Mechanical Performance of Low Fine Concrete

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ABSTRACT

World wide natural resources reduced day by day. The natural resource reduction cause change occurs in the environment, affect animals, birds and human being. The cement industry produces cement product but every one ton of cement product made by using 1.1 ton of natural resource and also 1 ton of carbon di-oxide released to the environment. The global warming main cause CO2. So, in this research decided coir husk ash replace by cement constantly 15%. So, the use of cement in concrete 15 percentage reduced. The concrete road made by high dense concrete cause the rain water cannot allow to the soil surface. So, the rain water run off on the concrete surface mixed some pollutant and rain water pollution is occurred. In this research create rain water permeable concrete or low fine concrete. In this concrete density lower compare to the normal concrete. This type of concrete rain water allow to percolate concrete and concrete to the soil and rain water run off reduced. The rain water pollution also reduced. In this research fine aggregate percentage reduced each mix similarly increase porosity and permeability. 20%, 40%, 60%, 80% and 100% reduced fine aggregate step by step in concrete. Fine aggregate 100% reduced specimen achieve high porosity and permeability value and poor mechanical values.

1. INTRODUCTION

In our nation developed advance structural element and high-density concrete used for buildings, bridges, road pavements and airport runways. The high-density concretes achieved highly durable and enhanced mechanical and durability properties. Present days the highly dense concrete used for bus stands, village streets, high way roads. The highly dense concrete is very low voids or porous so water permeability very poor. The village streets almost made by high-density concrete cause the rain water penetration on ground 99 percentage stopped. So, ground water table continuously decreased. Rain water running on the highly dense concrete pavement at the time several pollutants mixed to rain water. The pure rain water converted polluted water. The ground water table decrease day by day similarly water need increased day by day. Present days we are buying water after few years cost of water increase. Modern world cost of water of one litre is 7Rs to 10Rs. In this research increase the ground water table by using porous concrete. [1] Porous concrete made of cement and aggregate; small amount of fine aggregate mixed with water. The porous concrete also knows pervious concrete, permeable concrete. Porous concrete present high voids. [2] The porous concrete big advantage is top surface water easily percolated in the concrete and come out bottom surface. Porous concrete achieves high voids and high permeability. The porosity of porous concrete is 15% to 35%. The porous concrete very suitable for residential foot path, parking areas, swimming pool deck areas, slope stabilization, roads, park walking areas. The porous concrete utilization advantage is ground water table increased, storm water run off reduced, refreshing the water table and aquifer, storm water pollution reduced, increase agricultural developments.

In this investigation low fine concrete (porous concrete) made by ordinary Portland cement, well graded aggregate and small amount of fine aggregate and coir husk ash constantly 5% replacement of cement[3]. The mechanical properties investigated by using compressive strength test and split tensile strength test. Hydraulic properties investigated by using porosity test and permeability tests.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

The two types of cement available in market. One is ordinary Portland cement and another one is Portland pozzolana cement. 33.43.53 grade of cement available in market. OPC without Pozzolanic material and PPC contain same amount of pozzolanic material included. In this research ordinary Portland cement 53 grade utilized. The cement laboratory results are specific gravity of cement is 3.15, consistency 31%, initial setting time is 36min and final setting time is 295min. [4]

2.1.2 Coarse aggregate

Locally available well graded coarse aggregate used in this investigation. The coarse aggregate present important role of low fine concrete or porous concrete. 60% of coarse aggregate size below 20mm and 40% of coarse aggregate size below 10mm used for this study and the coarse aggregate laboratory results are specific gravity of coarse aggregate is 2.75, bulk density is 1625kg/m^3, water absorption is 1% and fineness modulus of coarse aggregate is 6.98. [4]

2.1.3 Fine aggregate

A 4.75 mm sieve is used to characterise fine aggregates as those that pass through but are held at a 0.075 mm sieve. The fine aggregate employed in the current investigation was river sand to Zone-II that complies with IS: 383-2016. It was verified to be devoid of silt, clay, and natural dust as well as clean and inert. the fine aggregate laboratory results are specific gravity of fine aggregate is 2.45, water absorption is 4% and fineness modulus of fine aggregate is 2.7. The fine aggregate every mix similarly reduced 20%, 40%, 60%, 80%,100%. [5]

2.1.4 Coir husk ash

Coir husk ash made by coconut coir pith. The coconut coir pith dried on sunlight and firing the coconut coir pith 500^{0}C, after firing gradually to cool to room temperature produced coir husk ash. The coir husk ash specific gravity is 2.2. 5% of cement replaced by coir husk ash all mix. (*V Balagopal et Al. (2020).Pdf*, n.d.; Venugopal & Sambamurthy, 2018)

2.2 Mix design

The mix proportion arrived from above materials laboratory test results and referred to the IS10262 code book. M20 grade concrete mix calculated. The one cubic meter concrete made by 440kg/m^3 cement, 650kg/m^3 fine aggregate, 1210kg/m^3 coarse aggregate, 200kg/m^3 water[8].

Table 1. Mix details

Sl.No	Mix	Cement kg/m^3	Coarse aggregate kg/m^3	Fine aggregate kg/m^3	water kg/m^3	Coir husk ash kg/m^3
1	Mix1	440	1210	650	200	0
2	Mix2	418	1210	650	200	22
3	Mix3	418	1210	520	200	22
4	Mix4	418	1210	390	200	22
5	Mix5	418	1210	260	200	22
6	Mix6	418	1210	130	200	22
7	Mix7	418	1210	0	200	22

2.3 Methods

The experimental investigation on fresh concrete and harden concrete. The slump cone test contacted by fresh concrete and harden concrete properties like compressive strength and split tensile strength analysed by using universal testing machine. Hydraulic properties of low fine concrete are investigated.

2.3.1 Fresh concrete method

In this study workability of low fine concrete or porous concrete measured by using slump cone test. Slump cone test very simple method to find the workability of concrete.

Slump Cone Test

The IS 1199-2000-compliant concrete slump test determines the workability or consistency of the concrete mix. The slump test is a very straight forward method used to quickly assess the workability of concrete.

Slump cone equipment is used to conduct the slump cone test. The cone that is utilised for the slump cone test is 30 cm tall, with bottom and top diameters of 20 cm and 10 cm, respectively. As shown in Figure 1, the steel tamping rod has a 16 mm diameter, is 60 cm long, and is rounded at one end. The 400x400mm metal base plate offers a level and secure platform for carrying out the test. [9]

Fig 1. Slump cone test

After the cement concrete has been properly mixed, the interior of the mould is cleaned and lubricated to make it simple to remove the cone and stop concrete from sticking to its surface. The base is positioned on a horizontal, smooth surface. Three layers of the prepared concrete mix are added to the container, and each layer is tamped 25 times with the tamping rod. The top surface of the mould is levelled once it has been fully filled, and then it is carefully pulled upward and the droop is measured right away. The height difference between the mould and the concrete's highest point is used to calculate the slump value.

2.3.2 Hardened Concrete methods

Compressive strength, split tensile strength, Modulus of rupture tests were conducted on control concrete and fibre reinforced cement concrete to assess its mechanical properties.

Compressive Strength Test

Using a sample of 15 cm x 15 cm x 15 cm, the compressive strength of control concrete and fibre reinforced concrete was evaluated in accordance with IS: 516-1959 (Reaffirmed 2013). 63samples were cast in total, and the compressive strength of each was evaluated. Compressive strength tests on cast samples were performed after 7, 14, and 28 days of curing. Concrete samples were tested in a compression testing equipment with a 2000 kN capacity to determine compressive strength. 140 kg/cm^2/min of force was applied at this rate until the specimen failed. Figure 2 depicts the test configuration. [9]

Fig 2. Compressive strength test

Split Tensile Strength Test

According to IS: 5816-1999, cylindrical concrete specimens measuring 15 cm by 30 cm were cast and tested for split tensile strength (Reaffirmed 2013). The curing times for control and fibre reinforced concrete samples were 7, 14 and 28 days. A compression testing equipment with a 2000 kN capacity was used to gauge the split tensile strength of the cylindrical samples.

The split tensile strength of a total of 63 samples was examined. The test setup is explained in Figure 3. [10]

Fig 3. Split tensile strength test

2.3.3 Hydraulic properties methods

Hydraulic properties are very important properties of low fine concrete or porous concrete. The service life is depending upon the hydraulic properties like porosity and permeability.

Porosity

The porosity of low fine concrete depends upon materials, compaction and material porosity. The life span of low fine concrete is depending upon porosity. The porosity of concrete two type, one is open porous and second is closed porous. The open porous of concrete is every porous interconnected. Open porous concrete is allowed liquid to flow. The closed porous is called as dead end porous and porous not interlinked. The closed porous concrete is allowed liquid to random flow.

The porosity of low fine concrete is equal to volume of void divided by total volume of specimen. The porosity calculated by two methods one is volumetric method and second is water displacement method. The porosity of low fine concrete is measure by using buoyancy float apparatus. [11] The porosity of concrete is

$$P = [\ 1- (\frac{w_1 - w_2}{p_{wV}})]\ x\ 100\%$$

where, P is the total porosity of the low fine concrete (%), w_1 is the weight of low fine concrete sample air-dried for 24 hours (kg), w_2 is the weight of low fine concrete sample submerged underwater (kg), V is the volume of low fine concrete sample (m^3) and p_w is the density of water (kg/m^3). Totally 63 porous concrete specimens of 10 cm diameter and height of 20 cm were cast to test porosity.

Fig 4. Porosity test

Permeability test

Permeability was tested using the falling head and constant head permeability methods and is one of the key hydraulic permeabilities used to evaluate the drainage capacity of low fine concrete or porous concrete. To test permeability, 63 examples of low fine concrete or porous concrete measuring 10 cm in diameter and 20 cm in height were cast.

Permeability test by variable head method

Permeability properties is indicated the water flow through porous of low fine concrete or porous concrete. The permeability properties depend on concrete compaction and mix ratio, aggregate gradation. The permeability variable head method principle is one dimensional flow approach. The permeability apparatus contains 3 parts. First part is 100mm diameter and 200mm long steel tube which is used to hold sample, second part is a long transparent tube with a marked scale that had been connected to top of steel tube, so that measurement of the water level could be obtained over time. The third part is another steel tube of 10 cm diameter moulded with reducer pipe and flow control valve which is attached to the bottom of sample holder steel tube.

The samples were covered on the sides with thin polythene sheets using waterproof tape so that water flow was not permitted through the sides of the specimen and one-dimensional flow was ensured along the vertical direction. The water was allowed to flow through the specimen by opening the valve and the time required for the flow of water from h_1 to h_2 was recorded. The coefficient of permeability was calculated using Darcy's law [12]

$$k = \frac{A_1 L}{A_2 t} \ln(\frac{h_2}{h_1})$$

where, A_1 – Area of the cross-section of tube in cm^2, A_2 – Area of the cross section of sample in cm^2, L – Length of specimen in cm, t – Time required for flowing water from h_1 to h_2 in Sec, h_1, h_2 are initial and final head in cm.

Permeability test by constant head method

The constant head permeability test involves the flow of water through a cylindrical column of pervious concrete sample under the constant head. The testing apparatus is equipped with an adjustment valve to maintain constant head and an outlet which allows maintaining a constant head during the test. Before starting the flow measurements, the concrete sample was saturated. Inlet and outlet flow was maintained at same level.

The time required to collect the particular quantity flowing of water was measured at the constant head. Knowing the length of the pervious concrete sample L in cm, the area of the cross-section A in cm2 and the

constant pressure head h in cm, the volume of water passing Q and the time interval t in second, permeability k of the sample can be calculated from the below equation [11]

$$k = \frac{QL}{A \times h \times t}$$

3. RESULT AND DISCUSSION

Fresh concrete properties, harden concrete properties and hydraulic properties are test results are discussed.

3.1 Slump cone test

Every mixing slump cone used to find the slump value. Totally 7 mix each mix arrived different slump value. The control mixes only achieve the moderate slump value and other mixes are arrived very poor slump value. The absence of fine aggregate similarly the slump value reduced. Mix 7 present fine aggregate content zero only mixed cement paste and aggregate that mix very stiff in nature.

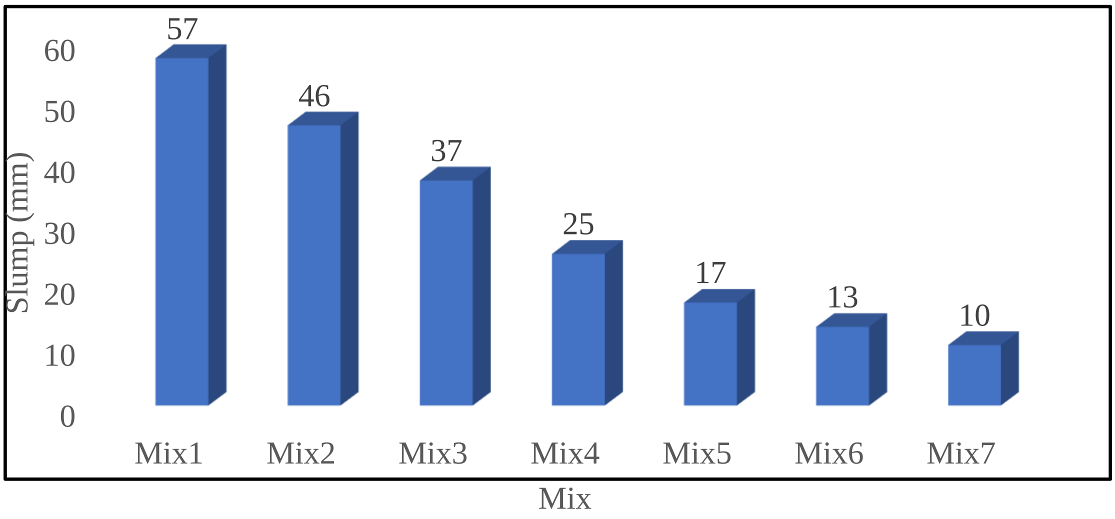

Fig 5. Slump Values

3.2 Compressive strength test

In this research every mix 3 cube specimens cast, cured and tested. Totally 63 cube specimens are tested. 7days, 14 days, 28 days strength are arrived from universal testing machine. The test results are shown in fig 6.

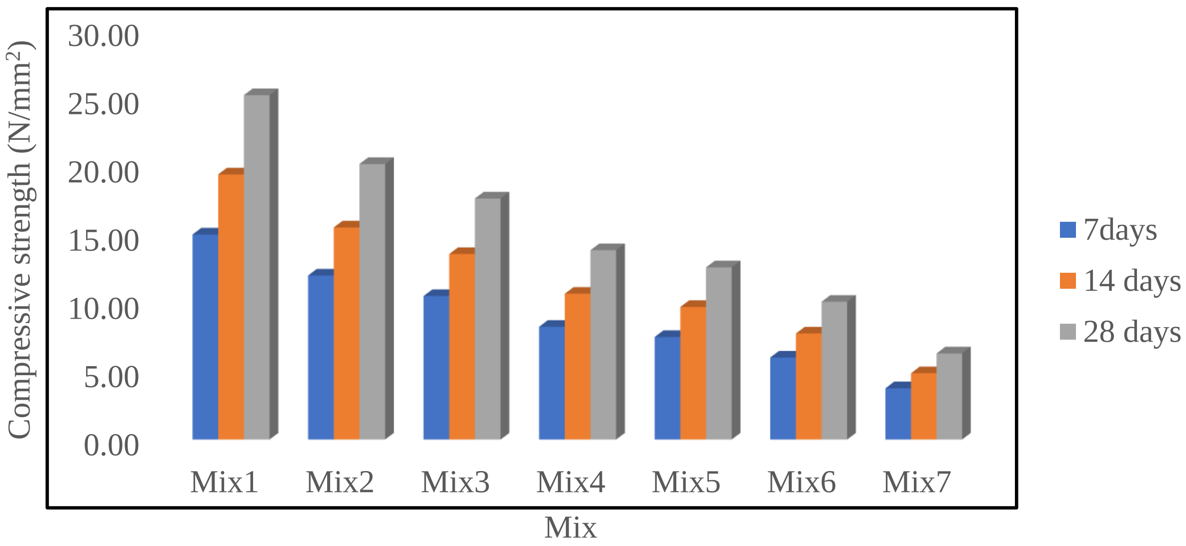

Fig 6. 7, 14 and 28days Compressive strength result

The compressive strength of control specimen is very high compare to low fine concrete specimens. Coir husk ash 5% of replacement of cement mix 2 achieve characteristic compressive strength of concrete. The fine aggregate reduced similarly compressive strength of concrete also reduced.

3.3 Split tensile strength test

The cylinder specimens adopt for the split tensile strength test. Every mix and days 3cylinder specimens tested. Totally 63 cylinders are cast, cured and tested. 7days, 14 days, 28 days strength are arrived from universal testing machine. The test results are shown in fig 7.

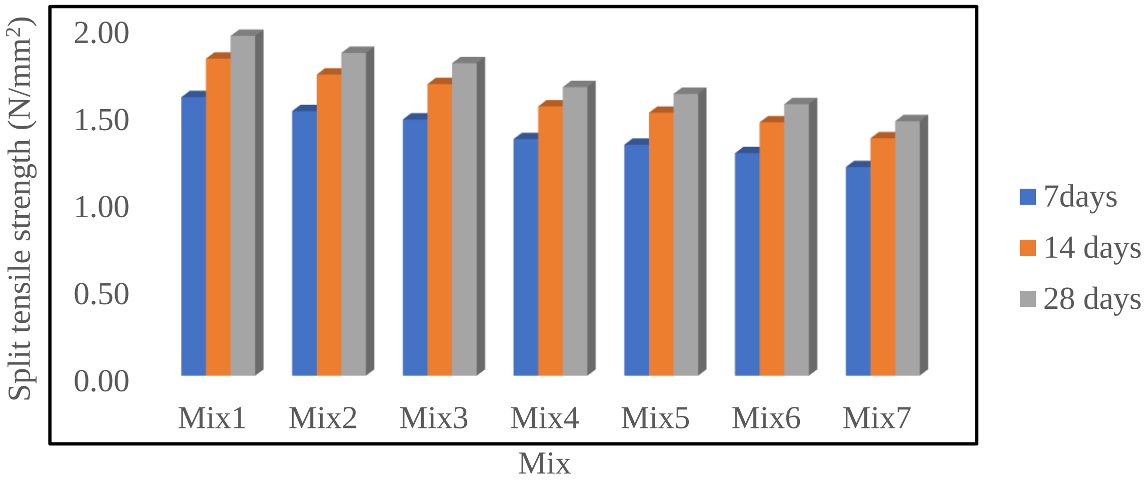

Fig 7. 7, 14 and 28days of Split tensile strength result

The split tensile strength of control specimen is very high compare to low fine concrete specimens. Coir husk ash 5% of replacement of cement mix 2 achieve characteristic split tensile strength of concrete. The fine aggregate reduced similarly tensile strength of low fine concrete also reduced.

3.4 Porosity

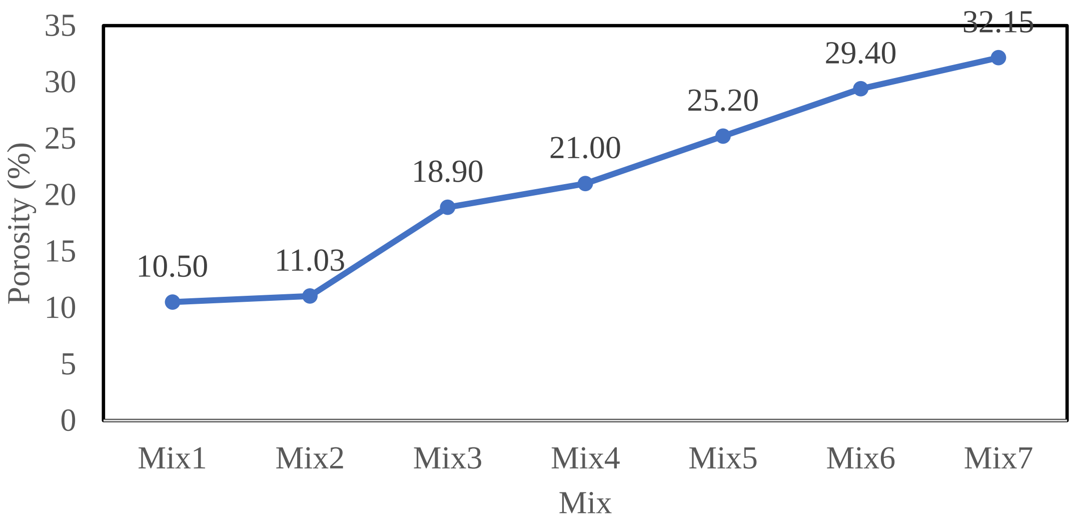

Fig 8. Porosity

Mix 1 porosity value is very lower compare to the mix 7. Mix 1 present 100% fine aggregate and Mix 7 present 0% fine aggregate. The percentage of fine aggregate content reduced at the time porosity of low fine concrete increased. The Mix7 specimens achieve optimum porosity values.

3.5 Permeability test by variable head method

10cm diameter, 20cm height cylindrical specimens cast, cured and tested. Totally 63 cylindrical specimens adopted for permeability variable head method.

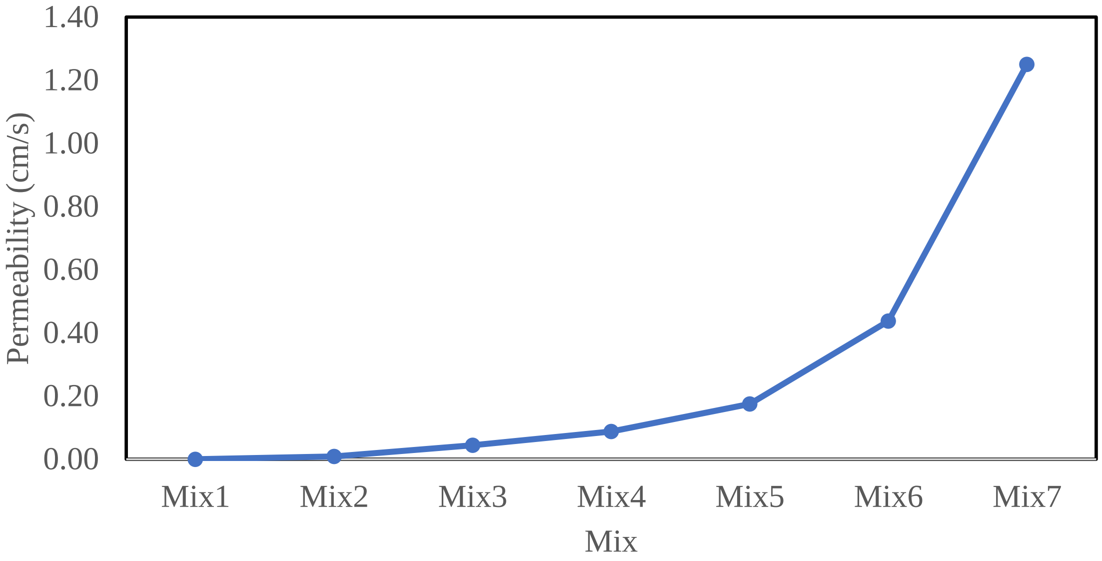

Fig 9. Permeability test result by variable head method

Mix 1 Permeability value is very lower compare to the mix 7. Mix 1 present 100% fine aggregate and Mix 7 present 0% fine aggregate. The percentage of fine aggregate content reduced at the time Permeability of low fine concrete increased. The Mix7 specimens achieve optimum Permeability values.

3.6 Permeability test by constant head method

10cm diameter, 20cm height cylindrical specimens cast, cured and tested. Totally 63 cylindrical specimens adopted for permeability constant head method. Mix 1 Permeability value is very lower compare to the mix 7. Mix 1 present 100% fine aggregate and Mix 7 present 0% fine aggregate. The percentage of fine aggregate content reduced at the time Permeability of low fine concrete increased. The Mix7 specimens achieve optimum Permeability values.

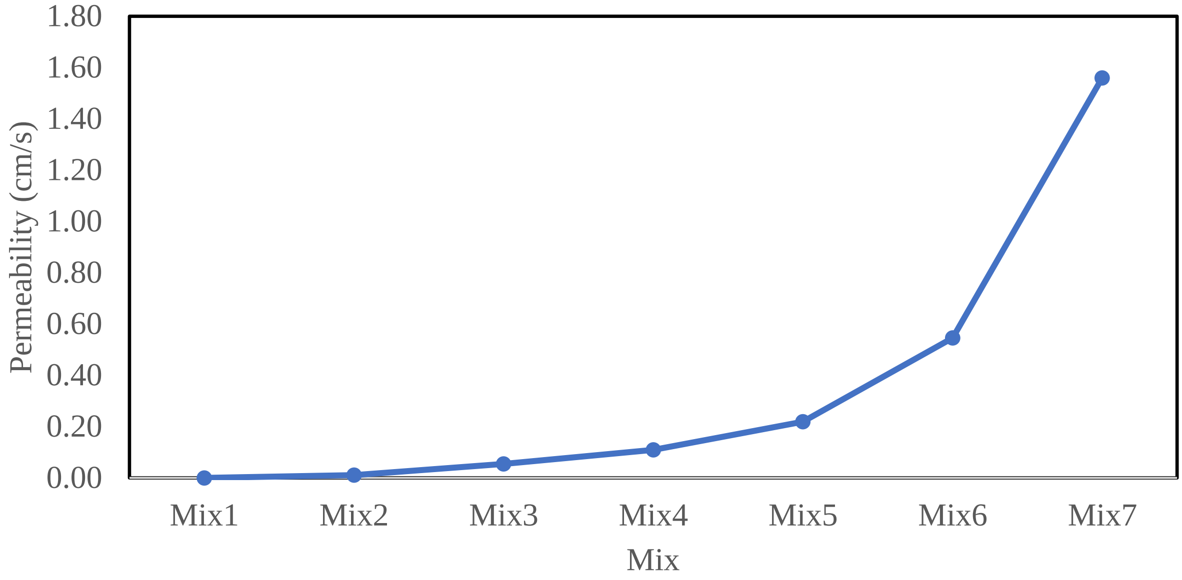

Fig 10. Permeability test result by constant head method

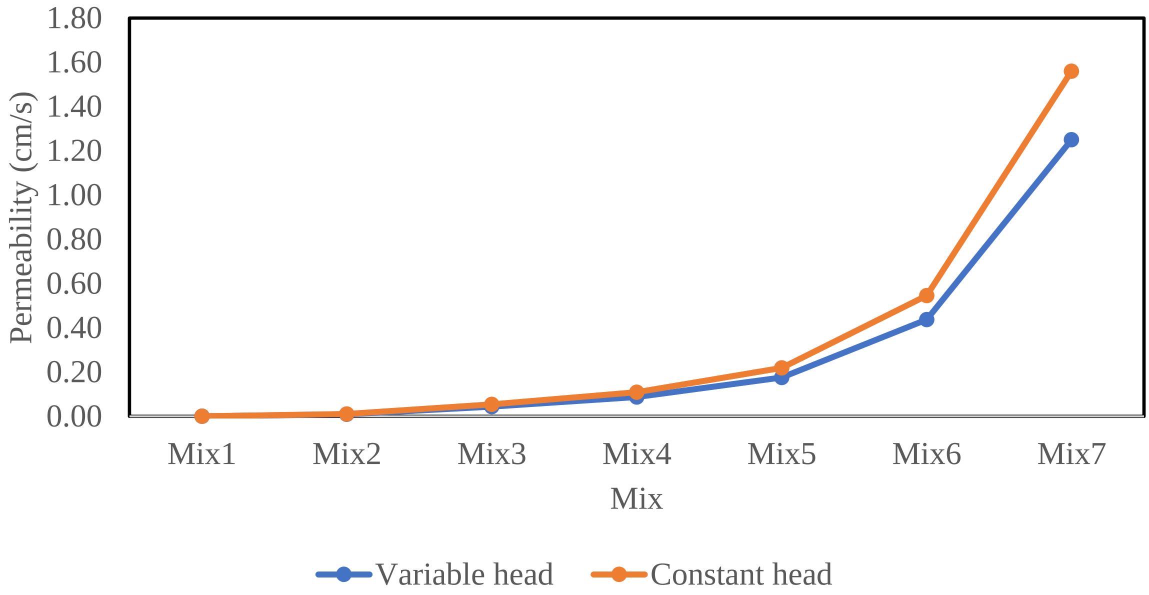

Fig 11. Comparison of Permeability test result by variable head and constant method

4. CONCLUSION

The compressive strength of low fine concrete is decreased similarly decreased the fine aggregate content. The highest compressive strength achieved by with fine aggregate specimens (mix1 and mix2). The split tensile strength of low fine concrete is increased similarly increase the percentage of fine aggregate. The optimum split tensile strength achieved by with fine aggregate specimens (mix1 and mix2). The porosity of low fine concrete increased each mix similarly fine aggregate percentage decreased. The highest porosity value achieved by mix7. Mix 7 contains no fine aggregate. The permeability of low fine concrete increased each mix similarly fine aggregate percentage decreased. The highest permeability value achieved by mix7. Mix 7 contains no fine aggregate. 15% of cement is reduced by using coir husk ash. The better performance creates the coir husk ash. The strength is not affected by using 15% of cement replaced by coir husk ash.

REFERENCE

(1) Navyasri, P.; Rao, V. S. Rainwater Harvestment by Using Pervious Permeable Pavement System. **2018**, 2735–2742. https://doi.org/10.15680/IJIRSET.2018.0703127.

(2) Vinod, K.; Roopa, A. Comparison of M15, M20, M25 Grades of Pervious Concrete with Conventional Concrete. **2017**, *06* (08), 1650–1654.

(3) HHM, D. Characterization of Coir Pith Ash Blended Cement Pastes. *Res. Dev. Mater. Sci.* **2021**, *15* (1), 1630–1639. https://doi.org/10.31031/rdms.2021.15.000851.

(4) Kisan, M.; Sangathan, S.; Nehru, J.; Pitroda, S. G. **1963**.

(5) IS:383. Specification for Coarse and Fine Aggregates From Natural Sources for Concrete. *Indian Stand.* **1970**, 1–24.

(6) Venugopal, B.; Sambamurthy, V. Development and Performance Evaluation of Coir Pith Ash as Supplementary Cementitious Material in Concrete. *J. Eng. Technol. Sci.* **2018**, *50* (6), 856–869. https://doi.org/10.5614/j.eng.technol.sci.2018.50.6.8.

(7) V Balagopal et Al. (2020).Pdf.

(8) Standard, I. OaQØhV FeJ Vuqikru EkxZn ’ KhZ Fl¼kar Lic En Se d t Lib Ra Ry @ o IR Iric ICEN En . Go LIB v . i n Lic En Se Ry @ o IR Iric ICEN En . Go LIB. **2019**, No. January.

(9) Kisan, M.; Sangathan, S.; Nehru, J.; Pitroda, S. G. **1959**.

(10) Kisan, M.; Sangathan, S.; Nehru, J.; Pitroda, S. G. **1999**.

(11) Mahalingam, R.; Mahalingam, S. V. Analysis of Pervious Concrete Properties. *Gradjevinar* **2016**, *68* (6), 493–501. https://doi.org/10.14256/JCE.1434.2015.

(12) Sanjaya, N.; Saloma; Hanafiah; Juliantina, I.; Nurjannah, S. A. Compressive Strength, Permeability and Porosity Analysis of Pervious Concrete by Variation of Aggregate and Compacting Method. *J. Phys. Conf. Ser.* **2021**, *1783* (1). https://doi.org/10.1088/1742-6596/1783/1/012073.

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