Effects of Fine Aggregates on Performance of Pervious Concrete: A Review

Paragdeep Tripathi[1], S. K. Jain[2]

[1]Post Graduation Student, Department of Civil Engineering, MITS Gwalior, Madhya Pradesh, India
[2]Professor, Department of Civil Engineering, MITS Gwalior, Madhya Pradesh, India

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Abstract - *Due to the rapid industrialization and development, more and more construction of structures increases. These structures are made up of normal concrete which is hardened mass of impervious nature. Due to the impervious nature, pavements constructed with normal concrete are not quite successful at some aspect. These pavements are not good in reducing storm water runoff, removal of pollutants from storm from storm water, reducing the glare effect on the eyes of drivers, recharging ground water table by allowing water to penetrate through it and reaches the ground water table. The better and eco-friendly solution of the problems mentioned above is pervious concrete. The pervious concrete is porous in nature and interconnectivity of pores makes it permeable for water to flow through it. Thus, it is quite effective to rectify above problems. The aim of this paper is to study the properties of pervious concrete and how it is different from normal concrete in structure and function by review of previous researchers.*

***Key Words*: Pervious Concrete, No Fine, Porosity, Storm Water Runoff, Compressive Strength, Flexural Strength, Permeability.**

1. INTRODUCTION

Concrete is composite material which is made up of aggregates, cement and water. Now a days, concrete is 2nd most consumed material in the world after water. Production of concrete is increasing due to high growth rate of development of infrastructure and construction work [3]. As we know that normal concrete is impervious in nature and does not allow water to penetrate into it that is why it will produce surface runoff of the storm water, this surface runoff carries pollutants through it and increases the load on sewers. There are also some problems experience in the impervious pavements that they do produce problems of urban heat island and problem of slipping while walking over wet surface [9]. The pervious concrete can give the solution of the problems mentioned above of impervious concrete. The pervious concrete allows the water to flow through it because of presence of voids in it. These voids also make the pervious concrete more absorbing in nature in term of noise, sound, heat. Thus, it helps in reducing noise pollution while maintaining coolness to the nearby areas or soil. Though the strength of pervious concrete is less as compared to the normal concrete because of interconnected pores. These interconnected pores make it permeable. Due to its low strength its application for heavily loaded pavement is negligible. But as the pace of development is increasing, we will find the application of pervious concrete at greater extent.

2. PERVIOUS CONCRETE

Pervious concrete is defined as the hardened mass which has porous structure. These pores are interconnected and makes the concrete permeable. The pervious concrete is made up of ingredients similar to the normal concrete with difference in having no fine aggregate. The absence of fine aggregate in the pervious concrete makes the voids interconnected. The term pervious concrete typically describes as zero slump, open graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixture and water. Generally, coarse aggregate of size ranges from 9.5 mm to 19 mm. The amount of fine aggregate is negligible or kept very less. Ordinary Portland cement used as binder. Some cementitious material such as fly ash, silica fume and slag cement can also be used. Ordinary water with water/cement ratio from 0.30 to 0.40. Admixture such as super plasticizer can also be used to increase workability [1]. The combination of these materials produced the hardened structure with interconnected void that allow the water to flow through it. The void contents ranges from 15-35 % with typical compressive strength of ranges 5-25 MPa. The drainage rate of pervious concrete ranges from 0.135 cm/sec to 1.22 cm/sec [8]. Pervious concrete had been used in the construction work since mid of 19th century but because of lack of publication it did not gain publicity among major construction work. It was first noticed at reasonable level when it was used for the building and proved good in providing insulation [1]. The pervious concrete is good in providing insulation by absorbing sound, noise, heat from the atmosphere. The pervious concrete was also called as gap graded and no fine concrete [1]. Pervious concrete is recognized as structural infiltration Best Management Practice by the Environment Protection Agency for providing first flush pollution control and storm water management [13]. The pervious concrete gained its recognition as construction materials after 2nd world war in the US. It was majorly used in the construction in countries like Spain, Germany, Hungary and other European countries [1].

Porous structure and interconnectivity of pores allows the efficient drainage of water through that matrix and offer sustainable drainage system [4]. It is helpful in the removal of heavy metals from the water and also helps to screen out debris from storm water [14]. The urban development leads to increase in construction works, impervious pavements are being developed but they allow the surface runoff of the storm water to flow over it. The stormflows along with polluted debris and ultimately reached the rural or undeveloped areas where it causes overland and stream bank erosion [14].

Some application of pervious concrete are as follows [1]:

- Parking lots
- Drainage layer under mall areas
- Pavements where sound absorption is required
- Structure near beaches
- Sludge bed in sewage treatment plant

Some application of pervious concrete pavement are as follows [1]:

- Controlling storm water pollution at site
- Increasing parking facility and eliminates the requirement of retention areas
- Controlling storm water runoff
- Reduce glare effect

3. PROPERTIES OF PERVIOUS CONCRETE

As we have discussed that pervious concrete is different from normal concrete, so it has properties differ from normal concrete. These properties are as follows:

- Density: Density of pervious concrete ranges between 1600 kg/m^3 to 2000 kg/m^3 [13]. It is also depending on the amount of compaction and ingredients.
- Permeability: Permeability of pervious concrete varies with aggregate sizes and density of mix. Generally, ranges between 0.135 cm/s to 1.22 cm/s [8].
- Porosity: Porosity lies between 15-35% by volume of concrete [8].
- Strength: Generally, the strength of pervious concrete is less as compared to normal concrete because of its porous structure. The compressive strength lies between 5 to 25 MPa [8]. Compressive strength can be increased by introducing fine aggregate, super plasticizer and other Cementous material.
- Relationship of strength of pervious concrete with water cement ratio is not similar to the normal concrete. If we increase value of water/cement ratio, the compressive and flexure strength increase up to certain value depending on the surrounding temperature but after that it will decrease [22].

4. STANDARDISED TESTS PROCEDURE AND GUIDELINES FOR PERVIOUS CONCRETE

List of available guidelines and standardized test procedure for pervious concrete evaluation are as follows:

Table -1: List of available guidelines and standardized tests [22]

S. No.	Standard Designation	Standard Full Name	Property of Pervious Concrete
1.	ACI522.1 -13	Specification for Pervious Concrete Pavement (under revision)	Pervious concrete pavement guidelines
2.	ASTM C 1688	Standard Test Method for Density and Void Content of Freshly Mixed Concrete	Fresh density and porosity
3.	ASTM C 1701	Standard Test Method for Infiltration Rate of In Place Pervious Concrete	Infiltration Rate
4.	ASTM C 1747	Standard test method for determining potential resistance to degradation of pervious concrete by impact and abrasion	% loss after 500 cycles in L.A. abrasion rotating steel drum
5.	ASTM C 1754	Standard Test Method for Density and Void Content of Hardened Pervious Concrete	Porosity and hardened density
6.	ASTM C 1781	Standard test method for surface infiltration rate of permeable unit pavement system	Infiltration Rate
7.	ASTM C 944	Standard test method for abrasion resistance of mortar surface by rotating cutter method	% mass loss after three 2-min periods of the abrasion treatment

5. RESEARCH FINDINGS

Researches have been done on pervious concrete and pervious concrete pavement to get the working of pervious concrete pavement and its effect on surrounding soil. The studies of researchers are as follows:

Richard C. Meininger (1988) tested pervious concrete and concluded certain points regarding the pervious concrete with various parameter. He showed the relation of compressive strength with air contents and stated that compressive strength is somehow inversely proportional to air contents of the pervious concrete. He also concluded that as the voids increases the compressive and flexure strength decreases. The presence of voids enables pervious concrete to allow the water to flow through it [21].

Nadar Ghafoori and Shivaji Dutta (1995) studied that no fine concrete can be used in the pavement construction for parking lots and low loaded roads in the United States and Europe. No fine concrete does not contain any fine at all but it contains single sized aggregate. The no fine concrete was used in the 1852 for 2 houses. But after the 2nd world war it gains its popularity among various European countries. They studied the use of no fine concrete in pavement applications. They used the no fine concrete in three areas such as no-fine concrete pavements, no-fines permeable base, no-fines concrete pavement edge drains or shoulders. Through their study, they concluded the construction of new homes, streets, shopping centres and parking lots had resulted in increase of storm water runoff and pervious concrete served the following purpose such as it reduce the surface runoff, recharged the ground water with fresh water and eliminate need of sewers and drainage [17].

Yang J. and Guoliang Jiang (2003) introduced a pervious concrete pavement material for the road. They studied the strength of pervious concrete was low by using common materials and methods. Their objective was to increase the strength by using a smaller size aggregate, silica fume and super plasticizer which can increase the strength of pervious concrete. They used the four type of aggregates ranges from 30-15 mm, 10-20 mm, 5-10 mm, 3-5 mm and particle size less than 2.5 mm as fine aggregates. They performed compressive strength, flexure strength tests and check pervious concrete ability under freeze and thaw. For the compressive strength uniaxial compression machine, for flexure three-point loading method and for freezing and thawing was done on 28 days cured specimen. The cured specimens were subjected to air of -15^{0} C for 5 hour and then subjected to water for thawing. The 25 cycles of freezing and thawing was done and after that strength of the specimen were checked and compared to the specimen which were not subjected to the freeze and thaw cycle. There are seven types of mix were prepared and out of these two were chosen for base and surface layer. The pervious concrete made up of two layer such as base layer and surface layer. The base layer was composed of aggregate size 5-10 mm, 15% fine aggregate, 6% silica and 0.8% superplasticizer, water/cement ratio 0.35 and surface layer was composed of 3-5 mm aggregate with no fine and silica fume and superplasticizer in same quantity as mentioned above. The composite of both type of mix were used to compose pervious concrete pavement. The compressive strength and flexure strength of the composite mix were 50 MPa and 6 MPa. They concluded that pervious concrete is good under flexure, compression and freezing and thawing durability. It can be used on the footpath and vehicle road. It was eco-friendly pavement materials [24].

Adam Marolf et al. (2004) carried out experimental investigation to check whether "Enhanced porosity concrete" (EPC) can be used for sound mitigation purpose. EPC mixtures were prepared using single-sized aggregates passing 9.5 mm sieve and 4.75 mm sieve and mixtures made up of blend of two different aggregate sizes. The water/cement ratio was kept constant which was 0.33. They performed sound absorption using an acoustic impedance tube, flexural strength using three-point bending and image analysis procedure was used to characterize the total porosity and size of the pores for each mixture. The result of the research showed that as compared to conventional concrete, EPC mixtures with single-sized aggregates significantly increase acoustic absorption [2].

Kelly A. Collins (2007) investigated the performance of pervious pavements of four different types and standard asphalt pavement in Kinston, NC. Each pavement layer comprises the area of 1200 square feet. The performance of pervious concrete had been tested for one year from March 2006 to March 2007. The major objective of their work was to evaluate and compared difference in water quality and runoff reduction between permeable pavements and standard asphalt, compare differences in water quantity among four types of permeable pavements and compare runoff reduction by four different types of permeable pavements. The four types of permeable pavements were Pervious concrete, Octa brick concrete paver, Concrete grid paver, Rima concrete stone. For their work, permeable pavements were divided into four different stalls and asphalt pavement covered outside area of permeable stalls. The asphalt section act as entry section for water ingress. The water enters from the entry section and permeable base had slope to carry out water at exit. The exfiltrate from both permeable pavement and asphalt pavements were collected and tested for total suspended solid concentration in water and checked the runoff reduction by permeable pavements. The result stated that grid paver and Octa brick paver reduce more volume of water than pervious concrete and Rima concrete. They concluded that rate of infiltration through pervious concrete decreased due to clogging with time [14].

Michael Kwiatkowski et al. (2008) conducted the monitoring program on the pedestrian area of Villanova University's campus for the evaluation of pervious concrete in changing the quantity and quality of storm water. They collected the infiltered water from the unsaturated soil through lysimeter and compared the infiltered water with storm water. Various tests such as pH, conductivity, number of dissolved solids and organophosphate pesticides in the water were tested. For the quantity of water, rain gauges were installed to find the water entering. They concluded that pervious concrete did not very effective in hexavalent chromium removal but pH of storm water decreases as compared to infiltered water [16].

John T. Kevern and Vernon R. Schaefer (2008) carried out experimental work to develop the pervious concrete mixture which has sufficient porosity for storm water infiltration along with sufficient strength and better freeze and thaw durability. They used the single sized aggregate passing from 9.5 mm and retained on 4.75 mm sieve. They carried out experimental work with constant water/cement ratio 0.27. They used the reducing agent, river sand up to 7 % by weight of coarse aggregate, polypropylene fibre by volume of cement up to 0.1%. They performed the porosity, compressive strength, tensile strength and permeability tests. The result obtained for compressive strength, tensile strength and permeability after 28 days were 26.5 MPa, 2.40MPa and 0.30 cm/s respectively. They concluded that as the fine aggregate introduce the compressive strength increases and porosity decreases [12].

Jesse Calkins et al. (2010) reported that pervious concrete also allows the removal of heavy metal and hydrocarbon. They carried out investigation on the interaction of heavy metal with pervious concrete sample and the interaction of materials consisting the pervious concrete mixture with heavy metals. They carried the 12-hr batch test for the interaction of heavy metal with the sand, aggregate, cement and nylon fibre and 24-hr batch test for the interaction of the heavy metal with pervious concrete. Water/cement ratio of the work was 0.23 and maximum compressive strength was 13.66 MPa. The permeability obtained were 1.79 cm/s with void content 34.33%. Through their study they came to the conclusion that the materials were quite good in removing heavy metal such as copper by the ion exchange mechanism while nylon 6 does not contribute to removal but their presence increases the rate of removal. They also concluded that with the increase of nylon fibre, void contents as wells the compressive strength decrease [10].

Liv Haselbach (2010) studied the comparison between the saturated and unsaturated condition for hydraulic conductivity of pervious concrete. The laboratory core infiltration test has been conducted. This test was done to evaluate the importance of pre wetting in the performance of pervious concrete. It was presumption that hydraulic conductivity can be the function of water content. Core specimen had been taken and hydraulic conductivity test conducted in drying as well as pre wetting condition. The specimens were casted with the aggregate of max size 9 mm. The specimens were mounted on the calibrated glass jar with collar at the top to hold it in position and free falling of water was allowed with maximum height was 13 mm. They concluded that there was no significant difference in the pre wetting and drying in case of conductivity performance of pervious concrete. They concluded the most recommended condition for conductivity was prewetting [15].

C. Lian and Y. Zhuge (2010) carried out the experimental work in which permeable concrete was prepared which had increased strength by introducing the little amount of fine. Water/cement ratio was varied between 0.30 to 0.38 while keeping another parameters constant. They are mainly concerned to find optimum mix design for pervious concrete so that the strength of pervious concrete can be increased. They used three different types of aggregates such as lime stone, dolomite and quartzite in the first stage of work to find which among them produce high strength pervious concrete. They found that dolomite was good in producing high strength concrete among them and also very resistive to abrasion in porous concrete and this character makes it suitable for further stage. They performed the flexure strength, compressive strength, porosity and permeability tests. In the final stage of work, they used silica fume 8% and quarry sand 18 % by weight of coarse aggregate and superplasticizer 0.8% by weight of cement. They concluded that addition of silica did not appear to be good for improving the compressive strength as expected and use of quarry sand increased the compressive strength. The water content also played crucial role in strength behaviour. The maximum compressive strength achieved 46.2 MPa and permeability of 2 mm/sec was achieved [6].

Qiao Dong et al. (2011) conducted study to evaluate the abrasion resistance of pervious concrete prepared with fibre and latex. They performed compressive strength, air voids, split tensile strength and permeability test along with two abrasion resistance tests. Two types of aggregates were used such as granite and limestone. The latex 10% by weight of cement and fibre content 0.9 kg/m^3 were used in the production of concrete. The four types of mixture were prepared consisting either limestone or granite as coarse aggregate. The four types of each mix consist of only latex, only fibre, both of them and none of them. They mainly focused on abrasion resistance of pervious concrete. The abrasion resistance was done by cantabro abrasion test and APA abrasion tests. Through their results, they found that latex increased the strength and abrasion resistance of concrete but fibre was not quite successful in improving the above. The test results of the study showed the pervious concrete features compressive strength 20-25 MPa and permeability 1-2 mm/sec [19].

Omkar Deo and Narayan Neithalath (2011) studied the proportion of pervious concrete mixture of desired porosity by varying the amount of cement paste. They performed the compressive strength test, porosity and determine pore size by image analysis on plane section. The above-mentioned tests were conducted as porosity was found out by casting cylindrical specimen of 95 mm size and 150 mm height, the critical pore size of the specimens was tested by images analysis and the number of open pores at the plane section were incorporated in granulometric opening distribution function. The pore size corresponding to the first local maximum in granulometric density function was designated as critical pore size. Seven types of mix were prepared with different paste volume i.e. high and low and each composed mix containing aggregate of different sizes. Four types of mix were prepared for high paste volume by different size of aggregate and for each type of aggregate three target porosities i.e. 0.19, 0.22, 0.27. Thus, total of 19 different mixes were made. They concluded that compressive stress and strain at peak stress has been decreasing with increasing porosity, strain also reduces with reducing paste content and there was rapid drop in the post peak response with reducing porosity [18].

J. T. Kevern (2012) studied the performance of pervious concrete with respect to normal concrete in the cold condition. They analysed gate motion by using embedded force plates, electromyography and tracking videography were used to find the subject mobility on icy and wet pervious concrete in cold weather condition. They found that pervious concrete may reduce the rate of slipping over the surface by three mechanism such as by reducing the accumulation of surface moisture and ice build-up, keeping the elevated temperature in their voids, by providing interface between the shoe sol and surface of the concrete. Kevern in 2009 stated the aggregates provides the insulation in the voids of the pervious concrete and prohibit the freezing of the soil. They concluded that pervious concrete had surface area 45% in comparison of normal concrete. They also concluded that shoe to pavement contact pressure was twice as compared to the normal concrete and the coefficient of friction was also five times the normal concrete [9].

Hariyadi and Hiroki Tamai (2015) in their study they used the pumice stone as a replacement of natural aggregate. The pervious concretes were prepared with varying the coarse aggregate in different percentages such as 0%, 50% and 100%. The water/cement ratio for the whole work was 0.25 and volcanic pumice stone replaced the aggregate in different percentage. The effect of variation of pumice stone in the concrete was checked. They performed the compressive strength, porosity, flexural strength and density tests and also found the modulus of elasticity by mathematical function. The modulus of elasticity (E_c) of the research was formulated as a function of unit weight (W) and compressive strength (F_C) of porous concrete. Regression analysis generated by the equation ($E_c = 9.31 \times 10^{-5} \times W^{2.342} \times F_C{}^{0.455}$) with R^2 value was 0.9761. The maximum compressive strength found was 22.50 MPa when there was no pumice stone and flexure value was 2.67 MPa at 24.33% void content. The value of modulus of elasticity was found to be 21680.87 MPa. They concluded that with the increase of pumice stone in concrete the porosity of the concrete increased but simultaneously decreased the modulus of elasticity of concrete [7].

R. Selvaraj and M. Amirthavarshini (2016) carried out the experimental work to study aspect of pervious concrete. They used the single sized aggregates in which size ranges from 6 mm to 20 mm. The aggregates of size 8 mm, 10 mm, 12 mm and 20 mm were used. The water/cement ratio of the work was 0.35. They performed compressive strength, tensile strength and permeability tests. The maximum value of compressive strength, tensile strength obtained were 12.61 MPa and 2.23 MPa respectively for 8 mm aggregate concrete and maximum permeability obtained was 6.1 mm/ sec for 20 mm aggregate concrete. They made the conclusion that as the size of coarse aggregate increases the void ratio also increases and the strength of pervious concrete was inversely proportional to the size of aggregate [20].

Xinzhuang Cui et al. (2017) carried out the experimental work to check the effects of water/cement ratio, aggregate/cement ratio and porosity on properties of porous concrete such as permeability, compressive strength and flexure strength. They performed compressive strength, flexural strength and permeability tests. The compressive strength tests were done on China Standard Mechanical Test Methods of Plain Concrete (GB/T 50081-2002). They also developed the modified permeability method for pervious concrete as the existing method for permeability did not considered the specimen-container interface for sidewall leakage. The 100×100×100 mm^3 cube, 400×100×100 mm^3 beam for compressive and flexural strength respectively. The mix designs were based on target porosities 10152025. Water/cement ratio were varied as 0.32, 0.34, 0.36, 0.38, 040. Based on their experimental work, they concluded 0.36 water cement ratio was found to be best as strength increases with increase of water/cement ratio up to 0.36 but after that value the values of compressive and flexure strength decreases. They also concluded that strength also decreases with increasing permeability [23].

Anush K. Chandrappa and Krishna Prapoorna Biligiri (2018) in their experimental study, 18 pervious concrete mixture were prepared and tested for different parameters such as hardened density, porosity, compressive strength and permeability. They focused primarily on the development of regression equation to assist them in the selection of appropriate mixture parameters for pervious concrete design. They concluded that equation can help to optimize the mixture in which it is possible to determine the required mixture variables before preparing and testing the specimens [5].

Jian -Xin Lu et al. (2019) investigated through his study that waste glass and recycled aggregates can be used as the replacement of natural coarse aggregate in the production of pervious concrete. In their experimental work they performed permeability, compressive strength, thermal conductivity and image of pore size tests. The pervious concrete was made up of two types in which one type contain 2.5 -5 mm aggregate with 0-2.36 mm waste glass as fine aggregate and another contain recycled aggregate as fine. The water cement ratios were varied from 0.29 to 0.32 in case of waste glass as fine and 0.35 to 0.40 in case of recycled aggregate as fine. They recommended that the use of silica can be useful for increasing the compressive strength. When they compared the concrete of natural aggregate with the concrete of blended aggregate of waste glass and recycled aggregate, they found that there was a decrease in the strength but permeability of the blended mix was quite good as it did not absorb water. They also concluded the use of small size aggregate gives better strength as compared to the larger size aggregates. The thermal conductivity decreased with increases with waste glass content in the mix [11].

6. CONCLUSION

Through the study of previous researcher, we can conclude that pervious concrete is low strength permeable concrete. The pervious concrete is good in storm water management, better insulation property. Though it possesses low strength as compared to the normal concrete but it can be increased by the use of superplasticizer, silica fume and other Cementous material. Due to its low strength its uses in loaded pavement is limited. As the time proceed, researchers will find way to enhanced its strength. If pervious concrete possesses high strength from now its application will be increased from current scenario.

REFERENCES

[1] ACI Committee 522 (2006), "Pervious Concrete", American Concrete Institute.

[2] Adam Marolf, Narayanan Neithalath, Eric Sell, Kristy Wegner, Jason Weiss and Jan Olek, (2004), "Influence of Aggregate Size and Gradation on the Acoustic Absorption of Enhanced Porosity Concrete", ACI Materials Journal- January, Page No. 1-36.

[3] Amarnath Yerramala Ramchandrdu C, (2012) "Properties of concrete with coconut shell as aggregate replacement", International journal of engineering Inventions, vol.1 issue 6, Page No. 21-31.

[4] Ammar Yahia, K. Daddy Kabagire, (2014), "New approach to proportion pervious concrete", department of civil engineering, Canada, Construction and building materials, vol. 62, Page No. 38-46.

[5] Anush K. Chandrappa and Krishna Prapoorna Biligiri, (2018), "Methodology to Develop Pervious Concrete Mixtures for Target Properties Emphasizing the Selection of Mixture Variables", Journal in transport engineering, part B: Pavement, vol. 144 (3), Page No. 04018031,1-10.

[6] C Lian and Y Zhuge, (2010), "Optimum Mix Design of Enhanced Permeable Concrete -An experimental

investigation", Construction and building materials, vol. 24, Page No. 2664-2671.

[7] Hariyadi and Hiroki Tamai, (2015), "Enhancing the performance of porous concrete by utilizing the pumice aggregate", Procedia engineering, Vol.125, Page No. 732-738.

[8] IRC 44-2017, "Guidelines for cement concrete Mix design for pavement" (third revision), Indian Road Congress, New Delhi.

[9] J. T. Kevern, G. W. King and A. P. Bruetsch, (2012), "Pervious Concrete Surface Characterization to Reduce Slip-Related Falls", Journal of performance of constructed facilities @ ASCE, vol.26, Page No 526-531.

[10] Jesse Calkins, Arthur Kney, Muhannad T. Suleiman, Austin Weidner, (2010), "Removal of Heavy Metals using Pervious Concrete", ASCE publication by world environmental and water resources congress, Page No. 3774 – 3784.

[11] Jian-Xin Lu, Xin Yan, Pingping He, Chi Sun Poon, (2019), "Sustainable design of pervious concrete using waste glass and recycled concrete aggregate", Journal of cleaner Production, Vol.234, Page No. 1102-1112.

[12] John T. Kevern, Vernon R. Schaefer, Kejin Wang, Mohd. T. Suleiman, (2008)," Pervious Concrete mixture proportions for improved freeze-thaw durability", ASCE publication, Journal of ASTM international, vol.5, Paper ID JAI101320.

[13] Kartik H. Obla, (2010), "Pervious concrete -an overview", Indian Concrete Journal, Page No. 10-18.

[14] Kelly A. Collins, William F. Hunt and Jon M. Hathway, (2007), "Evaluation of various types of permeable pavements with respect to water quality improvement and flood control", world environment and water resources congress 2007: Restoring our national habitat, ASCE Publication, Page No. 1-11.

[15] Liv Haselbach, (2010), "Pervious Concrete Testing Methods", ACSE publication by low impact development, Page No. 180 -193.

[16] Michael Kwiatkowski and Andrea L. Welker, (2008), "Development of a Monitoring Program for a Porous Concrete BMP", ASCE publication by World Water & Environmental Resources Congress, Page No. 1-10.

[17] Nadar Ghafoori, Shivaji Dutta, (1995), "Development of No-Fine Concrete pavement applications", J. Transport Engineering, ASCE publication, vol. 121, Page No.283-288.

[18] Omkar Deo and Narayanan Neithalatha, (2011), "Compressive response of pervious concretes proportioned for desired porosities", Construction and building materials, vol.25, Page No. 4181-4189.

[19] R. Selvaraj, M. Amirthavarshini, (2016), "Some Aspects on Pervious Concrete", International Journal of Engineering and Applied Sciences (IJEAS) ISSN: 2394, Vol. 3, Issue-1, Page No. 6-10.

[20] Richard C. Meininger, (1988), "No-Fines Pervious Concrete for Paving", Concrete International, Page No. 20-27.

[21] Richard C. Meininger, (1988), "No-Fines Pervious Concrete for Paving", Concrete International, Page No. 20-27.

[22] Somayeh Nassiri, Milena Rangelov and Zhao Chen, (2017), "Preliminary study to develop standard acceptance tests for pervious concrete", Research report, Agreement No. T1462, Task 11, WA-RD 868.1, Page No. A.1-A.67.

[23] Xinzhuang Cui, Jiong Zhang, Dan Huang, Zequn Liu, Fei Hou, Sheqiang Cui and Xiaonan Gong, (2017), "Measurement of permeability and the correlation between permeability and strength of pervious concrete", 1st International conference on transportation infrastructure and materials, ISBN: 978-1-60595-367-0, Page No. 885-892.

[24] Yang, J., & Jiang, G. (2003), "Experimental study on properties of pervious concrete pavement materials", Cement and Concrete Research, vol. 33, Page No. 381-386.

BIOGRAPHIES

Paragdeep Tripathi
M.E.- Civil (Structure)
PG Student, MITS Gwalior,
Madhya Pradesh.

Dr. S.K. Jain
PdF, Ph.D., M.E.,
Area of Interest: Structural Dynamics & Earthquake Engg.
Project Guide, MITS, Gwalior,
Madhya Pradesh.