Evaluating The Influence of Fines on the Characteristics of Pervious Concrete

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Abstract. Pervious concrete, also known as no-fines, gap-graded or porous concrete has an interconnected pore structure that freely allows the passage of water to flow through, thereby draining all or most of the water falling on its surface. This concrete can be used as paving material to reduce the storm water runoff to the drainage system and minimize water logging problems. In general, the porosity is achieved by omitting fine aggregate completely. But this results in a low strength concrete which cannot be used for most pavement applications. In this study, pervious concrete mixes have been formulated with a limited quantity of fines (10% and 20%) and the strength and permeability properties have been investigated for various types of fines (quarry dust, river sand and M-sand). While the strength of pervious concrete is increased considerably by adding fines to them, the permeability of the samples remains within the required range of 0.5 to 40mm/s. It has been observed that the addition of different types of fines had great influence in strength and permeability. The compressive strength increases with increase in fine content. Also, it is found that the compressive strength of cube with Quarry dust gives more strength compared to other fines.

1 Introduction

Pervious concrete, also known as gap graded concrete, porous concrete, and no-fine concrete, is a special type of concrete, in which the voids are intentionally created which allows water and other sources to pass through. Large and continuous voids are created by a complete elimination or drastic reduction of fine aggregates. It usually consists of Portland cement, uniform-sized coarse aggregate and water. This combination forms an agglomeration of aggregates surrounded by a thin layer of hardened cement paste at their points of contact. This configuration produces interconnected voids (typically of sizes in the range of 1 to 5 mm) between the coarse aggregates, which allow water to permeate at a much higher rate than conventional concrete.
Pervious concrete had its earliest beginnings in Europe. In the 19th century, pervious concrete was utilized in a variety of applications such as load bearing walls, prefabricated panels and pavements. Cost efficiency seems to have been the primary reason for its earliest usage due

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to the limited amount of cement used. In recent times, the use of pervious concrete as a substitute for conventional concrete has grown into a multifunctional tool in the construction industry. The proper utilization of pervious concrete can contribute towards efficient storm water management and ground water recharging.

[1] studied the performance and behaviour of pervious concrete using super plasticizers (Auramix-400 & Conplast SP 430) and different percentages of fiber (1 % & 2 %) in Indian climatic condition and compared the strength properties of conventional concrete and pervious concrete. It was found that the addition of 1 % of fiber by weight of cement and decrease in w/c ratio increased the strength of pervious concrete. It was inferred that cement/aggregate (C/A) ratio was inversely proportional to strength and directly proportional to permeability of pervious concrete. The effect of partial replacement of cement by 10 % and 20 % of fly ash and partial replacement of coarse aggregates by fine aggregates (ranging from 5 % -15 %) on the characteristics of pervious concrete using a w/c ratio of 0.54 was investigated by [2]. It was reported that addition of fine aggregates increased the compressive strength of the pervious concrete and reduced the permeability of pervious concrete by about 12 – 16 %. Work carried out by [3] on the mechanical properties and permeability of pervious concrete demonstrated that the smaller sized aggregates provided more compressive strength while larger sized aggregates contributed to more permeability. Also, the flexural strength of pervious concrete increased by addition of 50 % quarry sand to the mix. [4] analysed the performance of pervious concrete with coarse aggregates replaced by 30 % of fine aggregates (natural sand, soil, volcanic sand). It was reported that the highest compressive strength was achieved by porous concrete filled with volcanic sand whereas the highest vertical and horizontal permeability was achieved by natural sand. Studies by [5] reported the permeability of gap graded concrete with addition of fine aggregate. It was observed that permeability was higher in case of 0 % sand when compared to 10 % and 20 % sand content and it was same in the case of addition of mud. [6] investigated the influence of aggregate type and size on the properties of pervious concrete. The results suggested that higher amount of small aggregate fractions (4-8 mm) yielded higher density concrete mixtures with greater flexural strength. Total porosity obtained in pervious concrete with dolomite aggregate was higher when compared to steel slag aggregate. A higher proportion of coarse fraction in mixtures resulted in a higher value of overall porosity. [7] evaluated the effect of differential levels of compaction energy and analysed the influence of fine sand addition to several pervious concrete mixtures. The results suggested that the addition of small amount of fine sand (around 5 % of total aggregate weight) to concrete mixtures provided better mechanical and surface properties. The effects of aggregate size, gradation as well as the paste volume on unit weight, compressive and tensile strength, porosity and permeability of pervious concrete was determined by [8]. A minimum porosity of 19 % was required to produce functional pervious concrete with permeability higher than 1 mm/s and unit weight lower than 2100 kg/m^3. [9] illustrated the influence of angularity number on properties and behaviour of pervious concrete with fine and coarse aggregate. Angularity number was more for larger sized aggregate and vice-versa. The compressive strength decreased, and permeability increased with increase in the angularity. However, the angularity number had no influence on the abrasion value of pervious concrete.

From literature, it has been observed that unlike conventional concrete, which has a void ratio from 3-5 %, pervious concrete can have void ratios from 15-40 % depending on its application. Pervious concrete characteristics differ from conventional concrete in several other ways. Compared to conventional concrete, pervious concrete has a lower compressive strength, higher permeability, and a lower unit weight (approximately 70 % of conventional concrete). This work thus aims to investigate the effect of fines of fines - M-sand, river sand and quarry dust with and without super plasticizers on the strength and permeability characteristics of pervious concrete.

2 Materials and Methods.

2.1 Materials

Ordinary Portland cement of grade 53 was used in the study. River sand, Quary dust, M - sand was used as fine aggregates. Uniformly graded coarse aggregates with size ranging from 20 mm to 12.5 mm were used. Ceraplast 300 was used as superplasticizer.

2.2 Compression strength test

Compressive strength is the ability of the material to carry load on its surface without any crack or deflection. The compressive strength of pervious concrete is strongly affected by the mixture proportion and compaction effort during placement. Relatively high compressive strength of pervious concrete mixtures is possible with the reduction of air void. This results in a loss in percolating efficiency of pervious concrete. Although the water-cement ratio of a pervious concrete mixture is important for the development of compressive strength and void structure, the relationship between the water-cement ratio and compressive strength of conventional concrete does not apply to pervious concrete properties. A high water-cement ratio can result in the segregation of the aggregates while low water-cement ratio can result in reduced adhesion between aggregate particles and placement problems.
In this study, cubes of size 100×100×100 mm were casted with and without super plasticizer by varying the percentage (0 %, 10 %, 20 %) of different types of fines (river sand, M-sand, quarry dust) and tested for 28th day compressive strength. Preparation and testing of specimens were carried out as per IS 516-1959. The quantities of cement, fine aggregate, coarse aggregate and water for each batch was determined by weight as shown Figure.1 to an accuracy of 0.1 percent of the total weight of the batch.

Fig. 1. Weighing of materials

The concrete was hand mixed in such a manner to avoid loss of water or other materials. For hand mixing measured quantity of sand was spread evenly on a watertight non-absorbent platform followed by measured quantity of cement as shown in Figure 2. It was mixed well until the color of concrete mixture is uniform. Coarse aggregate was added to this mixture.

Fig. 2. Mixing the materials

Water was added and mixed until the concrete appears to be homogeneous and uniform in colour and consistency as shown in Figure 3.

Fig. 3. Mixing the materials

Mould of the specified size were cleaned and greased on the inner side. Concrete was filled in three equal layers by compacting each layer with 25 blows using a tamping rod followed by levelling of the top surface with shovel (Figure 4). The test specimens were stored in moist environment for 24 hours. After this period the specimens were removed from the moulds and kept in clear fresh water for 28 days. After curing the specimen was tested for its compressive strength using UTM. Minimum three specimens were tested for each design mix. The compressive strength of the specimen is given by

Compressive strength = Load in Newton / Area of cube in mm2

Fig. 4. Casting of cube

2.3 Flexural strength test

Flexure strength is one measure of the tensile strength of concrete. It is the measure of the unreinforced concrete beam or slab to resist failure on bending. The standard size of the slab is 15 × 15 × 70 cm is shown in Figure.5. Alternatively, if the largest nominal size of the aggregate does not exceed 19mm, specimens 100mm × 100mm × 500 mm may be used. The concrete beams were casted with and without super plasticizer by varying the percentage (0 %, 10 %, 20 %) of different types of fines (river sand, M-sand, quarry dust) and tested for 28th day flexural strength. The flexural test of the concrete can be conducted using center point load test (ASTM C293).

Fig. 5. Casting of beam

Flexural tests of moist-cured specimens were done as soon as they were removed from moist storage. Surface drying of the specimen results in a reduction in the measured modulus of rupture. To determine the dimensions of the specimen section for finding its modulus of rupture, measurements were taken across one of the fractured faces after testing. For each dimension, one measurement at each edge and one at the center of the cross section was taken. The three measurements for each direction (Figure.6) were used to determine the average width and the average depth and the modulus of rupture is calculated as

$R = 3\ PL/2bd^2$ (refer Figure 6)

where:

R = modulus of rupture, psi, or MPa,

P = maximum applied load indicated by the testing machine, lbf, or N,

L = span length, in., or mm,

b = average width of specimen, at the fracture, in., or mm, and

d = average depth of specimen, at the fracture, in., or mm.

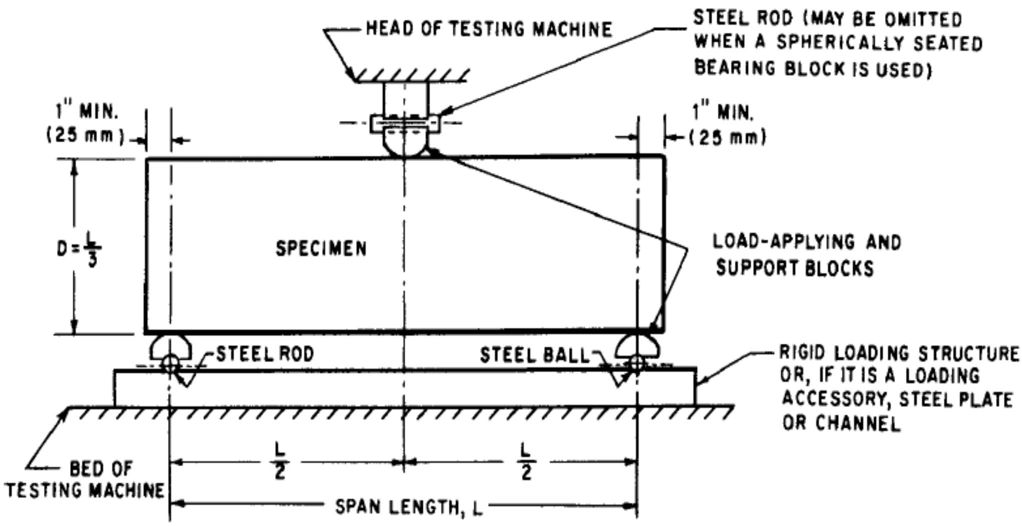

Fig. 6. Diagrammatic view of apparatus for flexure test of concrete by centre-point loading method (ref: Standard test method for flexural strength of concrete, ASTM C293 ,100 Barr harbor Drive, PO Box C700, West Conshohocken)

2.4 Permeability test

Permeability is the property of the material to allow the water to flow through it. It largely depends on the size of the pores, connectivity of the pores and how tortuous the path is for the permeating fluid. The factors influencing the permeability of concrete are water cement ratio, compaction and curing of concrete. Age of concrete, cement and aggregate properties, use of admixtures also plays a role. One of the most important features of pervious concrete is its ability to percolate water through the matrix. The percolation rate of pervious concrete is directly related to the porosity and the pore sizes.

To determine the permeability of pervious concrete, a cylinder of diameter 90 mm and height 150 mm was casted with and without super plasticizer by varying the percentage (0 %, 10 %, 20 %) of different types of fines (river sand, M-sand, quarry dust) and tested for 28th day permeability.

The permeability of pervious concrete was measured by a simple falling-head permeameter as shown in Figure.7. In this approach, the sample was enclosed in a latex membrane to avoid water flowing along the sides of the specimen. Water was added to the graduated cylinder to fill the specimen cell and the draining pipe. With the valve closed, the graduated cylinder is filled with water. The valve was then opened, and the time in seconds t required for the water to fall from an initial head *h*1 to a final head *h*2 was measured. The permeability *k* (mm/s) can be expressed as

$k = A/t$

where *A* is a constant equal to 7.7 in. (192 mm).

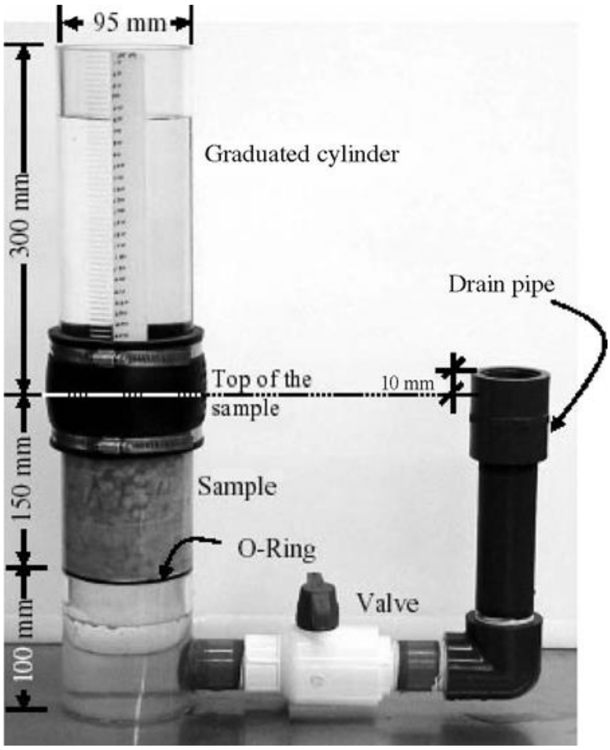

Fig. 7. Apparatus for measuring permeability of pervious concrete by a simple falling-head permeameter (Ref: ACI 522R-10)

3 Results and discussion

A total of 14 different mixes were investigated in this study. The details are listed in Table 1 and Table 2. Mixes 1 to 7 were samples without super plasticizers.

The compressive strength tests were conducted on cube size of 100 mm X 100 mm X 100 mm at age of 28 days curing using UTM as shown in Figure 8 & Figure 9. Figure 10 and Figure 11 shows variation in the compressive strength of the sample for different types of fine aggregate with and without superplasticizer for 28 days curing period.

Table 1. Mix Specifications of samples without super plasticizers.

MIX NO	CEMENT (Kg/m^3)	W/C RATIO	COARSE AGGREGATE (%)	FINE AGGREGATE (%)			SP
				RS	MS	QD	
1	300	0.4	100	-	-	-	-
2	300	0.4	90	10	-	-	-
3	300	0.4	80	20	-	-	-
4	300	0.4	90	-	10	-	-
5	300	0.4	80	-	20	-	-
6	300	0.4	90	-	-	10	-
7	300	0.4	80	-	-	20	-

Table 2. Mix Specifications of samples with super plasticizers

Mix NO	CEMENT (Kg/m^3)	W/C RATIO	COARSE AGGREGATE (%)	FINE AGGREGATE (%)			SP (%)
				RS	MS	QD	
8	300	0.4	100	-	-	-	1
9	300	0.4	90	10	-	-	1
10	300	0.4	80	20	-	-	1
11	300	0.4	90	-	10	-	1
12	300	0.4	80	-	20	-	1
13	300	0.4	90	-	-	10	1
14	300	0.4	80	-	-	20	1

Fig. 8. Compressive strength test

Fig. 9. Failure of specimen

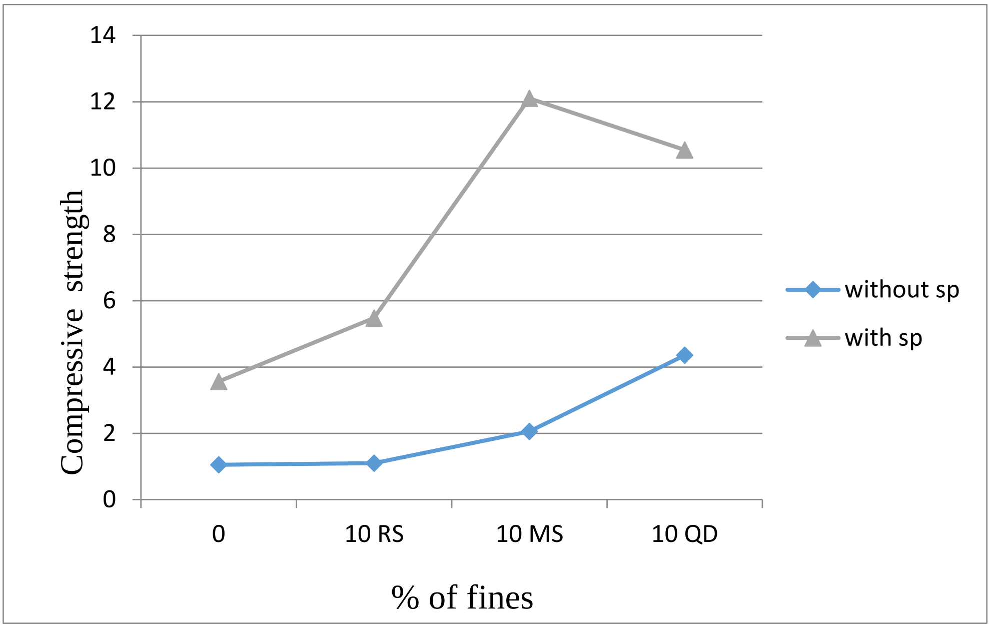

Fig. 10. Variation in compressive strength for 0 % fine and 10 % fines (RS, MS,QD)

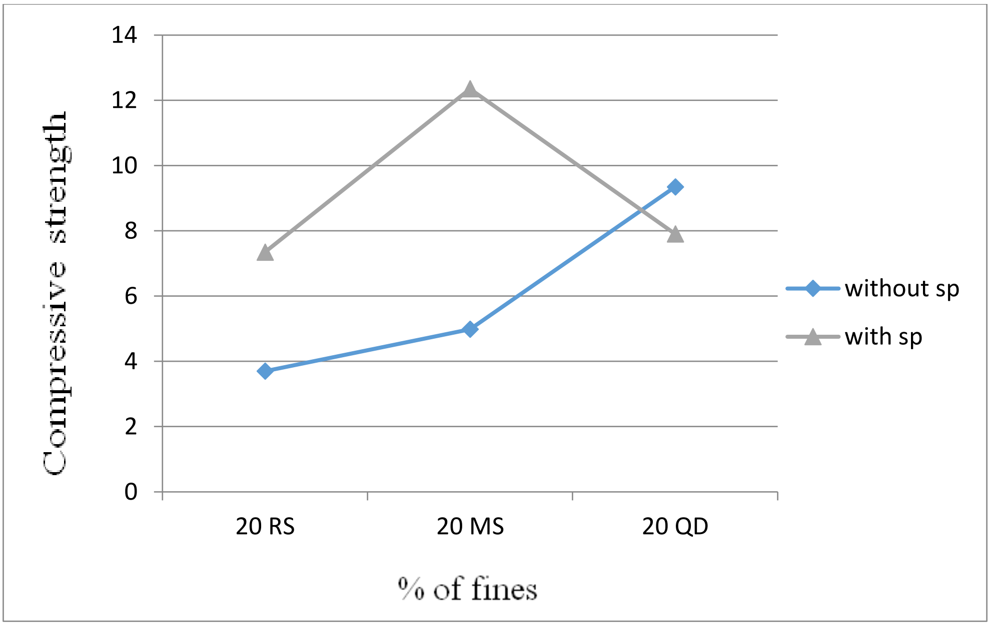

Fig. 11. Variation in the compressive strength for 20 % fines (RS, MS,QD)

Figure 12 shows the flexural strength test. Figure 13 and 14 shows variation in the flexural strength with varying percentages of fines.

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Fig. 12. Flexural strength test

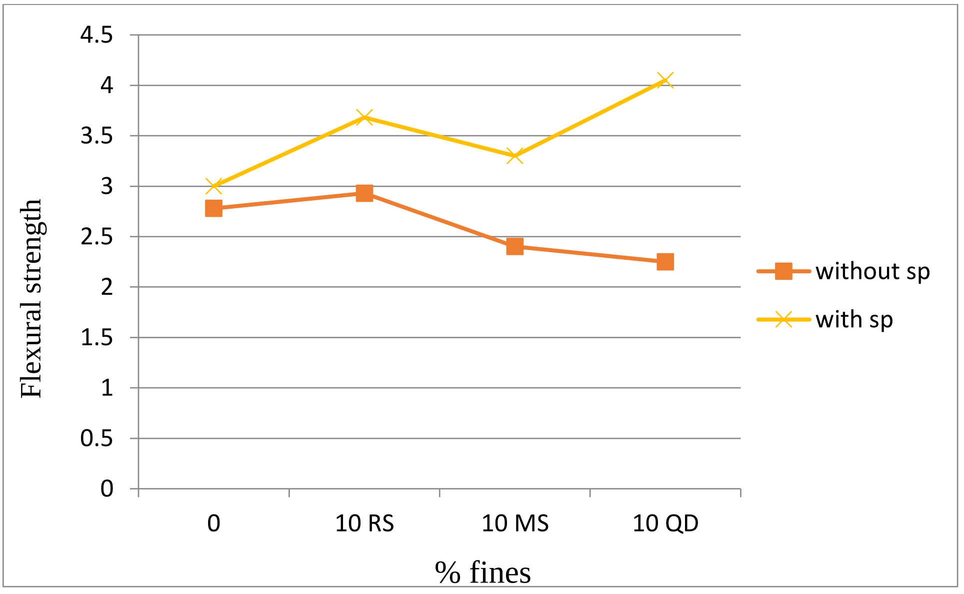

Fig. 13. Variation in flexural strength of specimen for 0 % fine and 10 % fines (RS, MS,QD)

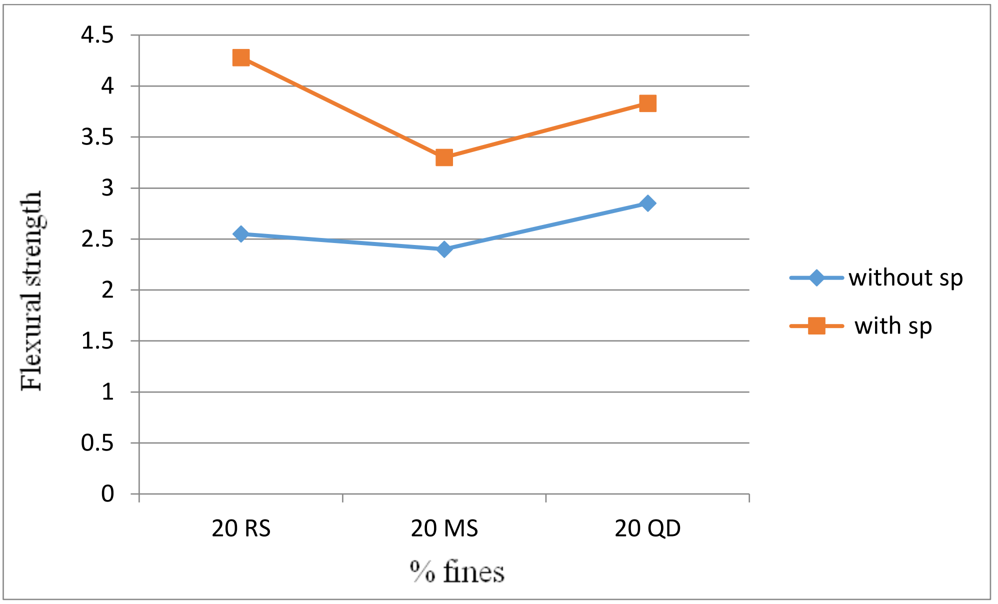

Fig. 14. Variation in flexural strength for 20 % fines (RS, MS, QD)

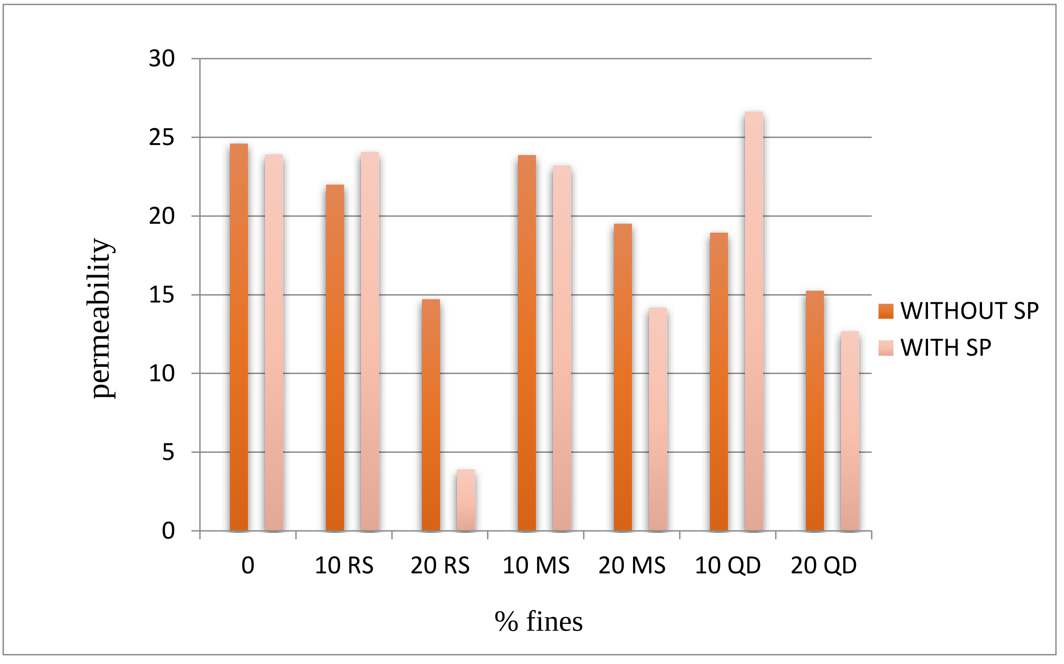

Fig. 15. Variation in permeability for different percentage of fines

The mixes were tested with respect to strength and permeability. The compressive strength varies from 1.05 N/mm2 to 9.35 N/mm2 (without SP) and for without super plasticizers it ranges between 3.61 N/mm2 to 15.13 N/mm2 whereas for flexural strength of beam without super plasticizers lies between 2.25 N/mm2 to2.93 N/mm2 and for beam with SP it ranges between 3.0 N/mm2 to 4.28 N/mm2 Similarly permeability lies between 14.71 mm/s to 24.59 mm/s for cylinder without super plasticizer and for cylinder with super plasticizer it lies between 3.879 mm/s to 26.634 mm/s. The influence of addition of fines, super plasticizers were evaluated and discussed below.

4 Conclusion

The following conclusions were drawn from the study.

i) The addition of different types of fines had great influence in strength and permeability.

ii) The compressive strength increased with increase in fine content.

iii) The compressive strength of cube with Quarry dust resulted in more strength compared to other fines (River Sand& M-Sand).

iv) While the strength of pervious concrete increased considerably by adding fines to them, the permeability of the samples remained within the required range of 0.5 to 40 mm/s.

v) Addition of super plasticizers by 1 % of weight of cement to the concrete mix increased the compressive strength and flexural strength of pervious concrete.

It is concluded that with no compromise on the porosity and permeability of the concrete mix, the fines, when added in limited quantities, can significantly increase the strength properties, thereby increasing the potential for the applications of pervious concrete.

References

[1]Sujeet Kumar Sah, Shaik Niyazuddin Guntakal, S. Senthil Selvan, Int. J. Appl. Eng. Res., **13**, 4550 (2018)

[2] M.Uma Maheshwari, T. Sundararajan, ‘Influence of Fly ash and Fine aggregates on the characteristics of Pervious concrete’ Int. J. Appl. Eng. Res. **12**,1598 (2017)

[3] R. Kishore ,Shaik Niyazuddin Guntakal , Int. J. Res. Civ. Eng. Technol. , **8,** 111 (2017)

[4] Djoko Sarwono, Djumari, Rochim, Ary Setyawan, Procedia Eng., **179,** 1429 (2017)

[5] Urmil Dave, Tejas Joshi, Ram Modhvadia, Shivam Suva, Chaitanya Vadher ,Hadric Velani , Int. J. Res. Civ. Eng. Technol.**7**,115 (2016)

[6] K.Cosic , L. Korat, V. Ducman ,I. Netinger, Constr. Build. Mater.**78**, 69 (2015)

[7] Alessandra Bonicelli, Filippo Giustozzi & Maurizio Crispino, Constr. Build. Mater. 91, 102 (2015)

[8] Ammar Yahia , K. Kabagiren, Constr. Build. Mater. **62**, 38 (2014)

[9] M. Uma Maheswari, V.L.Narasimha, Proceedings of the second conference of Transportation Research group of India, **104,** 198 (2013)