International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-2S December, 2018

Use of Steel Slag as Coarse and Fine Aggregate in Porous Concrete Pavements

Vishwanath B J, Rex

Abstract: ***Due to increasing demand of raw materials for construction of roads, the environmental eco system is getting imbalanced. Hence there is a need to preserve natural resources by using eco friendly alternative materials. Steel slag is one such alternative material, which is an industrial by product that can be used as an alternative to aggregates in partial replacement in road construction. Slag may be used as both coarse and fine aggregates in cement concrete. Hence in the present study mix design for conventional porous concrete was carried out for different proportion of fine and coarse aggregate (0:100, 10:90, 15:85, 20:80, and 30:70). The optimum dosage of FA:CA for the conventional porous concrete mix, giving high strength with acceptable permeability was fixed i.e 20:80 Then the mix design for porous concrete was carried out for partial replacement coarse and fine aggregates with steel slag in 20:80 mix. i.e Replacing only the coarse aggregate in FA:CA (20:80) mix with the air cooled LD slag in three different proportions such as 10%, 30% and 50% .i.e keeping FA-20% constant and replacing coarse aggregate by slag in 80% of CA and Replacing only the fine aggregate in FA:CA (20:80) with the granulated LD slag in three different proportions such as 30%, 60% and 90% .i.e keeping CA 80% constant and replacing fine aggregate by slag in 20% FA. Finally the mix design properties in terms of strength and permeability are evaluated for the porous concrete prepared with coarse and fine slag.***

Index Choice: Porous concrete; Air cooled LD slag; Granulated LD slag; Coarse aggregate

I. INTRODUCTION

Porous concrete is gaining lot of attention because of its good drainage property. Various environmental benefits such as controlling storm water runoff, restoring ground water supplies, and reducing soil and water pollution have become most important across the world. Porous concrete is a mixture of coarse aggregate, fewer fines or no fine aggregates, cement and other cementitious materials, admixtures and water.

By the construction of porous surface, storm water is given access to filter through pavement and rate of filtration is also depends on the permeability of underlying layer. This allows for filtration of pollutants also. Thus high flow of water through a porous concrete pavement allows rain water to percolate into the ground where the rate of percolation depends on gradation and permeability of supporting layers, reducing storm water runoff, recharging the ground water, thus supporting sustainable construction.

Providing the porous concrete pavements in low traffic volume roads instead of conventional concrete is one of the solutions to overcome pavement premature failure due to stagnation of water on pavement surface.

In developing countries like India, disposal of industrial waste is a major concern. Also preservation of natural Resources like aggregates being the main focus, reusing of waste materials like iron slag, steel slag, scrap tires and so on in the construction of roads is slowly gaining pace to minimize issues of transfer of waste material and consumption of regular assets.

Many literatures indicate use of various types of slags replacing cement. Steel slag is a by-product of steel making process, steel plants generates nearly 500 kg of total slag for one tonne of steel production. Now a day slags are also considered for replacing construction aggregates.

II. OBJECTIVES OF THE RESEARCH

1. To design various porous concrete mixes with different proportions of coarse and fine aggregates and thus achieve optimum mix proportion which satisfies the strength and permeability characteristics.
2. To study and compare the strength and permeability of porous concrete prepared with partial replacement of coarse and fine slag and thus achieve optimum proportion of coarse and fine slag.

III. EXPERIMENTAL WORK

A. Cement

OPC 53 grade cement used in present work and basic properties are conforming to the IS 12269(1987) requirements

SI. No	various tests conducted	Test results	Requirements as per IS 12269(1987)
1	Specific gravity	3.14	-
2	Normal consistency (%)	29	-
3	Initial setting time (sec)	124	Min 30 minutes
4	Final setting time (sec)	388	Max 600 minutes
5	Finesse test (%)	3	Not exceed 10%

TABLE 1: Basic Properties Of Cement

B. Coarse aggregate:

Normal crushed stone of maximum size 20mm was adopted and basic properties are within the limits as specified in IS: 383-1970.

Revised Manuscript Received on December 28, 2018.

Vishwanath B J, Department of Civil engineering, Malla Reddy Engineering College (A), Hyderabad, India
Dr. Rex, Department of Civil engineering, Malla Reddy Engineering College (A), Hyderabad, India

SI. No	Various tests conducted	Test results
1	Aggregate Impact Value (%)	23.2%
2	Aggregate Crushing Value (%)	24.12%
3	Specific gravity	2.69
4	Water absorption (%)	0.6%
5	Loose bulk density (kg/m^3)	1308
6	dry rodded bulk density (kg/m^3)	1526

Table 2: Physical Properties Of Coarse Aggregates

C. Fine aggregate:

Fine aggregate plays important role in porous concrete. Adding fine aggregate is responsible for permeability and strength characteristics. In present study river sand used as fine aggregate which confirming to the zone II as specified in IS: 383-1970.

SI. No	various tests conducted	Test results
1	Specific gravity	2.65
2	Water absorption (%)	1.26
3	Fineness modulus	2.8
4	Loose bulk density (kg/m^3)	1527
5	Dry rodded bulk density (kg/m^3)	1639

Table 3: Physical Properties Of Fine Aggregates

ACS – Air Cooled LD Slag:

ACS Slag was used to replace coarse aggregate in present work.

GS – Granulated LD Slag:

GS Slag was used to replace fine aggregate in present study.

SI. No	various tests conducted	Test results	
		Air cooled LD slag (coarse)	Granulated LD slag (fine)
1	Aggregate impact value (%)	10.8	-
2	Aggregate crushing value (%)	14.3	-
3	Specific gravity	3.17	3.42
4	Water absorption (%)	2.19	0.62
5	Loose bulk density (kg/m^3)	1628	1695
6	Rodded bulk density (kg/m^3)	1833	1851

Table 4: Physical Properties Of Steel Slag

D. Procedure

1. Initially the mix design for conventional porous concrete was carried out for different proportion of fine and coarse aggregate (0:100, 10:90, 15:85, 20:80, and 30:70). The optimum dosage of FA:CA for the conventional porous concrete mix, giving high strength with acceptable permeability was fixed i.e 20:80
2. Then the mix design for porous concrete was carried out for partial replacement coarse and fine aggregates with steel slag as follows,

a) Replacing only the coarse aggregate in FA:CA (20:80) mix with the air cooled LD slag in three different proportions such as 10%, 30% and 50% .i.e keeping FA-20% constant and replacing coarse aggregate by slag in 80% of CA.

b) Replacing only the fine aggregate in FA:CA (20:80) with the granulated LD slag in three different proportions such as 30%, 60% and 90% .i.e keeping CA 80% constant and replacing fine aggregate by slag in 20% FA.

Finally the mix design property in terms of strength and permeability is evaluated for the porous concrete prepared with coarse and fine slag.

E. Mix Design guidelines

Pervious concrete and the conventional concrete have the common basic elements except that it has voids in the range of 15% to 35%. The mix design was carried out using the guidelines of IS 10262:2009. In the present study volume of voids was taken as 15%.

The steps to be followed in mix design

1. Different trial mixes was carried out to fix the water cement ratio and cement content i.e. 0.35 and 370 kg/m^3 respectively.

2. Considering total volume of concrete as one unit, the total volume of aggregate is calculated by deducting the volume of paste and voids from the unit volume.

3. Volume of fine and coarse aggregate is calculated for different mixes by increasing the fine aggregate from 0 to 30%

Mix FA:CA	C (kg/m^3)	W/C	FA (kg/m^3)	CA (kg/m^3)	Ratio C:FA:CA
0:100	370	0.35	0	1614	1: 0: 4.36
10:90	370	0.35	160	1453	1: 0.43 : 3.9
20:80	370	0.35	240	1372	1:0.65:3.7
30:70	370	0.35	318	1291	1:0.86:3.5
40:60	370	0.35	477	1130	1:1.29:3.05

Table 5: Mix Proportions For Conventional Porous Concrete

C-cement FA-fine aggregate CA-coarse aggregate W/C-water cement ratio

Mix proportion CA:ACS	FA (20%)	CA+ACS (80%)		Ratio C:FA:CA:ACS
		CA	ACS	
	kg/m^3	kg/m^3	kg/m^3	
(90:10)	318	1162	154	1:0.86:3.14:0.42
(70:30)	318	904	460	1:0.86:2.44:1.24
(50:50)	318	646	766	1:0.86:1.75:2.07

Table 6: Ca Replaced By Ac Slag In 80% Of Coarse Aggregate And Keeping 20% Fine Aggregate Constant

Mix proportion FA:GS	FA+GS (20%)		CA (80%)	Ratio C:FA:GS:CA
	FA	GS		
	kg/m^3	kg/m^3	kg/m^3	
(70:30)	223	124	1291	1:0.60:0.34:3.5
(40:60)	128	247	1291	1:0.35:0.67:3.5
(10:90)	32	370	1291	1:0.09:1.00:3.5

Table 7: Fa Replaced By Gld Slag In 20% Of Fine Aggregate And Keeping 80 % Coarse Aggregate Constant

IV. TESTS CONDUCTED

A. Compression test

Test procedure was followed as per IS 516-1959 for cubes sizes 150mmx150mmx150

B.Flexural strength test

Test procedure was followed as per IS 516-1959 for beam sizes 100mmX100mmX500mm

C. Permeability Test

Constant head Permeability test was conducted on 28 days cured cylindrical moulds. The test setup prepared which simulates flow of water as same as in site condition.

- The cylindrical mould of dimensions 300mm height and 150mm diameter was casted and curing is done for 28 days for all combinations.
- The coefficient of permeability was determined by Darcy's Law equation, as given below

$$k = \frac{Q}{i \times A}$$

Where,

k = coefficient of permeability in cm/sec,

Q = quantity of water collected in time t seconds,

A = cross sectional area of specimen in cm^2,

i = hydraulic gradient (h/L),

D. Void Ratio Test

Void ratio was determined for cylindrical mould after 28 days curing.

$$\text{Void ratio} = \frac{\text{volume of water collected}}{\text{total volume of cylinder}} \times 100$$

FIG 1: PERMEABILITY TEST OF POROUS MOULD

V. TEST RESULTS

Mixes (FA:CA)	Compressive strength (Mpa)		Flexural strength (Mpa)		Permeability m/day	Void ratio
	7 days	28 days	7 days	28 days	28 days	28 days
0:100	11.02	14.77	1.76	2.23	372	23.42
10:90	12.89	19.73	2.01	2.53	242	12.31
15:85	14.40	23.81	2.51	3.14	220	10.34
20:80*	**18.02**	**31.03**	**2.76**	**4.42**	**203**	**9.37**
30:70	22.18	35.91	3.21	4.85	104	4.71

Table 8: Laboratory Test Results For Conventional Mixes

Mixes	Compressive strength (Mpa)		Flexural strength (Mpa		Permeability m/day	Void ratio
	7 days	28 days	7 days	28 days	28 days	28 days
CA1ACS (90:10)	18.32	27.02	2.99	3.87	203	9.08
CA2ACS (70:30)	18.90	28.68	3.35	4.21	212	9.69
CA3ACS* (50:50)	**20.56**	**30.18**	**3.56**	**4.57**	**232**	**11.23**
FA1GS (70:30)	21.04	31.97	3.37	4.27	212	9.33
FA2GS (40:60)	20.21	33.15	3.34	4.40	195	8.71
FA3GS* (10:90)	**23.32**	**38.94**	**3.95**	**4.99**	**188**	**8.01**

Table 9: Laboratory Test Results For Non Conventional Mixes (Partial Replacement Of Coarse Aggregate By Ac Slag And Fine Aggregate By Gld Slag)

VI. CONCLUSIONS

1. From conventional porous concrete it is observed that increase in the percentage of fine aggregates increases in compressive strength .i.e 0% of fine aggregates shows least strength because of high porosity. By increasing the sand content, voids get filled and forms better interlocking behavior. Higher percentage of sand gives maximum strength this is due the availability of sand for better lubrication and reduces the inter particle friction.

2. Permeability of pervious concrete is mainly depending on percentage of void ratio and compaction of specimen, which is also depending on gradation of mix adopted. Keeping the gradation same for all mixes, the percentage of void ratio varies with increase in the fine contents. Higher the void ratio higher is the permeability.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

From results it has been observed that permeability for all mixes ranges between 104 to 372m/day with maximum achieved for mix 0:100.and among all mixes FA:CA (20:80) showed required strength with an acceptable permeability so this considered as an optimum mix.3. From coarse slag and fine slag replacement, compressive strength of non conventional porous concrete increased as the percentage of AC slag (10%, 30%, and 50%) which is replaced in 80% of coarse aggregate and GLD slag (30%, 60% and 90%) replaced in 20% of fine aggregate and permeability increased as the percentage of AC slag increase (10%, 30% and 50%),it is because AC slag is porous in nature . but in another case i.e replacement of GLD slag (30%, 60% and 90%) the permeability value get decreased due to formation of slurry which results in the reduction of voids. Therefore to minimize this slurry w/c ratio should be balanced.

REFERENCES

1. Tennis,P,O, Lemming,M L and Akers,D J "Pervious concrete pavements", Special publication by the Portland cement association and the National Ready mixed concrete association , 2004.
2. Ghafoori,N,Dutta.S. "Laboratory investigation of compacted No fines concrete for paving materials". Journal of material in civil engineering vol 7, no 3,183-191, 1995.
3. Darshan S. Shah, Prof. J.R. Pitroda, "Pervious Concrete: New Era for Rural Road Pavement", (IJETT) Vol: 4, August 2013.
4. Wang K, Schaefer V R, Kevern J T and Suleiman M T. "Development of Mix Proportion for Functional and DurablePervious Concrete", Submitted to Concrete Technology Forum-Focuson Pervious Concrete, National Ready Mix Concrete Association,Nashville, TN, May 24-25, 2006, pp. 1-12.
5. PraveenkumarPatil and Santosh M Murnal, "Study on the Properties of Pervious Concrete" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 3 Issue 5, May – 2014, pp.819-822.
6. Yang,J, Jiang,G, "Experimental study on properties of pervious concrete pavement materials," Cement and Concrete Research,Vol.33 pergamon,2003.
7. Richard C Meininger, "No-Fine Pervious Concrete for Paving",Concrete International, vol.10, 1988, pp. 20-2
8. Guo, Peng Tang, Boming Zhu, HongzhouFeng, Min Zhang, Yibo. "Pavement performance of steel slag pervious concrete" International Conference on Transportation Engineering (ICTE), Chengdu, China, July-2011, pp. 1654-1659.