Improvement of Compressive Strength and Permeability Test on Pervious Concrete

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Abstract: Pervious concrete is a special type of concrete, which consists of cement, coarse aggregates, water and if required, admixtures and other cementations materials. As there are no fine aggregates used in the concrete matrix, the void content is more which allows the water to flow through its body. So the pervious concrete is also called as permeable concrete and porous concrete. There is lot of research work is going in the field of pervious concrete. The compressive strength of pervious concrete is less when compared to the conventional concrete due to its porosity and voids. Hence, the usage of previous concrete is limited even though it has lot of advantages. If the compressive strength and flexural strength of pervious concrete is increased, then it can be used for more number of applications. For now, the usage of pervious concrete is mostly limited to light traffic roads only. If the properties are improved, then it can also be used for medium and heavy traffic rigid pavements also. Along with that, the pervious concrete eliminates surface runoff of storm water, facilitates the ground water recharge and makes the effective usage of available land.

KEYWORDS: CEMENTITIOUS MATERIALS , NO FINES, PEA GRAVEL AGGREGATES, PERVIOUS CONCRETE, POROUS CONCRETE

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I. INTRODUCTION

Pervious concrete which is also known as the no- fines. Porous, gap-graded, and permeable concrete and Enhance porosity concrete have been found to be a reliable storm water management tool. By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate). When pervious concrete is used for paving, the open cell structures allow storm water to filter through the pavement and into the underlying soils.

Pervious concrete is also a unique and effective means to address important environmental issues and sustainable growth. When it rains, pervious concrete automatically acts as a drainage system, thereby putting water back where it belongs. Pervious concrete is rough textured, and has a honeycombed surface, with moderate amount of surface raveling which occurs on heavily travelled roadways.

Carefully controlled amount of water and cementitious materials are used to create a paste. The paste then forms a thick coating around aggregate particles, to prevent the flowing off of the paste during mixing and placing. Using enough paste to coat the particles maintain a system of interconnected voids which allow water and air to pass trough. The lack of sand in pervious concrete results in a very harsh mix that negatively affects mixing, delivery and placement. Also, due to the high void content, pervious concrete is light in weight (about 1600 to 2000 Kg/m^3).

Pervious concrete can be used in a wide range of applications, although its primary use is in pavements which are in: residential roads, alleys and driveways, low volume pavements, low water crossings, sidewalks and pathways, parking areas, tennis courts, slope stabilization. Sub- base for conventional concrete pavements etc.,,

1.1 Objective

To investigate the performance characteristics of the pervious concrete such as porosity, compressive strength, infiltration rate.

1.2 Brief History

Pervious concrete has been around for hundreds of years. The Europeans recognized the insulating properties in structural pervious concrete for their buildings. Europeans have also used pervious concrete for paving.

Pervious concrete was first used in 1852. Pervious concrete has been employed in European countries since the nineteenth century.

The earliest usage of pervious concrete in modern history was for two houses in England. Over 900 houses were built from 1942.

Most of the houses using pervious concrete are in the United Kingdom (ACI 522 Pervious concrete, 2006).

1.3 General properties of pervious concrete

The plastic pervious concrete mixture is stiff compared to traditional concrete. Slumps, when measured, are generally less than 20mm, although slumps as high as 50mm have been used. However, slump of pervious concrete has no correlation with its workability and hence should not be specified as an acceptance criterion. Typical densities and void contents are on the order of 1600 Kg/m^3 to 2000 Kg/m^3 and 20% to 25% respectively.

In contrast the steady state infiltration rate of soil ranges from 25 mm/hr to 0.25 mm/hr. this clearly suggests that unless the pervious concrete is severely clogged up due to possibly poor maintenance it is unlikely that the permeability of pervious concrete is the controlling factor in estimating runoff (if any) from a pervious concrete.

1.4 Benefits of pervious concrete

Pervious concrete pavement systems provides a valuable storm water management tool under the requirements of the EPA storm water phase 11 final rule phase11 regulations provide programs and practices to help control the amount of contaminants in our waterways. Impervious pavement particularly parking lots collect oil, anti-freeze, and other automobile fluids that can be washed into streams, lakes, and oceans when it rains.

EPA storm water regulations set limits on the levels of pollution in our streams and lakes. To meet these regulations, local officials have considered two basic approaches. They are

1. Reduce the overall runoff from an area
2. Reduce the level of pollution contained in runoff

1.5 Major applications of pervious concrete

- Low-volume pavement
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Low water crossings
- Tennis courts

- Sub base for conventional concrete pavements
- Slope stabilization
- Well linings
- Hydraulic structures
- Swimming pool decks

LITERATURE REVIEW

J.T. Kerven, V.R. Schaefer, (2006) Studied the methods of curing pervious concrete is to cover with plastic for 7 days. They presented results if combinations of four different pervious concrete mixtures cured using six common curing methods.

M. HarshavarthanaBalaji and M. R. Amarnaath From the test results it was concluded that the mix design with aggregate and cement ratio of 3 has the maximum strength, this mix design has the required void ratio for the water seepage.

Menninger Studied the effect of different aggregate sizes (10 mm and 20 mm) on hardened properties of non- fine concretes and the results showed that compressive strength reduces with increase in aggregate size.

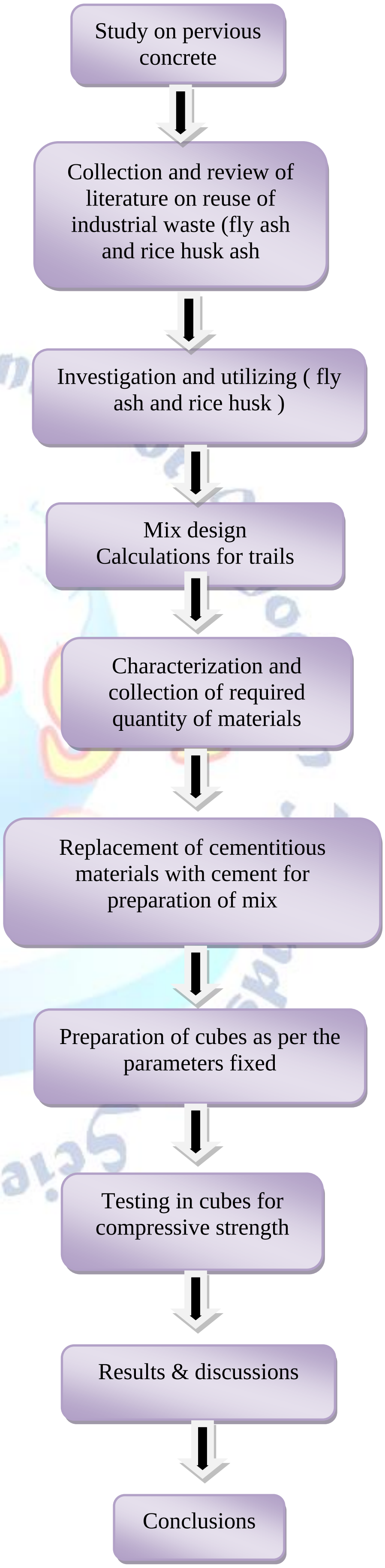
Ravindrarajak et. al By replacing 20% to 50% of cement with fly ash. The results of their investigation described that the permeability of pervious concrete was not notably affected when 50% of cement was replaced by fly ash.

Tennis, P.Leming. M.L., and Akers, D.j., The results suggest that properties such as permeability, porosity and specific yield are not significantly affected by different aggregate types.

Schaefer et al. (2006) Provides a summary of the available literature concerning the construction materials , material properties, surface characteristics, pervious pavement design, construction, maintenance, and environmental issues for PCPC.

The primary goal of the research conducted was to develop a pervious concrete that would provide freeze-thaw resistance while maintaining adequate strength and permeability for pavement applications. The research conducted at ISU included studies of the materials used in the pervious concrete, the mix proportions and specimen preparation, the resulting strength and permeability, and the effects of freeze-thaw cycling. A variety of aggregate sizes was tested and both limestone aggregates and river run gravels were used.

EXPERIMENTAL WORK



3.1 Materials of pervious concrete

3.1.1 Cement

- Ordinary Portland cement (OPC) of grade 53.
- As per BIS requirements the minimum 28 days compressive strength of 53 grade OPC should not be less than 53 Mpa.

3.1.2 Coarse aggregates

- Coarse aggregates of size 20 mm.
- Recent studies have also found that pervious concrete with smaller aggregate had higher compressive strength.

3.1.3 Water

- Water- to –cement ratios can range from 0.27 to 0.30 with ratios as high as 0.40.
- Carefully control of water is critical.

3.1.4 Cementitious materials: (Fly Ash)

Fly ash used as cement replacement

- Fly ash can significantly improve the workability of concrete. Recently, techniques have been developed to replace partial cement with high-volume fly ash (50% cement replacement).

3.1.5 Rice Husk

Rise husk ash

- The rice husk ash has good reactivity when used as a partial substitute for cement.
- These are prominent in countries where the rice production is abundant. The properly rice husk ashes are found to be active within the cement paste. So, the use and practical application of rice husk ash for concrete manufacturing are important.
- The incorporation of rice husk ash for concrete manufacturing is important. The incorporation of rice husk ash in concrete converts it into an eco-friendly supplementary cementitious material.

3.2 Mix design

Pervious concrete uses the same materials as conventional concrete, except that there is usually little or no fine aggregate. The quantity, proportions, and mixing techniques affects many properties of pervious concrete, in particular the void structure and strength. Usually single sized coarse aggregate up to 20mm size normally adopted.

The binder normally used in Ordinary Portland cement (OPC). Pozzolanic materials like fly ash, blast furnace slag and silica fume can also be used. However, use of pozzolanic materials will affect setting time, strength, porosity and permeability of the resulting concrete. Addition of fine aggregate will reduce the porosity and increase the strength of concrete.

Materials	**Proportions (Kg/m³)**
Cement (OPC)	270 to 415
Coarse aggregate	1190 to 1480
Water: cement ratio (by mass)	0.27 to 0.34
Fine-coarse aggregate ratio (by mass)	0 to 1:1
Cementitious materials are commonly used will increase strength	

Typical mix design of pervious concrete

Mixing of pervious concrete

3.3 Test conducted

1. Compressive strength on pervious concrete

2. Permeability test on pervious concrete

3. Infiltration test on pervious concrete

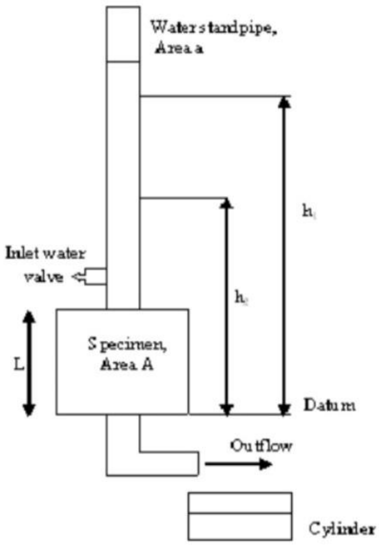
1. Compressive strength on pervious concrete:

In the laboratory, pervious concrete mixtures have been found to develop compressive strength in the range of 3.5 Mpa to 28 Mpa, Which is suitable for a wide range of applications. Typical values are about 17Mpa.

Cube samples for testing

2. Permeability test on pervious concrete:

The permeability of pervious concrete was determined using a falling head permeability set up figure in below:



Formula: **$K=2.303Al/a\ (t_2-t_1)\ \log (h_1/h_2)$**

Where,

a= the sample cross section area

A=the cross section of the standpipe of diameter (d) =0.95 cm²

L=the height of the pervious concrete

h_1=upper water level

h_2=lower water level

D=diameter of sample (10.5 cm)

d=diameter of standpipe (1.1 cm)

Theoretically, the coefficient of permeability generally in the order of 1 mm/sec for a void ratio of 20% and the rate of flow is in the range of 120 liters/min/m² to 200 liters/min/m².

3. Infiltration test in pervious concrete:

TEST RESULTS AND DISCUSSION

4.1 Compressive strength

(a) Compressive strength and unit weight of standard pervious concrete (0% fines)

S.No	Age of concrete (days)	Compressive strength of standard pervious concrete (Mpa)	Unit weight after 24 Hours (Kg/m³)
1	7	16.72	2112.20
2	14	19.26	
3	28	21.06	

Table1.2: compressive strength and unit weight of standard pervious concrete (0%fines)

(b) Compressive strength comparison between normal concrete and pervious concrete

S.No	Age of concrete (days)	Normal concrete of M20 (Mpa)	Pervious Concrete (Mpa)
1	7	18.53	16.72
2	14	25.67	19.26
3	28	28.20	21.06

Table1.3: comparison of strength between normal concrete and pervious concrete

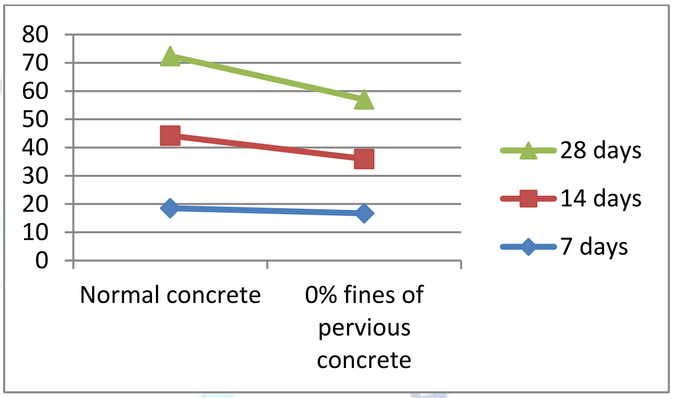


Figure: Graph of showing relation between compressive strength of normal and pervious concrete

4.2 compressive strength of pervious concrete with the replacement of cementitious materials:

We have tested 3 types of mixes. in the first mix, the fly ash is replaced by 10% of cement. In second mix, Rice Husk Ash is replaced by 10% of cement. In the third mix, mixture of both Fly Ash (5%) and Rice Husk Ash (5%) is replaced by 10% of cement.

4.2.1 Replacement of Fly ash by 10% of cement

Quantities of materials:

Cement : Fly ash : CA : Water

351 kgs : 39 kgs : 1510.60kgs : 117litres

All the materials are calculated for 1 CUM

S.No	Age of concrete (days)	Compressive strength of standard pervious concrete (Mpa)	Compressive strength of pervious concrete 10% Fly ash (Mpa)	Unit weight after 24 Hours (Kg/m³)
1	7	16.72	17.26	1941.92
2	14	19.26	19.92	
3	28	21.06	22.87	

Table1.4: Compressive strength and unit weight of pervious concrete with 10% fly ash

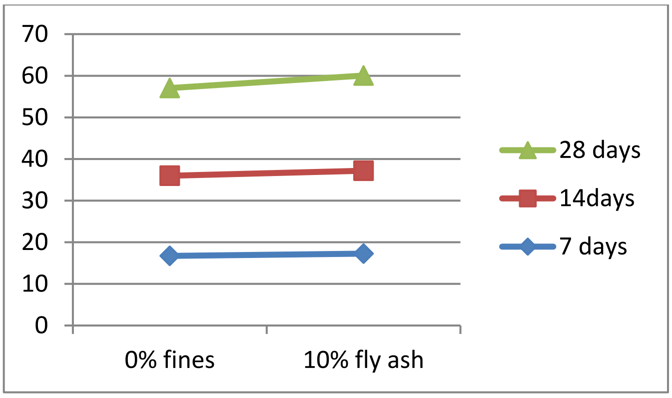


Figure: Graph of age of concrete Vs compressive strength of 10% fly ash replacement

4.2.2 Replacement of Rice Husk Ash by 10% of cement

Quantities of materials:

Cement : Fly ash : CA : Water

351kg/m³ : 39kg/m³ : 1510.60kg/m³ : 117litres

S.No	Age of concrete (days)	Compressive strength of standard pervious concrete (Mpa)	Compressive strength of pervious concrete 10% Rice Husk Ash (Mpa)	Unit weight after 24 Hours (Kg/m³)
1	7	16.72	18.47	
2	14	19.26	21.13	1960.60
3	28	21.06	23.93	

Table1.5: Compressive strength and unit weight of pervious concrete with 10% Rice Husk ash

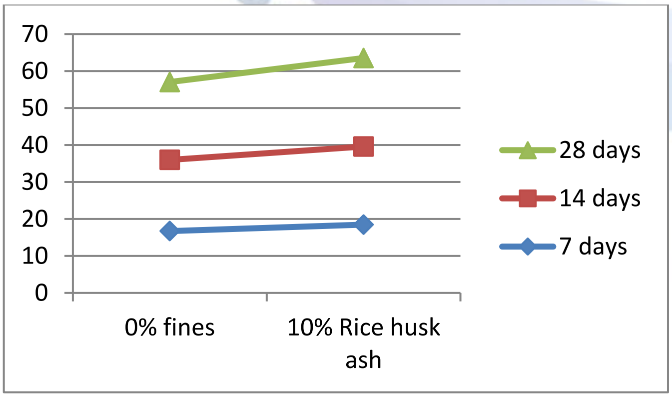


Figure: Graph of age of concrete Vs compressive strength of 10% rice husk ash replacement

4.2.3 Replacement of both Fly Ash (5%) and Rice Husk ash (5%) by 10% of cement

Quantities of materials:

Cement : FA : RA : CA : Water

351kgs : 19.5kg/m³ : 19.5kg/m³ : 1510.60kgs : 117liters

S.No	Age of concrete (days)	Compressive strength of standard pervious concrete (Mpa)	Compressive strength of pervious concrete 10% Fly ash and Rice husk ash (Mpa)	Unit weight after 24 Hours (Kg/m³)
1	7	16.72	16.79	
2	14	19.26	20.33	1952.85
3	28	21.06	23.12	

Table1.6: compressive strength and unit weight of pervious concrete with 10% fly ash and rice husk ash

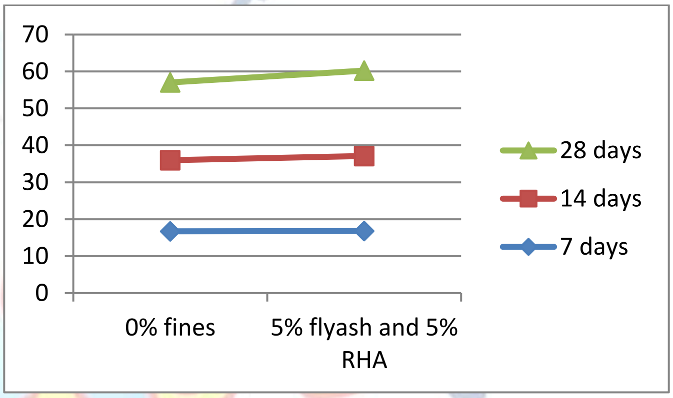


Figure: Graph of age of concrete Vs compressive strength of 5% fly ash and 5% Rice husk ash replacement

From the above three mixes, the cement replacement by mixture of fly ash and rice husk ash gives least values of compressive strength. this may due to different properties of fly ash and rice husk ash may not be homogeneous.

4.3 Permeability

4.3.1 Permeability of standard pervious concrete with 0% fine aggregates

Quantities of materials:

Cement : Fine aggregate : CA : Water

390kg/m³ : 0kg/m³ : 1660kg/m³ : 117liters

S.No	Unit weight of standard pervious concrete (0% fines) after 24 hours (kg/m³)	Coefficient of permeability K (cm/sec)

1	2118.84	1.02

Table1.7:Unit weight and coefficient of permeability of standard pervious concrete with 0% fines

4.3.2 Pervious concrete with 10% fly ash as cement replacement

Quantities of materials:

Cement : Fine aggregate : CA : Water

351kg/m³ : 0kg/m³ : 1660kg/m³ 117liters

S.No	Unit weight of standard pervious concrete (0% fines) after 24 hours (kg/m³)	Coefficient of permeability K (cm/sec)
1	1949.76	0.59

Table1.8: Unit weight and coefficient of permeability of standard pervious concrete with 10% Fly ash as cement replacement

4.3.3 Permeability of pervious concrete with 10% Rice Husk ash as cement replacement

Quantities of materials:

Cement : Fine aggregate : CA : Water

351kg/m³ : 0kg/m³ : 1660kg/m³ : 117liters

S.No	Unit weight of standard pervious concrete (0% fines) after 24 hours (kg/m³)	Coefficient of permeability K (cm/sec)
1	1949.76	0.53

Table1.9: Unit weight and coefficient of permeability of standard pervious concrete with 10% rice husk ash as cement replacement

4.4 Comparisons

4.4.1 Compressive strength comparison of standard pervious concrete and pervious concrete with cement replacement:

S. No	Days	Standard pervious concrete with 0% fines, Mpa	Pervious concrete with 10%FA as cement replacement,Mpa	Pervious concrete with 10% RHA as cement replacement,MPa	Pervious concrete with 10% FA and RHA as, MPa
1	7	16.72	17.26	19.92	17.79
2	14	19.26	19.92	21.13	20.33
3	28	21.06	22.87	23.93	23.12

FA = Fly ash RHA = Rice Husk ash

Table2.0: Compressive strength of pervious concrete with cement replacement

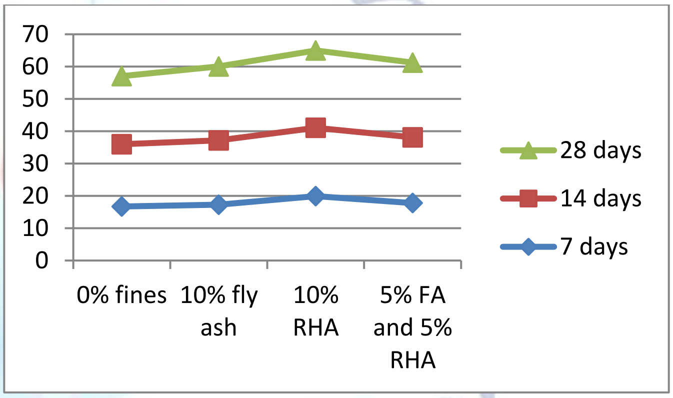


Figure: Graph of age of concrete Vs compressive strength value comparisons with the cementitious materials

4.4.2 Permeability Comparisons

S.No	Standard pervious concrete with 0% fines (cm/sec)	Pervious concrete with 10% fly ash as cement replacement (cm/sec)	Pervious concrete with 10% rice husk ash as cement replacement (cm/sec)
1	1.02	0.59	0.53

Table2.1: Coefficient of permeability of pervious concrete with addition of different quantities of fine aggregates and cementitious materials

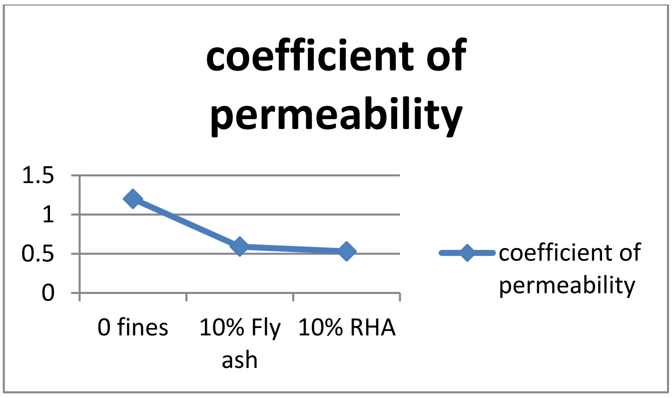


Figure: Graph of coefficient of permeability of pervious concrete with addition of cementitious materials

4.4.3 Unit weight Comparisons

S.No	Standard pervious concrete with 0% fines Kg/m³	Pervious concrete with 10% fly ash as cement replacement Kg/m³	Pervious concrete with 10% rice husk ash as cement replacement Kg/m³	Pervious concrete with 10% FA and RHA as, Kg/m³
1	2112.20	1941.92	1960.60	1931.85

Table2.2: Unit weight of pervious concrete with cementitious materials replacement

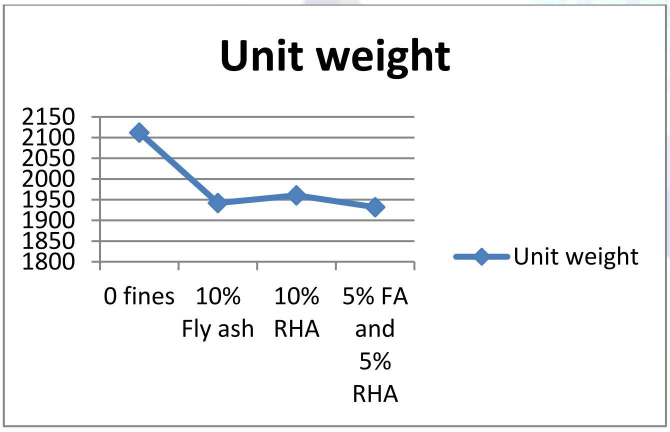


Figure: graph of unit weight of pervious concrete with cementitious materials replacement

4.5 Infiltration test on pervious concrete

Pervious concrete pavement does not look or behave like conventional concrete pavement….. Typical pervious concrete has between 15% and 25% voids. This would allow for infiltration rates of between 10-20*103mm/hr.

Conclusion

- The size of coarse aggregates, water to cement ratio and aggregate to cement ratio play a crucial role in strength of pervious concrete.
- The void ratio and unit weight are two important parameters of pervious concrete in the context of mix design.
- The compressive strength of pervious concrete is increased by 8.59 % when 10% Fly ash was replaced in the place of cement.
- The compressive strength of pervious concrete is increased by 13.62 % when 10% Rice Husk ash was replaced in the place of cement.
- The compressive strength of pervious concrete is increased by 9.78 % when 5% Fly ash and 5% Rice Husk ash was replaced in the place of cement.
- The coefficient of permeability is decreased by 42.15 % when 10% cement is replaced by Fly ash in standard pervious concrete.
- The coefficient of permeability is decreased by 48.03 % when 10% cement is replaced by Rice Husk ash in standard pervious concrete.

Scope for future work

- In the past due to the scarcity of cement, the pervious concrete has been used extensively.
- The pervious concrete has lost its importance after successful production of cement in large quantities.
- But now a day, the usage pervious concrete has gained its popularity due to many advantages.
- The urban areas all over the world have become CONCRETE JUNGLES. The discharge of storm water is very difficult problem in the present conditions.
- By using the pervious concrete we can able to recharge the ground water table and the storm water disposal can also be done.
- So, in future to tackle aforesaid problems and to protect people from flood prone areas, the pervious concrete is one effective solution.

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