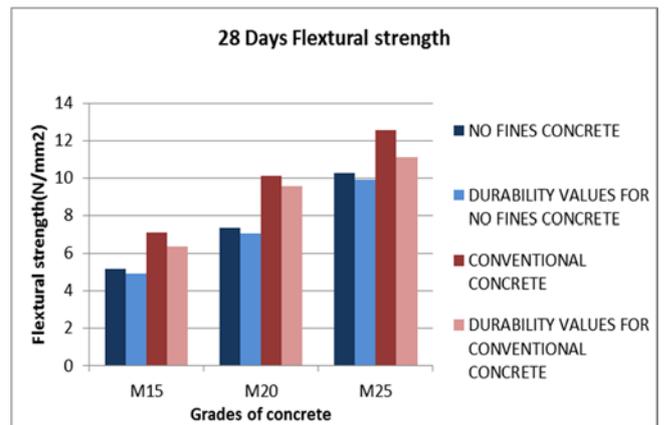


Fig 8: Twenty eight days flextural strength variation of conventional And No fines concrete cured in water and cured in MgSo4.

Flexural Strength

These results are obtained by testing the total 6 specimens for 7 days and 28 days and by considering the average of the test results that are tabulated in table

Table 12: Flexural strength of No fines concrete beams cured in water and cured in MgSo4.

Grades Of Concrete	Flexural Strength(N/mm ²)			
	Cured In Water		Cured In MgSo ₄	
	7 Days	28 Days	7 Days	28 Days
M15	3.79	5.18	3.13	4.91
M20	6.68	7.36	6.09	7.06
M25	8.89	10.28	8.26	9.92

Table 13: Flexural strength of conventional concrete beams cured in water and cured in MgSo4.

Grades Of Concrete	Flexural Strength(N/mm ²)			
	Cured In Water		Cured In MgSo ₄	
	7 Days	28 Days	7 Days	28 Days
M15	5.43	7.1	4.51	6.37
M20	8.44	10.12	7.32	9.55
M25	10.37	12.57	9.03	11.12

Table 15: Permeability of conventional concrete and No fines concrete

Pressure Difference (Pa)	Permeability Of Conventional Concrete(cm/sec)			Permeability Of No Fines Concrete (cm/sec)		
	M15	M20	M25	M15	M20	M25
5	5.6X10 ⁻¹⁴	3.2X10 ⁻¹⁴	1.39 X10 ⁻¹⁴	6.6 X10 ⁻³	1.01X10 ⁻³	9.42 X10 ⁻⁴
10	1.8X10 ⁻¹⁴	9.48 X10 ⁻¹⁵	7.47 X10 ⁻¹⁵	1.2 X10 ⁻³	8.2 X10 ⁻⁴	6.01 X10 ⁻⁴
15	8.6X10 ⁻¹⁵	6.23 X10 ⁻¹⁵	3.25 X10 ⁻¹⁵	8.9 X10 ⁻⁴	5.4 X10 ⁻⁴	2.9 X10 ⁻⁴

Density of Concrete

The density of concrete cubes for different grades of conventional and no fines concrete are shown below.

Table 14: Density of conventional concrete and No fines concrete

Grade Of Concrete	Density Of Concrete (kg/m ³)	
	Conventional Concrete	No Fines Concrete
M15	2340	1612
M20	2375	1656
M25	2394	1685

Permeability Test

These results are obtained by testing the total 9 specimens for conventional and no fines concrete by varying the pressure differences and the results are tabulated in the table.

Discussion

Compressive Strength

A decrease in the compressive strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete by 18.2%, 14.5% and 12.6% respectively is found compared to the conventional concrete. The computed values of the compressive strength of both conventional and no fines concrete establish that compressive strength of no fines concrete is less than that of conventional concrete.

Split Tensile Strength

It is evident from the study that the tensile strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 40.2%, 38.4% and 36.2% respectively in comparison with the conventional concrete.

The calculated split tensile strength values of both conventional and no fines concrete prove that the tensile strength of no fines concrete is less than that of conventional concrete.

Flexural Strength

Observations conclude that the flexural strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 29.9%, 27.6% and 24.6% respectively when compared to the conventional concrete.

Illustrative computation of flexural strength values of both conventional and no fines concrete prove that flexural strength of no fines concrete is less than that of conventional concrete.

Density of Concrete

It is observed that the density of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 31.1%, 30.2% and 29.6% as against that of conventional concrete.

The computed density of no fines concrete is noted to have decreased in comparison with that of conventional concrete.

Permeability

It has been observed that coefficient of permeability of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is increased by 82.4%, 79.6% and 72.8% respectively in comparison with the conventional concrete.

Computations establish that the coefficient of permeability values is more for no fines concrete than the conventional concrete.

Workability

From the calculated workability values it is observed that for M₁₅, M₂₀ and M₂₅ grades of no fines concrete are increased by 5.8%, 5.6% and 5.4% respectively when compared to the conventional concrete.

Durability by Sulphate Attack

Compressive Strength:

(A) No Fines Concrete

The compressive strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 15.5%, 16.2% and 12.8%.

(B) Conventional Concrete

The split tensile strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 14.8%, 13.7% and 15.05% respectively.

Split Tensile Strength

(A) No Fines Concrete

The split tensile strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 11.4%, 11.46% and 11.21% respectively.

(B) Conventional Concrete

The split tensile strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 10.42%, 11.5% and 9.4% respectively.

Flexural Strength

(A) No Fines Concrete

The flexural strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 11%, 10.1% and 8.2% respectively.

(B) Conventional Concrete

The split tensile strength of M₁₅, M₂₀ and M₂₅ grades of no fines concrete is decreased by 10.28%, 8.5% and 11.5% respectively.

Conclusions

The following conclusions are drawn based on the experimental investigations on compressive strength, split tensile, flexural, durability, permeability considering the "environmental aspects" also:

- Pervious concrete has less strength than conventional concrete by 18.2% for M₁₅, 14.5% for M₂₀ and 12.6% for M₂₅.
- Similarly the tensile and flexural strength values are also comparatively lower than the conventional concrete by 30%.
- Though the pervious concrete has low compressive, tensile and flexural strength it has high coefficient of permeability hence the following conclusions are drawn based on the permeability, environmental effects and economical aspects.
- It is evident from the project that no fines concrete has more coefficient of permeability. Hence, it is capable of capturing storm water and recharging the ground water. As a result, it can be ideally used at parking areas and at residential areas where the movement of vehicles is very moderate.
- Further, no fines concrete is an environmental friendly solution to support sustainable construction. In this project, fine aggregates as an ingredient has not been used. Presently, there is an acute shortage of natural sand all around. By making use of FA in concrete, indirectly we may have been creating environmental problems. Elimination of fines correspondingly decreases environment related problems.
- In many cities diversion of runoff by proper means is complex task. Use of this concrete can effectively control the run off as well as saving the finances invested on the construction of drainage system. Hence, it can be established that no fines concrete is very cost effective apart from being efficient.

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