Review of Experimental Studies on Pervious Concrete Utilizing GGBFS and Silica Fume As a Partial Replacement of Cement

Rajeshvarsinh A. Jadeja[1], Krunal J. Dhandha[2]

[1]*Research Scholar, Department of Civil Engineering, DIET-Rajkot, Gujarat, India*

[2]*Assistant Professor, Department of Civil Engineering, DIET-Rajkot, Gujarat, India*

ABSTRACT

In order to develop material specification for pervious concrete, it is necessary to conduct tests to evaluate the performance of this new type of high-performance concrete made by conventional cementitious materials, aggregates and water. Main focus of this investigation is 1) To evaluate optimum sand content (%) for ordinary pervious concrete (OPC) by ratio of sand used in three phases (5%, 7.5%, 10%). 2) To prepare pervious concrete replacing cement with silica fume (5%,10%,15%) and Ground Granulated Blast Furnace Slag (GGBFS) (10%,20%,30%) and evaluate its mechanical properties such as density, void content, compressive strength, flexural strength, abrasion resistance, split tensile strength, water permeability, porosity and optimum percentages.

Keyword:- *Pervious concrete, GGBFS, Silica Fume, Sand Content, Mechanical Properties of Pervious concrete.*

1. INTRODUCTION

Portland Cement Pervious Concrete (PCPC) has been used in construction for past several years with first documented usage in Europe. World over, Pervious Concrete has becoming popular due to its great environmental benefits in storm water management and futuristic pavement construction. More than just the drainage of surface water runoff, its advantages include pollution treatment of runoff water, reducing traffic noise, recharging of aquifers, increasing skid resistance, and minimizing the heat island effect in large cities. Pervious concrete has been used in the United State for over 3 decade. Pervious concrete is special type of high porosity concrete which allows water and other water soluble particles to percolate through it and reducing the water flow on ground and increases the ground water level.

According to National Ready Mixed Concrete Association (NRMCA) “pervious concrete is a special type of concrete with a high porosity used for concrete flatwork applications that allows water from precipitation and other sources to pass-through it, thereby reducing the runoff from a site and recharging ground water-levels.” It is also known as **“no-fines concrete”** and composed of Portland cement, coarse aggregate, water, admixtures, and little or no sand.

Generally for construction of pavements Conventional normal weight Portland cement concrete is used. The impervious nature of the concrete pavements contributes to the increased water runoff into the drainage system, and by that, over-burdening the infrastructure and causing excessive flooding in built-up areas. So in this era of urbanization, pervious concrete would be a boon. Pervious concrete is a type of concrete with significantly high water permeability compared to normal weight concrete. It has been mainly developed for draining water from the ground surface, so that storm water runoff is reduced and the groundwater is recharged.

Pervious concrete, however, has deficiencies which limit its application as pavements. These limitations include low compressive strength and flexural strength, clogging and other durability issues. This issue can be addressed efficiently by researching the optimum material and process of making the pavement by pervious concrete.

2. MATERIAL SELECTION OF PROJECT

2.1 Ground Granulated Blast Furnace Slag (GGBFS):

The GGBFS could be a by-product of the iron manufacture business. Iron ore, coke and stone are insert the chamber and also the ensuing ore, coke and limestone insert the chamber and also the ensuing liquefied scum oats higher than the melting iron at a temperature of regarding 1600 ºC to 1700°C. The soften scum incorporates a composite of regarding four-hundredth to five hundredth SiO2 and regarding hour CaO, that is near the chemical composition of hydraulic cement. Once the liquefied iron ore taped of, the stay liquefied scum, that consists of in the main oxide and aluminous residue is then water quenched quickly, leading to the formation of a glassy granulate. The assembly of geo-polymer concrete is administered exploitation the traditional concrete technology strategies. The GGBFS primarily based geo-polymer concrete consists seventy fifth to eightieth by mass of mixture, that is certain by a geo-polymer paste fashioned by the reaction of the element and metallic element among the GGBFS and also the alkaline liquid created of hydrated oxide and soluble glass answer with addition of super plasticizer. This glassy granulate is dried and ground to the specified size and this can be referred to as ground granulated blast furnace slag (GGBFS).

To investigate the utilization of GGBFS primarily based geo-polymer concrete has increase because of the environment sustain possibility of mistreatment subordinate in nursing industrial waste on type helpful material. Analysis and industry terms area unit exacted concerning the new direct of a concrete made of industrial by product this might scale back the matter of eliminate these materials. The GGBFS used powder form in this research work which are replacement with cement in the concrete mix and to determine the properties of GGBFS.

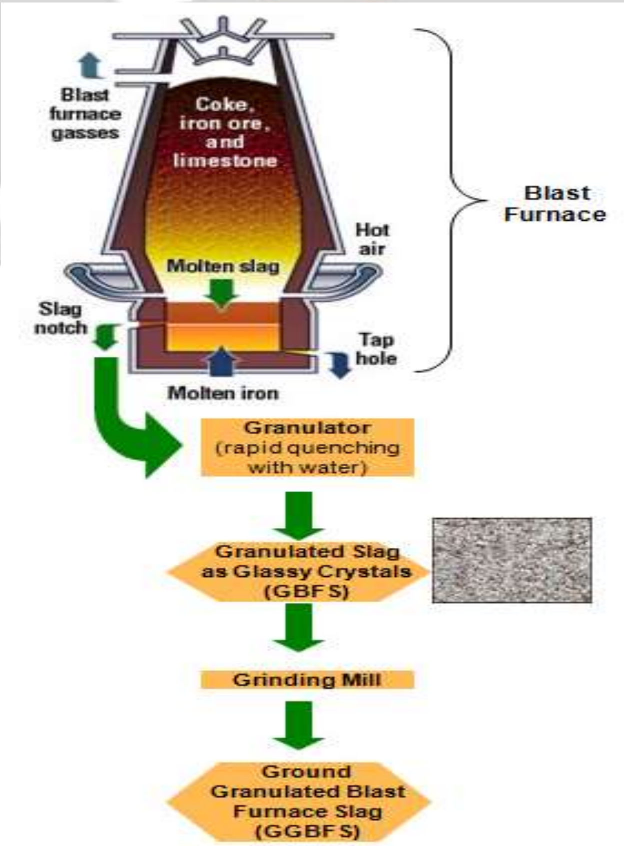

Figure 1. Process of GGBFS manufacturing

Figure 2. GGBFS

Table 1. Chemical Properties of GGBFS

Sr. No.	Characteristic	Test Report (%)
1	SiO_2	35.47
2	CaO	35.89
3	MgO	8.06
4	Fe_2O_3	2.41
5	Al_2O_3	14.27
6	Loss on Ignition	0.70
7	Insoluble Residue	0.52
8	MnO	0.34
9	Alkalis	0.20
10	Sulphide Sulphur as SO_3	1.58
11	Fineness	3820
12	Specific Gravity	2.8

2.2 Silica Fume:

Silica fume is a by-product gained by collecting exhaust gas generated in the process of refining ferrosilicon, metal silicon etc. These spherical superfine particles consist primarily of non-crystalline silicon dioxide (SiO2), and the average particle diameter of each primary particle is approximately 0.1 to 1.0 μm. By adding the superfine particles of silica fume to cement and other materials, the gaps between the particles are filled.

This effect achieves the production of dense, high-strength products. Silica fume improves the flowability and workability of cement. This effect reduces the unit water amount required for achieving the specific flowability.

Soluble silica reacts with calcium hydroxide to produce a water-insoluble, curable siliceous compound. The main ingredient of silica fume is non-crystalline SiO2, which reacts with Ca(OH)2 produced by hydration of the cement and produces calcium silicate hydrate. By this reaction, the intensity and the water-tightness of the cement are improved. It is used in concrete products to improve water tightness, higher-mechanical strength and reduce rebound amount when spraying.

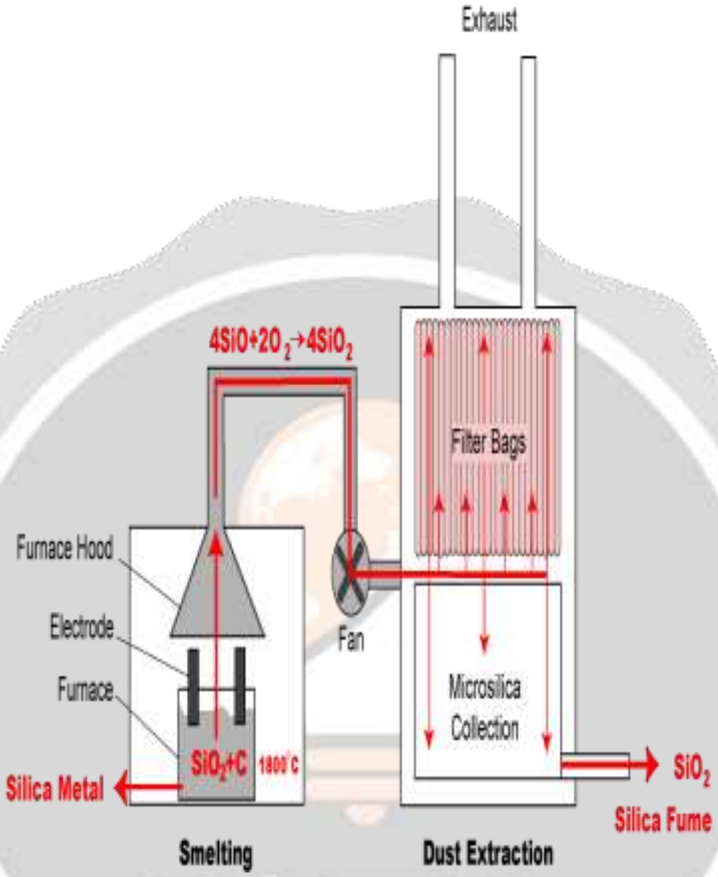

Figure 3. Production of Silica Fume

Figure 4. Silica Fume

Table 2. Chemical Properties of Silica Fume

Sr. No.	Characteristic	Test Report (%)
1	SiO_2	93.00
2	CaO	0.10
3	MgO	1.50
4	Fe_2O_3	1.00
5	Al_2O_3	1.40
6	Loss on Ignition	-
7	Insoluble Residue	-
8	MnO	-
9	Alkalis	2.50
10	Sulphide Sulphur as SO_3	0.50
11	Fineness	2250
12	Specific Gravity	2.23

3. LITERATURE REVIEW

In the past, number of research and development has been done on Pervious concrete. There has been a substantial and increasing number of publications of all types. In this section, those considered most relevant to the current study are reviewed and summarized here.

Darshna shah, Prof. Jayeshkumar Pitroda and Prof.J.J.Bhavsar published a research paper ‘Pervious Concrete: New Era for Rural Road Pavement’ in 2013. Object of the study was to evaluate the cost effectiveness of the pervious concrete compared to normal concrete. In this study, Normal concrete was used as per IS design of M20 grade, which was constituted by 59.25 kg of cement (300rs/50kg), 88.88 kg of Fine aggregate (600rs/1 ton) and 177.8 kg of course aggregate (1000rs/1ton). Pervious concrete was used as per NRMCA guideline, which was constituted by 46.5 kg of cement (300rs/50kg) and course concrete (1000rs/1ton). They conclude that the pervious concrete reduce the storm water runoff to increase the ground level water to eliminate the costly storm water management practices. And there is considerable saving in amount about 29rs/m3 or 18rs/ft2.[3]

Husain N Hamdulay, Roshni J John and D R Suroshe published an experiment in 2015 named ‘Effect of Aggregate Grading and Cementitious by Product on Performance of Pervious Concrete’. Object of the study was to replace the cement with industrial by-product such as fly ash, GGBFS which have been used successfully as supplementary Cementous material. In this study, cement of 53 grade (specific gravity 3.15), coarse aggregate (passed through 20 mm and retained on 10 mm sieve), GGBFS (specific gravity 2.88), fly ash and water are used. Now maintaining the W/C ration constant, following mix proportions are used. FA are used in 85:15 and 65:35 proportions and GGBFS are used in 75:25 and 50:50 proportion. They concluded that the compressive strength of concrete was increased by using GGBFS as supplementary material and grading of aggregate is equally important to get strength and permeability, grater size have law compressive strength and high permeability vice versa.[4]

Sukamal Kanta Ghosh, Ananya Chaudhury, Rohan data and D.K.Bera published a review paper named ‘A Review of Performance of Pervious Concrete Using Waste Material’ from KIT University from Odisha. This review paper illustrates the performance of pervious concrete with solid waste like fly ash, furnace slag, and rice husk ash, silica fume, and solid waste (glass powder, ceramic waste, bottom ash) and its effect on compressive strength and permeability. Fly ash (2-50%), RHA (10-30%), GGBFS (35-70), Silica fume (8-12%), Rubber waste, Glass powder (20-40%) are used replacement of cement. They conclude that the compressive strength and permeability with using waste material are as follows. Fly ash gives long term compressive strength when increase portion then compressive strength decrease. Rice husk ash gives more then 10-12% decrease compressive strength, permeability, and durability. GGBFS gives higher strength but law permeability. Silica fume increases compressive strength but no influence in permeability. Glass powder increases strength durability and workability. Ceramic powder improves durability.[5]

Alessandra Bonicelli, Filippo Giustozzi, Maurizio Crisino published experimental study named ‘Experimental Study on Effect of Fine Sand Addition on Differentially Compacted Pervious Concrete’. The main goal of the experiment is to evaluate the effect on mixture properties caused by the addition of small percentage of sand depending on w/c ratio. The three reference mixes had the same aggregate distribution curve but different w/c ratios namely, 0.27, 0.30 and 0.35. Three sand mixes were proportioned to have 5% of the aggregate substituted with fine sand and the latter three sand mixes so that 10% of aggregates was replaced by the fine sand. Two types of sand were used: type 1 (0.25-0.35mm) and type 2 (0.3mm). This experiment shows that addition of sand in pervious concrete favours in improving admissible stress and tensile strength but drain ability was reduced. The effectiveness of sand addition also depends on the water content of the mixes: low w/c ratio did not show benefits after adding sand.[6]

Saeid Hesami, Saeed Ahmadi and Mahdi Nematzadeh published a paper in 2014 named ‘Effect of Rice Husk and Fibre on Mechanical Properties of Pervious Concrete Pavement’. In this paper, glass material, steel fibre and PPS fibres and also RHA in different pro-portions, were used to improve the mechanical properties of pervious concrete and finding its effect on compressive strength, tensile strength, flexural strength and permeability. Coarse aggregate sized from 2.36 to 19.0 mm, RHA of 0%, 2%, 4%, 6%, 8%, 10% and 12% weight percentage as a cement replacement, PPS fibre 0.3%, steel fibre 0.5% and glass fibre 0.2% are to remain constant at 3 different w/c ratio of 0.27, 0.33 and 0.40. Outcome of Study was as described below. a) The compressive, tensile and flexural strength were found to be maximum at w/c ratio of 0.33. b) For 10% replacement of RHA and w/c ratio of 0.33, the compressive strength of pervious concrete containing fibres increases by 34%, 37% and 36% respectively for glass, steel and PPS fibres. c) For the above mentioned mix design, the tensile strength increases by 31%, 30% and 28% for glass, steel and PPS fibres respectively. d) Finally, the flexural strength undergoes a 64%, 63% and 69% increase when glass, steel and PPS fibres are used, respectively.[7]

In the context based on literature review and experiments of use of waste material like GGBFS, Silica fume, glass powder in pervious concrete. Following facts can be derived. Compared to the normal concrete, pervious concrete gives low compressive strength, law flexural strength and high permeability. Compared to the normal concrete, pervious concrete construction cost is low, but maintenance cost is high and need highly skilled labour. In general, the grading of aggregate is most important to get required void ratio and high permeability. Increasing in w/c ratio will increase the comp. strength and density but decreases the porosity so it is to be maintain near to 0.33. Use of glass fibre and steel fibre also increase the comp. strength but it also increase cost which is not advisable. Increase in the cement content will definitely increase the compressive strength of pervious concrete but it will decrease the pore hole, so porosity will decrease.

4. CONCLUSION

In the context of pervious concrete, making concrete eco-friendly with the needed properties such as permeability, abrasion resistance, flexural strength and compressive strength will be studied. Current research is focused in sustaining significant environmental and economic benefits with good compressive strength and optimum permeability in context of pervious concrete. By my proposed scheme, we can achieve eco-friendly, optimum compressive, tensile, flexural strength and good permeable concrete. My future work comprises the implementation of proposed scheme, I hope that my effort will be helpful to the making this type of concrete.

5. ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to my guide Prof. Krunal J.Dhandha, Associate Professor, Department of Civil Engineering, for his valuable guidance, constant encouragement and motivation throughout the project work. I am deeply indebted to him for the inspiration he has nurtured and developed during the period of this work.

I also express my sincere gratitude to our coordinate Prof. Dipak K. Jivani and Prof. Yogesh V. Akbari for his willing cooperation and most generous help. I am also grateful to Principal Dr. R.G. Dhamsaniya and Head of Department Prof. M.D. Barasara.

I express my sincere gratitude to all the lab staff members of strength of materials lab and extend my thanks to all the faculty members of Civil Engineering Department and to all my friends for their guidance Last but not the least; I thank God, the almighty for his blessing without which nothing would have been possible.

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