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EXPERIMENTAL STUDY ON EFFECT OF FLY-ASH ON MECHANICAL PROPERTIES OF PERVIOUS CONCRETE

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ABSTRACT: Natural resources are increasingly exhausted at present due to rapid urbanization and infrastructure developments. Most of the land areas in countries are occupied with highly dense structures and impermeable concrete pavements. Less quantity of rainwater enters into the underground because of the impermeability nature of concrete surfaces. Various approaches are being followed by engineers to protect and retain the world's natural ecosystem. One such approach is the application of pervious concrete, which is a special type of concrete, consisting of high porosity and permeability. Pervious concrete is a new construction material used to reduce storm water runoff and to recharge the groundwater level. Pervious concrete is a composite material consisting of coarse aggregate bonded together with cement paste with or without fine aggregate, admixtures and additives. It is used as paving material for the parking areas, low volume pavements and sidewalks. Permeable concrete construction is gaining rapid popularity in most of the places in the world because of its ability to reduce urban heat and noise mitigation. It has a capability to solve the important environmental issues, hence it is considered as a suitable management practice for the sustainable development. The pores in the pervious concrete influence many properties. Hence, the detailed examination and necessary testing are to be carried out to understand the characteristics of the pervious concrete at macro and micro level by changing the content of ingredients. The main objective of this research work is to evaluate the properties and performance of the pervious concrete experimentally and theoretically by varying aggregate size, and addition of fly ash Test on the pervious concrete was conducted at fresh and hardened state. Slump was observed at fresh state, mechanical properties were examined in this research work at hardened state. The properties of the pervious concrete were tested by aggregate sizes such as 4.75 mm–9.5 mm (S1), 9.5 mm–12.5 mm (S2) and 12.5 mm–16 mm (S3). In that

optimum mix, fly ash were added with cement from 5% to 20% at 5% interval. The addition of fly ash with smaller size aggregate mix showed better mechanical properties.

INTRODUCTION: The rapid urbanization and infrastructure developments cause densely constructed buildings and air proof concrete pavements in several parts of the country. The natural resources are increasingly consumed at present to build these structures. Many parts of the countries are facing problems of depletion in groundwater table drastically due to lack of percolation of rainwater into the subsoil and unplanned water withdrawal for agricultural and industrial purposes. The impermeable concrete construction restricts the penetration rainwater into underground that influences increased surface runoff, excess flooding and overburdening in existing drainage system. Throughout the world, various strategies are being followed by engineers to protect the natural ecosystem from the above mentioned adverse environmental impacts. One among them is the application of pervious concrete with interconnected pores that allow air and water into the ground surface. Pervious concrete functions on the concept of “When it Rains, it Drains”. The pervious concrete pavements become popular as an effective stormwater management tool to reduce surface runoff and concentration of pollutants (Shu et al. 2011).

MIX DESIGN FOR M25 GRADE AS PER IS 10262:2009

Details of material:

Water / cement ratio	- 0.40
Dry rodded density (unit weight)	- 1741.20 k/m^3
Specific gravity of coarse aggregate	- 2.75
Absorption	- 1.2 %
Void content	- 20 %

No fine aggregate

Step-1: Determine aggregate weight:

For 10 mm coarse aggregate with no fine aggregate, code recommends b/bo of 0.99 with dry rodded density given as 1741.20 kg/m^3.

$$Wa = 1741.12*0.99*1$$
$$= 1723.78 \text{ Kg}$$

Step-2: Adjust to SSD weight:

Given that the percentage absorbance of 1.2%

$$Wssd = 1723.78*1.012$$
$$=1744.46 \text{ Kg}$$

Step-3: Determine paste volume:

For 20% voids(well compacted curve), the percentage is 15% of a cubic meter is 0.15

Thus Vp=0.15m3

Vp=[cement/(3.15*1000)] + [water /1000)]

=[C/(3.15*1000)] + [W /1000)]

Substituting water/cement ratio – w/cm.

Thus,

W = (w/cm)c,

Vp = [c/(3.15*1000)] + [(w/cm)c/1000]

= (c/1000)[3.15+(w/cm)]

Step-4 Determine Cement content:

C = [Vp/(0.315+w/cm)]1000kg/m3

C= [0.15/(0.315+0.40)]1000

C = 314.68Kg

Step-5: Determine water content:

W = c(w/cm)

=314.68*0.4

W = 125.87Kg

Step-6: Determine solid volume:

Aggregate volume (Va) = 1744.46/(2.75*****1000)

= 0.634m3

Cement volume (Vc) = 315(3.15*1000)

= 0.099m3

Water volume (Vw) = 125.87/1000

= 0.125m3

Total Solid volume (Vs) = Va+Vc+Vw

= 0.634+0.099+0.125

= 0.858m3

Step-7: Determine percent voids:

Percent voids = (Vtotal – Vs)/Vtot*100

Percent voids = (1-0.858)*100

=14.2%

Step-8: Check estimated porosity:

At 14% voids, the perculation approx. 10 in/min

Step-9: Iterative trail batching and testing:

The trail batch weights per cubic meter are as follows

Cement	=	315 kg
Water	=	125.87 kg
10mm aggregate	=	1745 kg(SSD)
Total weight	=	2185.87 kg
Density	=	2185kg/m3

CASTING PROCEDURE:

Preparation of moulds:

The moulds for casting concrete cubes & cylinders are to be prepared carefully before casting. All moulds should be fitted properly. Oiling is done on the surface of the moulds for easy removal of specimens.

Calculation of materials:

The required materials are calculated for casting. The materials should be dry and well graded.

Mixing of concrete:

The prepared materials are mixed well uniformly to cast the cubes.

Figure1: Mixing of concrete

Casting Cubes:

Place the concrete into the moulds with a trowel. The concreting should be done in layers of 5cm each. For each layer proper compaction is required by tamping bar of 25 blows. After compacting top layer, the moulds are vibrated on the vibrating table for better mixing and bonding.

Demoulding:

The specimens should be removed after proper setting of concrete. The specimens are remoulded and processed for curing.

Casting of Cubes:

For each trail 3 cube specimens were casted for calculating 7 days and 28 days strengths. The dimensions of specimen for cube are of 150mm x 150mm x 150mm.

Casting of Cylinders:

For each trail 3cylinder specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the cylindrical specimen are of

Height = 300mm and Diameter = 150mm

Curing of Specimens:

The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the curing tank therefore cubes are cured in fresh water. Curing is most important process in concreting. Concrete strength increases with age of curing. The specimens should be kept in curing tank for better improvement in strength. Generally curing is done by ponding curing tanks. The water used for concrete curing should be free from salinity, scrap, vegetation and chemicals.

We need to change the water for every 7 days of curing. The specimens are tested for 7 days and 28 days curing.

Figure 2: Curing of test specimens

FRESH PROPERTIES:

Fresh properties of concrete are observed at the time of concreting. To measure the fresh properties of concrete workability tests are very important. If concrete is good in workability will shows better properties in its life time. Before pouring concrete into the moulds we need to check the workability by slump cone method.

Slump cone method:

Slump test is the most commonly used method for measuring consistency of concrete which is employed either in laboratory or at site work. The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a cone having the internal dimensions as under:

Bottom diameter : 20 cm

Top diameter : 10 m

Height : 30 m

The thickness of the metallic sheet for the mould should not be thinner than 1.6mm. For tamping the concrete, a steel tamping rod is 16mm diameter 0.6m along with bullet is used. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each approximately 1/4th of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. By using the tamping rod or a trowel strike of the excess concrete above the slump cone. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as slump of concrete. The difference between actual height and formed cone height 31 will give slump value. The difference in height is taken as slump of concrete. For the present work, slump tests were conducted as per IS: 1199 -1959 for all mixes.

Figure 3: Slump cone arrangement

Figure 4: slumps testing

RESULTS AND DISCUSSIONS

Figure 5.1: compressive strength test

SLUMP CONE: The workability of pervious concrete can be assessed by using slump cone. It was observed that slump values increased with rise of fly ash in cement. Using 4.75mm aggregate the slump values was increased to 80 to 162 mm and using 10 mm aggregate the slump value was increased to 90 to 167 mm and also using 12.5mm aggregate the slump value was increased to 95 to 160 mm. the slump was increased due to the ball bearing action of spherically shaped fly ash particles.

Slump cone results:

Slump cone (mm)	CF 0	CF 5	CF 10	CF 15	CF 20	CF 25	CF 30
4.75mm	80	100	120	136	145	150	162
10mm	90	107	114	125	130	145	167

12.5mm	**95**	**103**	**109**	**115**	**130**	**145**	**160**

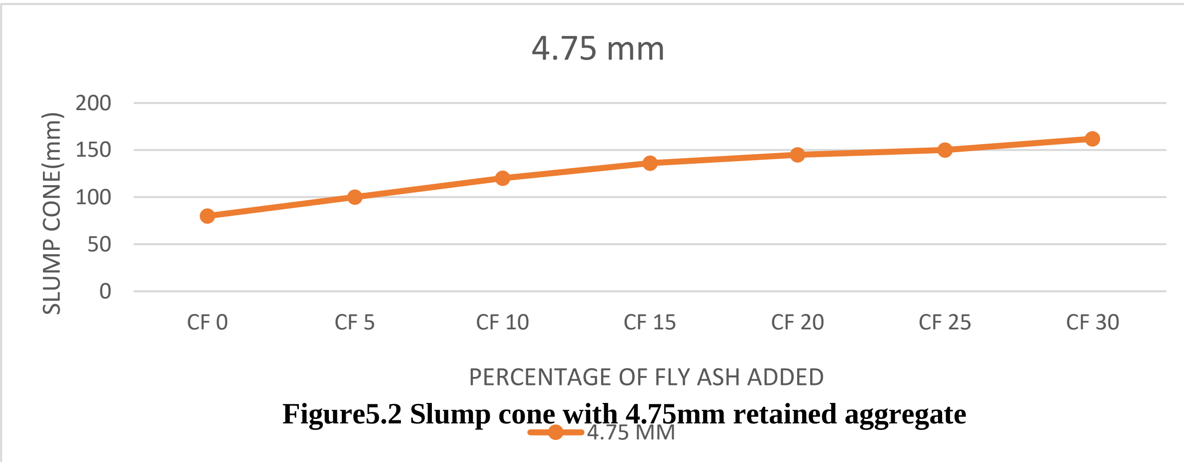

Figure5.2 Slump cone with 4.75mm retained aggregate

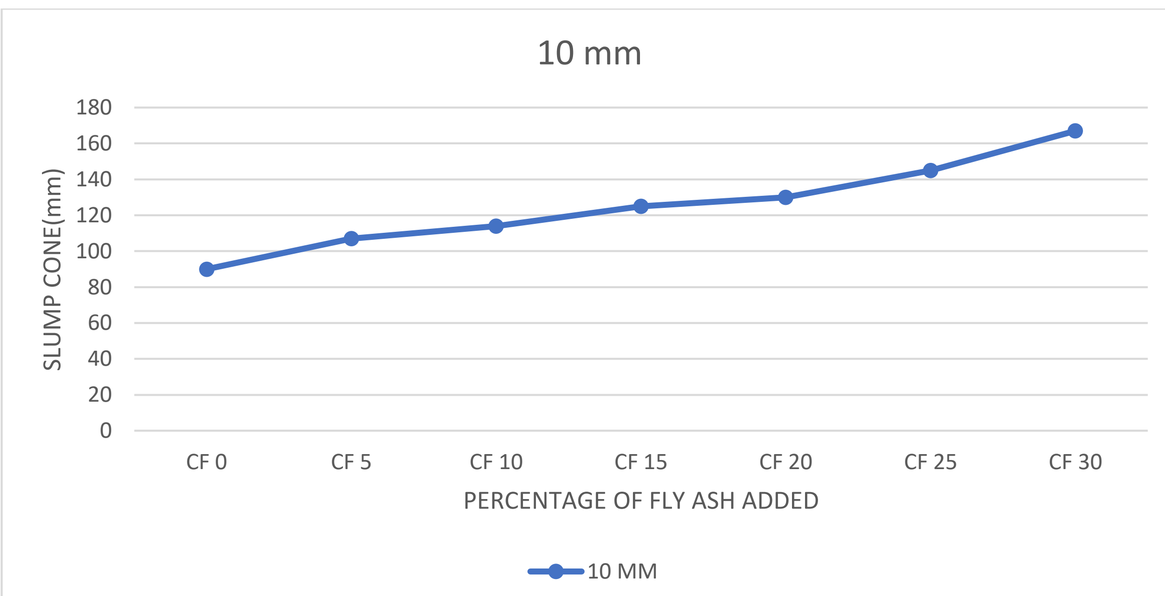

Fig5.3 Slump cone with 10mm retained aggregate

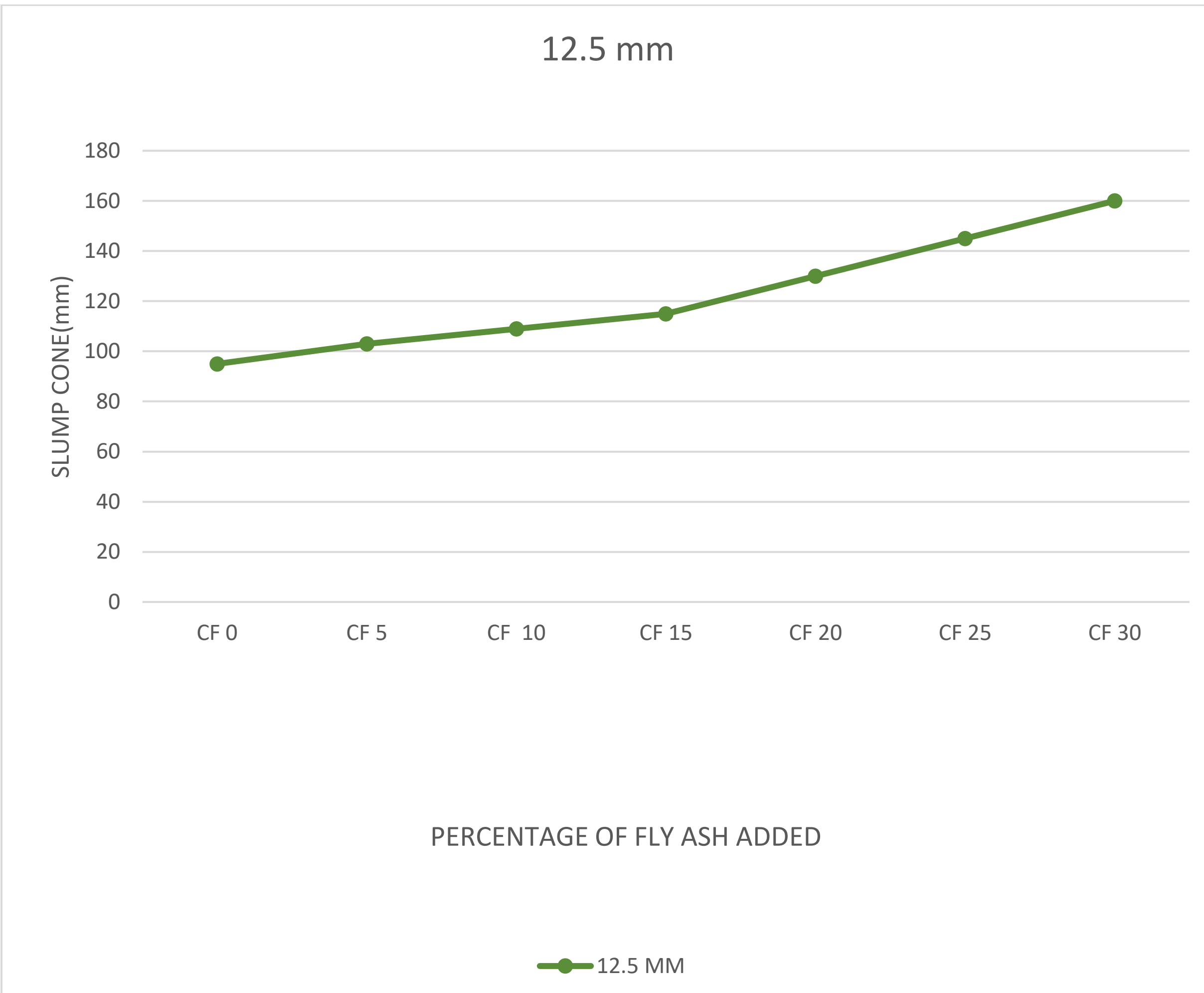

Fig:5.4 Slump cone with 12.5mm retained aggregate

Compressive strength:

The influence of fly ash replacement level on pervious concrete compressive strength as shown in graph. The test is carried out on cubic specimen of size 150 x150 x150mm each specimen is tested for 7days and 28 days. It is clear that the use of fly ash has a significant effect on compressive strength due to the pozzolanic effect. Where increase in fly ash content to extent increases the compressive strength of different mixes of pervious concrete 20% fly ash content gives the maximum compressive strength. For 7 days the compressive strength was decreased from 6.87 MPa to 4.88 MPa for 4.75 mm aggregate and for 10mm compressive strength was decreased from 6.79 MPa to 4.67 MPa and 12.5mm compressive strength was decreased from 6.43 MPa to 4.55 MPa. For 28 days compressive strength was increased for 0% to 20% fly ash in cement and decreased in 20% to 30% fly ash for 4.75 ,10 and 12.5 mm aggregate. For 4.75 mm aggregate was increased from 17.99 MPa to 21.84 MPa and decreased from 21.84 MPa to 17.23 MPa. For 10 mm aggregate was increased from 16.13 MPa to 20.38 MPa and decreased from 20.38 MPa to 17.1 MPa. For 12.5 mm aggregate was increased from 14.64 MPa to 19.12 MPa and decreased from 19.12 MPa to 15.62 MPa.

Table 1 Compressive strength results for 7 days:

Sieve Size/ Mix name	Compressive Strength (MPa) at 7 days						
	CF 0	CF 5	CF 10	CF 15	CF 20	CF 25	CF 30
4.75mm	6.87	6.5	5.9	5.6	5.3	5.01	4.88
10mm	6.79	6.42	5.8	5.4	5.03	4.84	4.67
12.5mm	6.43	5.93	5.75	5.12	4.93	4.71	4.55

Table 2 Compressive strength results for 28 days:

Sieve Size/ Mix name	Compressive Strength (MPa) at 28 days						
	CF 0	CF 5	CF 10	CF 15	CF 20	CF 25	CF 30
4.75mm	17.99	18.32	19.34	20.45	21.84	19.63	17.23
10mm	16.13	17.41	18.80	19.35	20.38	19.61	17.1
12.5mm	14.64	15.20	17.11	18.76	19.12	17.99	15.62

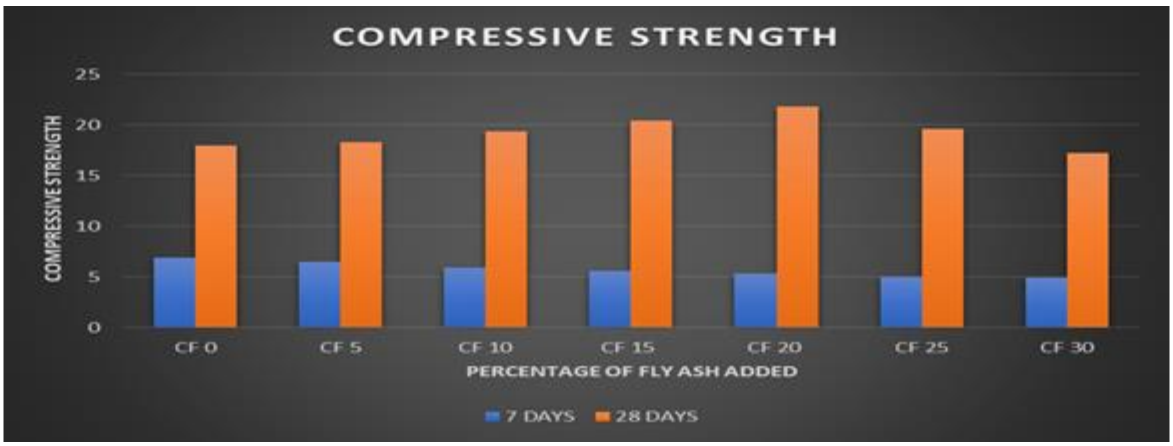

Fig:5.5 Compressive strength with 4.75mm retained aggregate

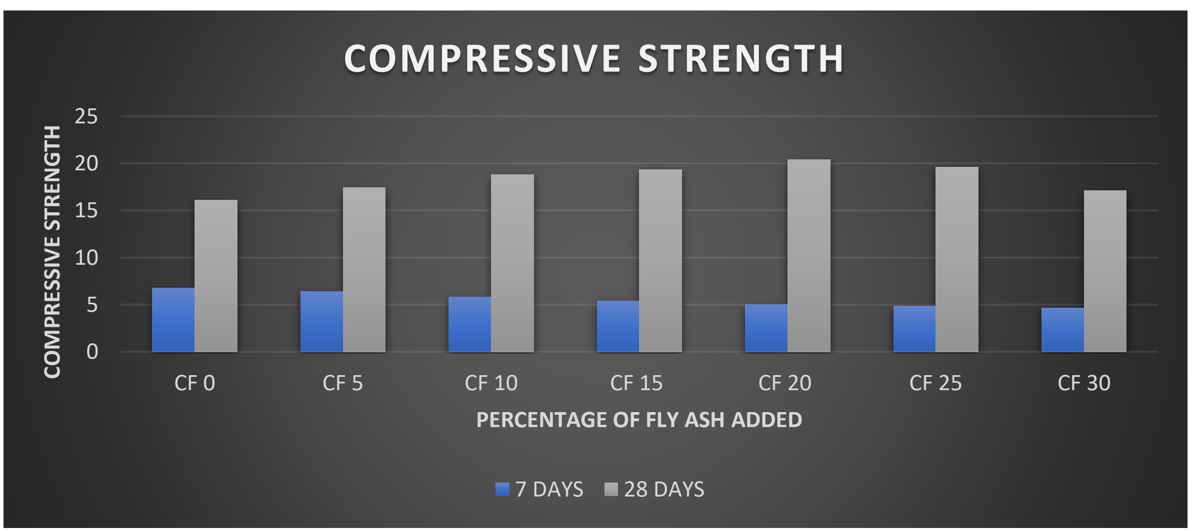

Fig5.6 Compressive strength with 10mm retained aggregate

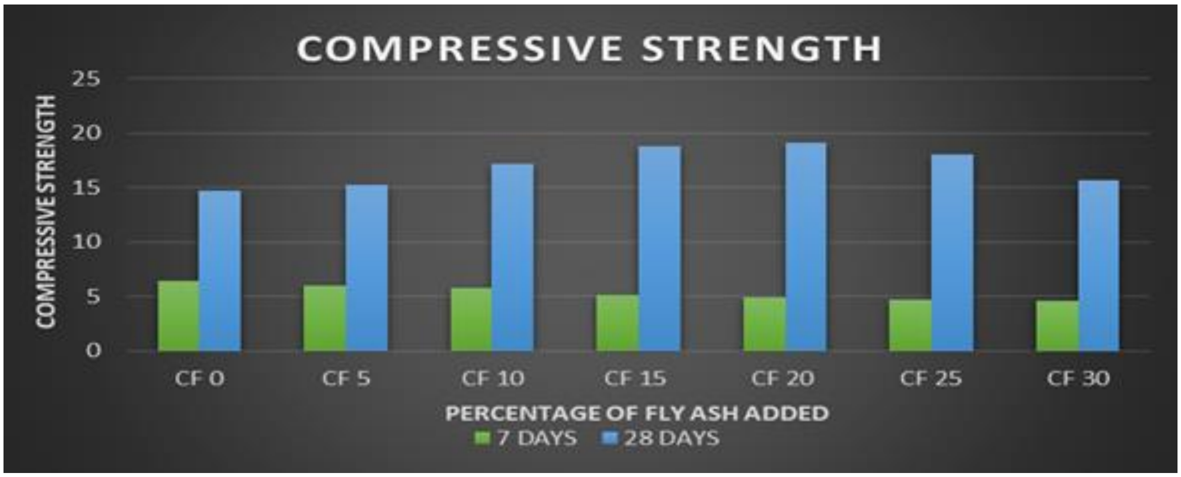

Fig: 5.7 Compressive strength with 12.5mm retained aggregate

Split tensile strength:

The influence of fly ash levels on pervious concrete split tensile strength. The test is carried out on cylindrical specimen of size 150 x 300 mm. Each specimen is tested for 7 days and 28 days. Due to the pozzolanic effect of fly ash the split tensile strength increases the fly ash content increases to certain extent. 20 % fly ash content gives the maximum split tensile strength. For 7 days the split tensile strength was decreased from 2.32 MPa to 1.98 MPa for 4.75 mm aggregate and for 10mm split tensile strength was decreased from 2.26 MPa to 1.95 MPa and 12.5mm. split tensile strength was decreased from 2.14 MPa to 1.9 MPa. For 28 days split tensile strength was increased from 0% to 20% and decreased 20% to 30% for 4.75 ,10 and 12.5 mm aggregate. For 4.75 mm aggregate was increased from 3.09 MPa to 3.47 MPa and decreased from 3.47 MPa to 3.12 MPa. For 10 mm aggregate was increased from 2.91 MPa to 3.39 MPa and decreased from 3.39 MPa to 3.08 MPa. For 12.5 mm aggregate was increased from 2.84 MPa to 3.31 MPa and decreased from 3.31 MPa to 3.01 MPa.

Split Tensile Strength results for 7 days:

Sieve Size/ Mix name	Split tensile Strength (MPa) at 7 days						
	CF 0	CF 5	CF 10	CF 15	CF 20	CF 25	CF 30
4.75mm	2.32	2.3	2.26	2.22	2.18	2.04	1.98
10mm	2.26	2.21	2.17	2.15	2.1	2.01	1.95
12.5mm	2.14	2.12	2.09	2.05	1.99	1.96	1.9

Split Tensile Strength results for 28 days:

Sieve Size/ Mix name	Split tensile strength (MPa) at 28 days						
	CF 0	CF 5	CF 10	CF 15	CF 20	CF 25	CF 30
4.75mm	3.09	3.14	3.23	3.35	3.47	3.26	3.12
10mm	2.91	3.06	3.17	3.31	3.39	3.18	3.08
12.5mm	2.84	2.98	3.12	3.27	3.31	3.11	3.01

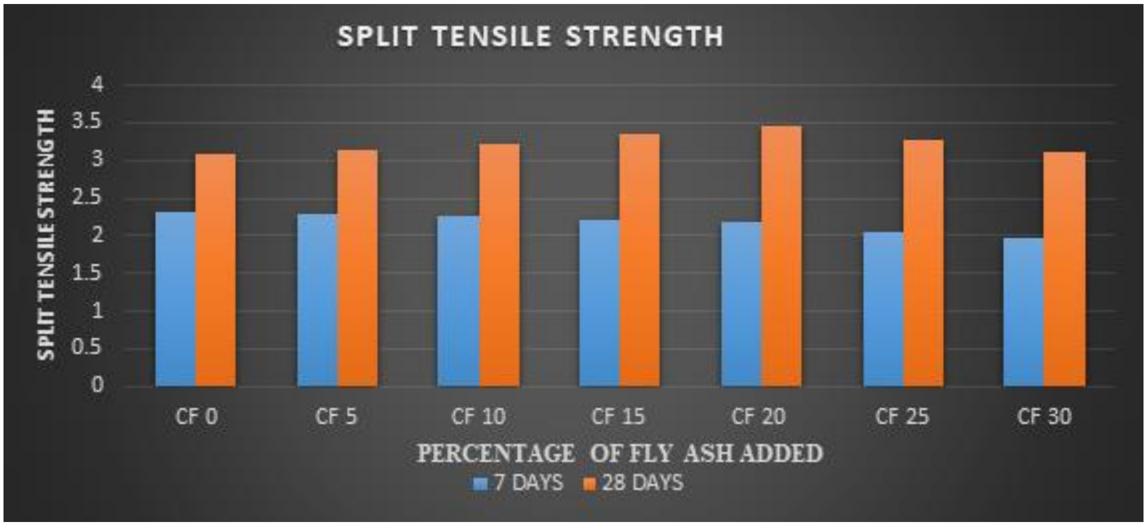

Fig:5.8 **split tensile strength with 4.75mm retained aggregate**

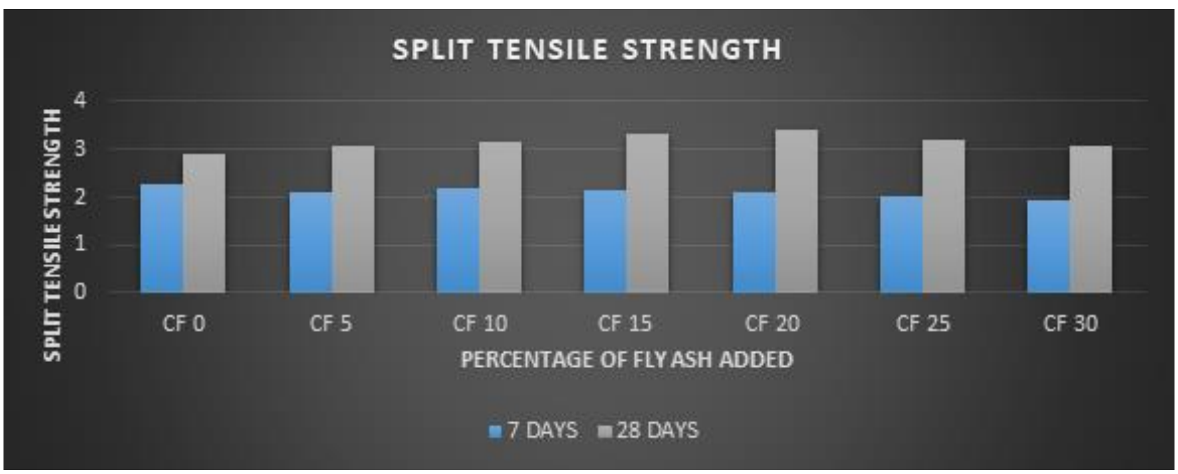

Fig: 5.9 split tensile strength with 10mm retained aggregate

Fig:5.10 split tensile strength with 12.5mm retained aggregate

CONCLUSION

STRENGTH PROPERTIES:

The experimental tests were conducted to determine the basic strength properties such as compressive and split tensile using different mixes of pervious concrete. In this study, investigation was carried out on pervious concrete containing three different sizes of aggregate excluding fine aggregate with and without admixtures.

slump cone:

By the addition of fly ash with 0%,5%,10%,15%,20%,25%,30% for the aggregate then the slump is increasing.it was observed that by the rise of fly ash by 30% the workability of pervious concrete has been enhanced to 50%.in addition aggregate size also influenced the workability, the aggregate size is proportional to the workability.

Compressive Strength:

Generally, the changing aggregate size from bigger size to smaller size shows improvement in strength properties due to increase in paste thickness surrounding the aggregate. It was found that addition of fly ash in pervious concrete increases the strength up to 20% for all three different aggregate mixes and then further addition decreases the strength. Addition of 0%,5%,10%,15%,20%,25% and 30% of flyash in pervious concrete revealed maximum strength due to improved bonding effect between the aggregate and cement paste. The better compressive strength was obtained from the fly ash blended mix due to pozzolanic action and micro filler effect results in dense structure.

Split Tensile Strength:

The split tensile strength increases along with the increase in compressive strength. The compressive strength of pervious concrete is average of 6 times of the tensile strength for all pervious concrete mixes.

The increase in split tensile strength was observed with the addition of 0%,5%,10%,15%,20%,25%,30% of fly ash beyond that there is no further improvement in split tensile strength due to the presence of inactive particles. The ultimate maximum split tensile strength was obtained by incorporating 20% of fly ash with smaller size aggregate blended pervious concrete mix when compared with other mixes. The relation between split tensile strength and compressive strength of pervious concrete shows good correlation for all mixes.

REFERENCE

1. ACI 522R 2010, Report on pervious concrete, ACI Committee, 522, Farmington Hills, p.38.

2. ACI Committee 544, 1989, 'Measurement of Properties of Fiber Reinforced Concrete', American Concrete Institute.

3. Adewumi, AA, Owolabi, TO, Alade, IO & Olatunji, SO, 2016, 'Estimation of physical, mechanical and hydrological properties of permeable concrete using computational intelligence approach', Applied Soft Computing, vol. 42, pp. 342-350.

4. Ahangari, K, Najafi, Z, Sheikh Zakariaee, SJ & Arab, A, 2013, 'Estimating strain changes in concrete during curing using regression and artificial neural network', Journal of Construction Engineering, pp.1-8.

5. Akand, L, Yang, M & Gao, Z, 2016, 'Characterization of pervious concrete through image based micromechanical modeling', Construction and Building Materials, vol.1 no.14, pp. 547-555.

6. Allard, F and Atalla, N, 2009, 'Propagation of Sound in Porous Media', John Wiley & Sons Ltd.

7. ASTM C 1688, 2008, 'Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete,' Annual Book of ASTM Standards, vol. 4, no. 2.

8. ASTM C 496, 1999, 'Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens', ASTM International.

9. ASTM C 78, 2000, 'Standard test method for flexural strength of concrete', ASTM International, Philadelphia, p. 3.

10. ASTM E 1050, 2008, 'Impedance and Absorption of Acoustical Materials using a Tube', Two Microphones and Digital Frequency Analysis System.

11. ASTM C 143, 2003, 'Standard Test Method for Slump of Hydraulic Cement Concrete', ASTM International.

12. ASTM C 177, 2004, 'Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus', Annual Book of ASTM Standards, West Conshohocken.

13. ASTM C 192, 2012, ‘Standard practice for making and curing concrete test specimens in the laboratory concrete’, ASTM International, West Conshohocken.

14. ASTM C 351, 1999 ‘Standard Test Method for Mean Specific Heat Capacity of Thermal Insulation’.

15. ASTM C 39, 2001, ‘Standard test method for compressive strength of cylindrical concrete specimens’, ASTM International.

16. ASTM C522, 2009, ‘Standard Test Method for Airflow Resistance of Acoustical Materials’, American Society for Testing and Materials, West Conshohocken.

17. ASTM C944, 2012, ‘Standard test method for Abrasion resistance of concrete or mortar surfaces by rotating cutter method’, Philadelphia.

18. Atis, CD, 2003, ‘Abrasion-porosity-strength model for fly ash concrete’, Journal of materials in civil engineering, vol. 15, no. 4, pp. 408-410.

19. Awoyera, PO, Akinmusuru, JO, Dawson, AR, Ndambuki, JM & Thom, NH, 2018, ‘Microstructural characteristics, porosity and strength development in ceramic-laterized concrete’, Cement and Concrete Composites, 86, pp. 224-237.

20. Badida, M, Dzuro, T & Franko, S, 2015, ‘Utilization infrared thermography in the automotive industry to determine faults by using thermal camera Fluke Ti10’, Global Management and Economics, vol. 1, pp. 7-13.

21. Barbhuiya, S, Chow, P & Memon, S, 2015, ‘Microstructure, hydration and nanomechanical properties of concrete containing metakaolin’, Construction and Building Materials, vol. 95, pp. 696-702.

22. Barreira, E & de Freitas, VP, 2007, ‘Evaluation of building materials using infrared thermography’, Construction and building materials, vol. 21, no.1, pp. 218-224.

23. Berryman, JG & Blair, SC, 1987, ‘Kozeny–Carman relations and image processing methods for estimating Darcy’s constant’, Journal of Applied Physics, vol. 62, no. 6, pp. 2221-2228.

24. Bhardwaj, R, Phelan, PE, Golden, J & Kaloush, K, 2006, January, ‘An urban energy balance for the Phoenix, Arizona USA Metropolitan Area’, In ASME 2006 International Mechanical Engineering Congress and Exposition, American Society of Mechanical Engineers, pp. 367-376.

25. Bhutta, MAR, Tsuruta, K & Mirza, J, 2012, ‘Evaluation of highperformance porous concrete properties’, Construction and Building Materials, vol. 31, pp. 67-73. 26. Cahill Associates, 2009, ‘Porous pavement operation and maintenance protocol’.

27. Cengel, Y, 2003, ‘Heat Transfer: A Practical Approach’, McGraw-Hill, New York, pp. 492.

28. Chandwani, V, Agrawal, V & Nagar, R, 2015, ‘Modeling slump of ready mix concrete using genetic algorithms assisted training of Artificial Neural Networks’, Expert Systems with Applications, vol. 42, no. 2, pp. 885-893.

29. Chen, Y, Wang, KJ & Zhou, WF, 2013, 'Evaluation of surface textures and skid resistance of pervious concrete pavement', Journal of Central South University, vol. 20 no. 2, pp. 520-527.
30. Cheng, S, Shui, Z, Li, Q, Sun, T & Yang, R, 2016, 'Properties, microstructure and hydration products of lightweight aggregate concrete with metakaolin and slag addition', Construction and Building Materials, vol. 127, pp. 59-67.
31. Chindaprasirt, P, Hatanaka, S, Chareerat, T, Mishima, N & Yuasa, Y, 2008, 'Cement paste characteristics and porous concrete properties. Construction and Building Materials', vol. 22, no. 5, pp. 894-901.
32. Chopra, M, Kakuturu, S, Ballock, C, Spence, J & Wanielista, M, 2009, 'Effect of rejuvenation methods on the infiltration rates of pervious concrete pavements', Journal of Hydrologic Engineering, vol. 15, no. 6, pp. 426-433. 33. Chu, L, Fwa, T, Fwa & Tan, Kiang, H, 2017, 'Laboratory Evaluation of Sound Absorption Characteristics of Pervious Concrete Pavement Materials', Journal of the Transportation Research Board, vol. 2629, pp.91-103.
34. Coughlin, JP, Campbell, CD & Mays, DC, 2011, 'Infiltration and clogging by sand and clay in a pervious concrete pavement system', Journal of Hydrologic Engineering, vol. 17, no. 1, pp. 68-73.
35. Cox, TJ & D'antonio, P, 2009, 'Acoustic absorbers and diffusers: Theory, Design and Application', CRC Press. 36. Criado, M, Fernandez-Jimenez, A, De La Torre, AG, Aranda, MAG & Palomo, A, 2007, 'An XRD study of the effect of the SiO2/Na2O ratio on the alkali activation of fly ash', Cement and concrete research, vol. 37, no. 5, pp. 671-679.
37. Dahou, Z, Sbartai, ZM, Castel, A & Ghomari, F, 2009, 'Artificial neural network model for steel–concrete bond prediction', Engineering Structures, vol. 31, no. 8, pp. 1724-1733.
38. Deo, O & Neithalath, N, 2010, 'Compressive behavior of pervious concretes and a quantification of the influence of random pore structure features', Materials Science and Engineering: A, vol. 528, no. 1, pp. 402-412. 39. Deo, O, Sumanasooriya, M & Neithalath, N, 2010, 'Permeability reduction in pervious concretes due to clogging: experiments and modeling', Journal of Materials in Civil Engineering, vol. 22, no. 7, pp. 741-751.
40. Deshpande, N, Londhe, S & Kulkarni, S, 2014, 'Modeling compressive strength of recycled aggregate concrete by artificial neural network, model tree and non-linear regression', International Journal of Sustainable Built Environment, vol. 3, no. 2, pp. 187-198.
41. Dong, Q, Wu, H, Huang, B, Shu, X & Wang, K, 2012, 'Investigation into laboratory abrasion test methods for pervious concrete', Journal of Materials in Civil Engineering, vol. 25, no. 7, pp. 886-892.