Relationship between Properties of No Fines Concrete-A Review paper

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Abstract: ***In the current century, the construction industries have shown an increasing interest in no fines (pervious concrete), an environmentally friendly material. No fines concrete (pervious concrete is a composite material consisting of course aggregate, cement, water and admixtures with the elimination of fine aggregate. Recently an emphasis has been placed on the relationship between the Unit Weight, compressive Strength, Fracture, Fatique, Void Ratio, Splitting Tensile Strength, porosity and permeability. Researchers have been carrying out investigations to characterize the relationship between the properties of no fines concrete. The objective of this paper is to highlight the important relationship between the properties of no fines concrete. This overview presents the correlation among the properties of no fines concrete including strength, permeability, porosity and void ratio. Based on the results of previous research works on no fines concrete (pervious concrete), it was found that there is a correlation between the properties of no fines concrete and by determining the correlation between the properties of no fines concrete, it could possible to obtain proper no fines concrete used for various construction applications.***

***Keywords*—No Fines Concrete, Unit Weight, Compressive Strength, Fracture, Fatigue, Void Ratio, Splitting Tensile Strength,Porosity, Permeability.**

I. INTRODUCTION

Today in the present world we are very much fond of sustainable and eco-friendly means of construction. Particularly in a country like India where flooding and water-logging problems are the major environmental issues sustainable development has become a necessity. Various sustainable and eco-friendly means are being implemented to tackle these problems where No-fine concrete pavement is one among them. Working on rain-drain" concept No-fine concrete allows a significant amount of storm water to seep into the ground, thereby recharging the ground water and reducing the storm water runoff. No-fine concrete is a light-weight concrete produced by omitting the fines from conventional concrete. No-fine concrete (sometimes referred to as porous or open-textured concrete) is a concrete consisting of cement, coarse aggregate and water. It has its origin in late 1940s and now been widely used in the United States, Japan and Europe because of its various environmental benefits such as controlling storm water runoff, restoring groundwater supplies and reducing water and soil pollution. Apart from this, it has the potential to reduce urban heat island effects and can be used to reduce acoustic noise in roads. No-fine concrete is a discontinuous mixture of coarse aggregate, hydraulic cement and other cementations materials, admixtures and water. By creating a permeable surface, storm water is given access to filter through the pavement and underlying soil, provided that the underlying soil is suitable for drainage. This allows for potential filtration of pollutants. The advantages of no-fine concrete are:

- Water treatment by pollutant removal;
- Less need for curbing and storm sewers.
- Improved road safety because of better skid resistance.
- Recharge to local aquifers.

Pervious concrete can be used for a number of applications, but its primary use is in road pavement such as in rural areas. This study will focus on the pavement applications of the concrete, which also has been referred to as porous concrete, permeable concrete, no-fines concrete, gap-graded concrete, and enhanced-porosity concrete. Pervious concrete pavement in rural areas is a unique and effective means to achieve important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff.

Lightweight concrete produced by omitting fine particles is studied in this paper. Temporary ban on extraction of sand from river bed, demand and increasing market price for sand has made to think to produce a concrete which is free from fine aggregates, light in weight and also to attain sufficient strength with low cost of production. As the omission of fine particles in concrete leads to lower surface area of aggregates that would be coated with cement paste, less cement content will be used in this no-fines concrete than the conventional concrete which ultimately results in low cost of production. By using No-fines concrete blocks in buildings as masonry unit will reduce the overall dead weight of the structure which gives the flexibility in designing the size of foundation. Using no-fines concrete in pavement reduces the runoff thereby recharging ground water. There is no segregation in no-fines concrete as light hand compaction is given and either less or no fine particles are used in no-fines concrete. Large number of voids present in no-fines concrete makes it more permeable and a very good sound absorber.

[1].Typically no fines concrete has water to cementitious materials ratio (W/C) of 0.28 to 0.40 [2]. Comparing to conventional concrete which has a void ratio of about 3-5%, no fines possesses void ratio as high as 15-40% depending on its application. The high percentage of void ratio results in low unit weight of about 70% of that of conventional concrete [3]. It has been used in many countries and it continues to gain the popularity as environmentally friendly materials.

II. COMPONENTS OF NO FINES CONCRETE

The main components of no fines concrete (pervious concrete) are coarse aggregate, cement, and water. In case higher compressive strength is required, little amount of fine aggregate may be added. Other admixtures such as High/Middle Range Water Reducer (HRWR, MRWR), water retarder, viscosity modifying admixtures, hydrophobic admixtures, Cellulose Fibers etc. are usually used. In some cases, cementitious materials are used as a substitute for Portland cement to enhance the environmental friendliness of permeable concrete.

III. COMPONENTS OF NO FINES CONCRETE (PERVIOUS CONCRETE)

There are no specific codal provisions relevant to the mix design of no fines concrete (pervious concrete) in any standard. ACI 211.3 has provided a procedure for proportioning pervious concrete mixtures. Typical mix designs of pervious concrete also had been recommended by different agencies such as National Ready Mixed Concrete Association (NRMCA), and the Southern California Ready Mix Concrete Association (SCRMCA). Table 1 provides typical ranges of materials proportions in no fines concrete (pervious concrete). Often, local concrete producers will be able to best determine the mix proportions for locally available materials based on trial batching and experience. Sometimes chemical admixtures/retarders are used to ease the placement of no fines concrete (pervious concrete) and reduce the W/C ratio. Little fine aggregate may also added resulting in decrease of the void content and increase of the strength.

TABLE 1 A TYPICAL MIX PROPORTION OF NO FINES CONCRETE

Sr No	Materials	Amount per m^3 of Concrete		
		ACI211.3	NRMCA	SCMCA
1	Cement (kg)	270 to 415	224 – 388	286-316
2	Aggregate Kg	1190 to 1480	1431-1670	1027
3	Water: cement ratio (by mass)	0.17 to 0.36	0.27 to 0.38	0.29 – 0.36
4	Fine: course aggregate ratio (by mass)	0 to 1:1	NA	NA
5	Achieved strength at 28 Days (MPa)	20	NA	NA

IV. CORRELATION AMONG STRENGTH, FRACTURE AND FATIGUE OF NO FINES CONCRETE (PERVIOUS CONCRETE)

Yu Chen et. Al [2012-13] analysed the correction between strength, fracture toughness and fatigue. In above study, strength, fracture toughness and fatigue life of two types of pervious concrete, supplementary cementitious material (SCM)-modified pervious concrete (SPC) and polymer-modified pervious concrete (PPC), are investigated. The results indicate that high strength pervious concrete (32–46 MPa at 28 days depending upon the porosity) can be achieved through both SCM modification, using silica fume (SF) and super plasticizer (SP), and polymer-modification, using polymer SJ-601. For both SPC and PPC, porosity significantly affects compressive strength, but it has little effect on the rate of strength development. Flexural strength of pervious concrete is more sensitive to porosity than compressive strength. Pervious concrete has more significant size effect than conventional concrete.PPC demonstrates much higher fracture toughness and far longer fatigue life than SPC at any stress level.

Yang and Jiang [12] demonstrated that use of silica fume (SF) and superplasticizer (SP) could enhance pervious concrete strength substantially.Kevern [13] reported that the addition of polymer (styrene butadiene rubber) could improve pervious concrete workability, strength, and permeability as well as freeze–thaw resistance.Inaddition,the performance of laboratory, field produced pervious concrete mixtures and field cores were evaluated and compared through laboratory performance tests, including air voids, permeability, compressive and split tensile strengths, as well as Cantabro and freeze–thaw durability tests by Shu et al. [14].

V. CORRELATION AMONG COMPRESSIVE STRENGTH AND DURABILITY ASPECTS OF NO FINES CONCRETE(PERVIOUS CONCRETE)

F. Tittarelli et. Al [2013-14] studied effect of hydrophobic admixture and recycled aggregate on physical-mechanical properties and durability aspects of no-fines concrete. No-fines concrete with a compressive strength in the range 7-30 MPa at 28 days of curing were optimized by changing the water/cement ratio from 0.41 to 0.34 and the aggregate/cement ratios from 8 to 4. Some mixtures were also repeated with the addition of a hydrophobic admixture and prepared by fully replacing the ordinary aggregate with recycled aggregate to evaluate durability effects. High susceptibility to carbonation was observed for all the no-fines mixes studied. The use of recycled aggregate increases capillary water absorption (about 50%) : however , the related decrease in durability could be easily counteracted with the use of a hydrophobic admixture.

VI. CORRELATION AMONG UNIT WEIGHT, POROSITY AND COMPRSSIVE STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

Cristián Gaedicke et. Al [2013] studied a method for comparing cores and cast cylinders in virgin and recycled aggregate pervious concrete. This approach uses cylinders subjected to different compaction levels via a Proctor-hammer to create

Curves that relate the concrete porosity and the desired property. The cores are then compared to the corresponding curve values that match the core’s porosity to create adjustment factors for unit weight, permeability, and compressive strength. Cores were comprised of pea gravel, limestone, and recycled aggregate concrete mixtures. Experimental results show that, compared to compacted cylinders of the same porosity, cores have on average the same unit weight, 20% less permeability, and 17% lower

Compressive strength. The unit weight of fresh concrete cylinders was on average 3.6% higher than the dry unit weight. For a constant porosity and paste content, higher unit weights were achieved by mixtures made with pea gravel, followed by those made with limestone and Recycled Course Aggregate Blended. Cores from mixtures prepared with virgin aggregates had on average 15% less permeability compared to compacted cylinders of the same porosity. Cores made with recycled aggregates had a 29% lower permeability compared to compacted cylinders of the same porosity. The compressive strength of recycled aggregate concrete cylinders was on average 8% lower than pea gravel and 15% lower than limestone aggregate mixtures, for a porosity equal to 20%.

VII. CORRELATION AMONG COMPRESSIVE STRENGTH,TESNILE STRENGTH AND FLEXTURAL STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

Saeid Hesami et. Al[2013-14] studied Effects of rice husk ash and fiber on mechanical properties of pervious concrete pavement. The use of pervious concrete pavement is significantly increasing due to reduction of road runoff and absorption of noise. However, this type of pavement cannot be used for heavy traffic due to a high amount of voids and consequently low strength of pervious concrete. In this paper, rice husk ash (RHA) was used in order to strengthen pozzolanic cement paste and the effect of 0%, 2%, 4%, 6%, 8%, 10% and 12% weight percentages as a cement replacement in concrete mixtures on the mechanical properties was studied. Moreover, 0.2% Vf of glass (where Vf is the proportion of fiber volume to total volume of concrete), 0.5% Vf of steel and 0.3% Vf of polyphenylene sulfide (PPS) fibers were used to improve the mechanical properties of the pervious concrete. Also, several water to cement (w/c) ratios were made and then, physical and mechanical properties of hardened concrete including porosity, permeability, compressive strength, tensile strength and flexural strength were investigated. The results indicated a significant increase in compressive, tensile and flexural strengths. Also, in all of w/c ratios, a similar trend was observed in the compressive, tensile and flexural strengths of concrete containing RHA (Rice Husk Ash) and fibers but the optimum percentage of RHA was different so that, it increases rapidly to the optimization point but gradually decreases after this point. The w/c ratio of 0.33 significantly increased the mechanical properties of the pervious concrete and reduces the amounts of voids and its permeability.

VIII. CORRELATION AMONG VOID RATIO, COEFFICIENT OF PERMEABILITY, COMPRESSIVE STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

Muhammad Aamer Rafique Bhutta et. Al[2013-14] studied on Properties of porous concrete from waste crushed concrete (recycled aggregate). The purpose of this study was to develop porous concrete with acceptable permeability and strength using recycled aggregate from waste crushed concrete. The optimum mix proportions were employed to prepare porous concretes using normal and recycled aggregates. Tests carried out on porous concrete were: void ratio, coefficient of permeability, compressive and flexural strengths. The effect of recycled aggregate on total void ratio, strength and permeability was examined. Styrene butadiene rubber-based redispersible polymer powder and latex were introduced to mixtures to improve strength properties. The total void ratio of porous concrete incorporating recycled aggregate was larger than that of porous concrete with normal aggregate. The addition of polymer modification resulted in a slight decrease in total void ratio regardless of type of aggregate. The compressive strength of porous concrete using recycled aggregate was lower the one using normal aggregate. However, the compressive strengths of porous concretes using normal and recycled aggregates were significantly improved by 57% and 79% respectively, due to polymer modification. The use of recycled aggregate along with optimum content of polymer could produce acceptable porous concrete with both enough drainage and strength properties.

IX. CORRELATION AMONG VOID RATIO, COEFFICIENT OF PERMEABILITY,COMPRESSIVE AND FLEXTURAL STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

M. Aamer Rafique Bhutta et. Al[2012-13] studied on Evaluation of high-performance porous concrete properties. The aim of this laboratory study was to evaluate the properties of high performance porous concrete. It required no special vibration equipment and curing. The optimum mixture proportions were used in the preparation of high performance porous concretes containing three sizes of coarse aggregates with appropriate amount of high water-reducing and thickening (cohesive) agents. Tests carried out on this concrete were: slump, slump-flow, void ratio, and coefficient of permeability, compressive and flexural strengths, and strength development rate. Furthermore, a test was proposed to determine the effects of high water-reducing and thickening (cohesive) agents on self-compaction of high performance porous concrete. It was meant to evaluate its hardened properties from the viewpoint of practical application. Its strength development rate was also examined at curing age of 1, 3, 7, 14 and 28 days at 20^0 C and 60% relative humidity (R. H.). Consequently, high performance porous concrete exhibited good workability and cohesiveness with no segregation or bleeding, and developed high strength compared to conventional porous concrete. The results of proposed self-compaction test for this porous concrete also showed good workability and cohesiveness without any special compaction or vibration.

X. CORRELATION AMONG VOID RATIO, COMPRESSIVE STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

P. Chindaprasirt et. Al [2006-07] studied on Cement paste characteristics and porous concrete properties. The results indicate that cement paste characteristics are dependent on the water to cement ratio (W/C), admixture and mixing time. Cement paste with high viscosity and high flow suitable for making porous concrete is obtained with the use of low W/C of 0.20–0.25, an incorporation of 1% superplasticizer, and sufficient mixing. Porous concretes having suitable void ratios are produced with appropriate paste content and flow, and sufficient compaction. Good porous concretes with void ratio of 15–25% and strength of 22–39 MPa are produced using paste with flow of 150–230 mm and top surface vibration of 10 s with vibrating energy of 90 kN m/m^2. For low void ratio, high strength porous concrete of 39 MPa is obtained using paste with low flow. For high void ratio, porous concrete of 22 MPa is obtained using paste with high flow.

XI. CORRELATION AMONG COMPRESSIVE STRENGTH, TENSILE STRENGTH, POROSITY AND PERMEABILITY OF NO FINES CONCRETE(PERVIOUS CONCRETE)

Ahmed Ibrahim et. Al [2012-13] studied on Portland cement pervious concrete mechanical and hydrological properties. Pervious concrete layer is one of the effective concrete pavement mixes to address a number of important environmental issues, such as recharging groundwater and reducing storm water runoff. Portland Cement Pervious Concrete (PCPC) is produced by eliminating most or all of the fine aggregate in the mix, which allows interconnected void spaces to be formed in the hardened matrix. These interconnected void spaces allow the concrete to transmit water at relatively high rates. Twenty-four PCPC mixtures were prepared and tested to address the effect of different size fractions of coarse aggregate, water-to cement ratio, cement content, and coarse aggregate volume on the relationships between compressive strength, tensile strength, porosity, and permeability. The mixtures used in this study consisted of either one or two aggregate sizes. Linear regression relationships were developed to establish relationships between density and porosity, compressive strength and permeability, tensile strength and permeability, and compressive strength and porosity. The results showed that properties such as permeability, porosity, are significantly affected by using either one or two coarse aggregate sizes in all concrete mixtures. Furthermore, density can be an effective factor for predicting compressive strength, and porosity. In this study, the maximum compressive strength was 6.95 MPa, which obtained by using one aggregate size of 9.5 mm with 250 kg/m3 cement content. The obtained results showed that PCPC could be produced using one or two aggregate sizes at most.

XII. CORRELATION AMONG UNIT WEIGHT, COMPRESSIVE STRENGTH, SPLITTING TENSILE STRENGTH AND FLEXUTRAL STRENGTH OF NO FINES CONCRETE(PERVIOUS CONCRETE)

Oguz Akin Duzgun et. Al [2005] studied effect of steel fibers on the mechanical properties of natural lightweight aggregate concrete (No-Fines Concrete). In order to determine the effect of steel fiber ratio on the mechanical properties of concrete, (1) 25%, 50%, 75%, and 100% pumice ratios were used instead of natural aggregate by volume, (2) 0.5%, 1.0%, and 1.5% steel fiber ratios were used by volume of the sample and (3) also, 300 kg/m3 cement dosage and 3T0.5 cm slump were used. The test results showed that the increasing pumice aggregate ratio decreased the unit weight and the mechanical properties of the concretes. When compared to the control sample that contains no fiber, with the increase of steel fiber ratio in the mixtures unit weight, compressive strength, splitting-tensile strength and flexural strength of concretes increased up to 8.5%, 21.1%, 61.2% and 120.2%, respectively. Moduli of elasticity and deformation capability were decreased with increase of pumice aggregate and steel fiber ratio in the mixture.

XIII. CORRELATION AMONG UNIT WEIGHT, COMPRESSIVE STRENGTH, SPLITTING TENSILE STRENGTH AND FLEXUTRAL STRENGTH OF NO FINES CONCRETE (PERVIOUS CONCRETE)

Baoshan Huang et. Al studied Laboratory evaluation of permeability and strength of polymer-modified pervious concrete. A laboratory experiment was conducted in this study to improve the strength properties of pervious concrete through the incorporation of latex polymer. This study focused on the balance between permeability and strength properties of polymer-modified pervious concrete (PMPC). In addition to latex, natural sand and fiber were included to enhance the strength properties of pervious concrete. The test results indicate that it was possible to produce pervious concrete mixture with acceptable permeability and strength through the combination of latex and sand. It is seen that most of the mixtures had porosities within the range from 20% to 30%,which is acceptable. The three coarse aggregates with different sizes exhibited similar porosity, indicating that aggregate gradation did not have a significant effect on the porosity results. The mix made with latex, sand, and fiber could still achieve the porosity. The effect of latex, natural sand, and fiber on permeability was similar to that on porosity. Although the addition of sand and latex could lead to a reduction in permeability, the permeability value was comparable and acceptable compared to the general requirement of drainage. As expected, the smaller the coarse aggregate size, the higher the compressive strength. It is evident that the addition of sand or latex could both increase the compressive strength of concrete mixtures. When fiber was added into control mix without latex or sand, fiber appeared to increase the compressive strength significantly. However, after sand and/or latex were also incorporated into the mix, addition of fiber could not further improve the strength. Similar to the compressive strength, concrete mixtures containing smaller size aggregates had higher split tensile strength. However, the effect of latex was still significant in improving the split tensile strength of pervious concrete. This is attributed to the latex network formed during the commingling and inter-penetration of the latex and cement hydration products. it is seen that the effect of fiber on split tensile strength was similar to the effect on compressive strength. The addition of fiber appeared to lead to a significant increase in the split tensile strength of the control mix. Use of fiber did not lead to the increase of split tensile strength of pervious concrete mixtures containing sand and/or latex.

XIV. CONCLUSION

This paper presents an overview of the correlation between different properties of No-Fines Concrete such as Unit Weight, compressive Strength, Fracture, Fatigue, Void Ratio, Splitting Tensile Strength, porosity and permeability.

1) By Reviewing Correlation among Strength, Flexural Strength and Fatigue property- High strength pervious concrete, 32–46 MPa at 28 days depending upon the porosity, can be achieved through both SCM-modification using silica fume (SF) and superplasticizer (SP), and polymer-modification, using polymer SJ-601.PPC has both higher Flexural Strength and higher Flexural-to-compressive strength than SPC at the same porosity level at 28 days. Both high strength SPC and PPC produced improved fatigue property than conventional pervious concrete.
2) By Reviewing Correlation among Compressive Strength and Durability aspects- No fines concrete with compressive strength ranging from 7 to 30 MPa werer obtained by changing the w/c from 0.41 to 0.34 and a/c ratio from 8 to 4.By using Hydrophobic admixtures improves durability performance and decreasing capillary water absorption from its original value of about 70%.
3) By Reviewing correlation among Unit weight, Porosity and Compressive strength - For a constant porosity and paste content, higher unit weight were achieved by mixtures made with pea gravel, followed by those made with limestone and Recycled Course aggregated blended. The compressive strength of recycled aggregate concrete cylinders was on average 8% lower than pea gravel and 15% lower than limestone aggregate mixtures, for a porosity equal to 20%.

4) By Studying relationship between Compressive Strength, Tensile Strength and Flexural Strength - The mechanical properties including Compressive, Tensile and Flexural Strength were found to be maximum for w/c ratio of 0.33. For 8–10% replacement of RHA and w/c ratio of 0.33, the compressive strength of pervious concrete containing fibers and RHA increases by 34%, 37% and 36% for glass, steel and PPS fibers, respectively. Also, for the above-mentioned mix design, the tensile strength increases by 31%, 30% and 28% for glass, steel and PPS fibers, respectively. Finally, the flexural strength undergoes a 64%, 63% and 69% increase when glass, steel and PPS fibers are used, respectively.
5) By Studying the correlation among properties like Void Ratio, Coefficient of Permeability, Compressive and Flexural Strength- the total void ratio of porous concrete incorporating recycled aggregate was higher than those having normal aggregate. Use of Recycled aggregate along with polymer modification could produce acceptable porous concrete having both enough drainage and strength properties.
6) By reviewing relationship between Void ratio, Coefficient of Permeability, Compressive and Flexural Strength-Use of combination of SP and cohesive agent could produce acceptable HPPC with good workability and strength properties. The addition of cohesive agent to HPPC mixture could decrease the total void ration and permeability and significantly increase the compressive and flexural strengths.
7) By Studying Void Ratio and Compressive Strength –Cement paste with high viscosity and flow of 150-230 mm suitable for making porous concrete is obtained with W/C of 0.20-0.25, 1% SP and sufficient mixing. The use of high void ratio with low flow paste produces porous concrete with relatively low strength. At the other end, the use of the low void ration with high flow paste produces relatively high strength porous concrete.
8) By studying relationship between Compressive Strength, Tensile Strength, Porosity and Permeability-Compressive Strength of pervious concrete is low compared to conventional concrete due to its high porosity. Using cement content of 150 kg/m^3 with a single size aggregate of 9.5 mm decreased the compressive strength by 75% compared to the highest value obtained. As expected, if the density of pervious concrete increases, the porosity and water permeability decrease.
9) By Reviewing the relationship between Unit Weight, Compressive Strength, Splitting Tensile Strength and Flexural Strength-The analysis of test results leads to the conclusion that no real workability problem was encountered in the mixtures when using the SF up to 1.5% by volume. With the increase of SF ratio in the mixtures, unit weight, compressive strength, splitting tensile strength and flexural strength of the concrete increased up to 8.5%, 21.1%, 61.2% and 120.2%, respectively. Using Steel fibers in lightweight aggregate concrete, the properties which are desirable in as structural member such as lightness, sound and thermal insulation and strength can be obtained.
10) By reviewing the correlation among Unit weight, Compressive and Splitting Tensile Strength, Flexural Strength –Use of combination of latex, natural sand, and fiber could produce acceptable pervious concrete with both enough drainage and strength properties. Latex and sand could both decrease the porosity and permeability of pervious concrete and increase the compressive strength of pervious concrete. However, only addition of latex could increase the split tensile strength of pervious concrete.

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