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Utilization of Admixtures in Self-Compacting High Performance Concrete

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ABSTRACT- Flowable concrete or self-consolidating or self-compacting concrete (SCC) is a particularly flowable, non-segregating concrete which flows, plugs formwork, and captures the utmost congested rebars with none use of mechanical vibration. When used with admixtures to enhance the performance of concrete, it is called as self-compacting high performance concrete. An extant literature survey was taken up to understand the utilization of waste polyethene, fly ash and micro-silica in SCC to make it a SCHPC. It has been seen that very less amount of research work is available on use of waste polythene in conventional concrete as well as SCC. A few studies have reported positive results towards the mechanical properties i.e. compressive strength and flexural strength of concrete while no literature is available taking into account its initial cost and the durability aspects of such concrete.

KEYWORDS- SCC, concrete, high performance, flowable, construction

I. INTRODUCTION

Flowable concrete or self-consolidating or self-compacting concrete (SCC) is a particularly flowable, non-segregating concrete which flows, plugs formwork, and captures the utmost congested rebars with none use of vibration. SCC is defined as a concrete that can be positioned decently with the help of its self-weight without any vibration which results in pouring of SCC as much less labour-intensive in comparison to normal (standard) concrete mixes. SCC is generally comparable to the normal concrete with respect to its setting and curing time, and strength; once poured. SCC was theorized in the year 1986 by Okamura, who is a professor at Ouchi University, Japan. During that time, the skilled labours were inadequate in supply and leading to complications in concrete and construction industries. The early practical form of SCC was manufactured in 1988 and was termed as High Performance Concrete (HPC), and later was anticipated to be termed as Self-Compacting High Performance Concrete (SCHPC).

The usage of chemical admixtures has always been essential when manufacturing SCC so as to enhance the workability and decrease segregation. As compared to normal concrete, the amount of coarse aggregate and the water to binder ratio in SCC are lesser. Consequently, SCC comprises of huge quantity of fine particles such as micro-silica, nano-silica, blast-furnace slag, fly ash, etc. to evade the gravity segregation of large particles in the freshly prepared SCC mix. SCC brings striking advantages while sustaining all the expected mechanical and durability properties of the concrete [1][2].

II. UTILIZATION OF WASTE POLYTHENE, MICRO-SILICA AND FLY ASH IN SCHPC

A. *Waste Polyethene*

As per the recent studies, one of the fastest growing industry is the plastic industry and nearly about 1.2 trillion plastic bags per annum are being utilized around the globe. This is just a single example of plastic products whereas there are a number of plastic goods used in the everyday life. Discarding of polythene wastes is a gigantic issue as plastic is non-renewable and non-biodegradable and pollutes the environment. The chemical bonds of polythene increases its resistance in contradiction to the natural procedure of degradation. Plastic material especially, polythene, has become an indispensable part of our everyday life that rises the amount of plastic wastes which either mixes with municipal wastes or landfilled in abundance. The dumping of plastic waste by land-filling or by incineration methods have substantial adverse effects on the environment i.e. it leads to land, air and water pollution. Plastic bags have adversative influences on our natural habitats and also have been found to be accountable for the demise of a number of animals due to suffocation encountered by them after eating the plastic. Plastic bags can last for hundreds of years and therefore there is a need to find alternative option for the same to curb the ill-effects of plastics on various species and environment as a whole [3][4][5][6][7][8][9][10][11][12]. Various researchers have come up with the theoretical overview of utilization of

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plastic waste in concrete of various kind in different aspects.

B. Micro Silica

It is a mineral admixture that comprises of vitreous solid glassy particles (spherical) of SiO_2. Most of the micro-silica units are less than 0.00004 inch diametrically which is usually 50 to 100 times finer than an average cement and even fly ash particles. In construction and manufacturing industry, it is generally known as condensed silica fume which is a by-product of the engineering of ferro-silicon and metallic silicon at high-temperature in furnaces (electric arc). The utilization of micro-silica creates a lot of changes in the strength and durability in concrete by acting in two different ways. Firstly, as a pozzolan, it offers an additional
uniform distribution of the particles and a superior size of hydration products. Secondly, when it is used as a filler, it reduces the average pore size in the paste (cement + water). When utilized as an admixture, it can enhance various properties of concrete such as fresh, workability, mechanical and durability properties. With the addition of micro silica, the rate of carbonation is reduced while it diminishes the permeability to chloride ions. It possesses high electrical resistivity, and has slight consequence on oxygen transport. When it is utilized as a partial replacement for cement, it can additionally provide advantages for energy-consuming cement without compromising with the quality of concrete [2][13][14][15][16][17][18][19][20][21].

C. Fly Ash And Red Mud

Pulverized fuel ash or Fly ash, is a by-product of coal combustion (thermal power station) comprised of the particulates of fuel that are gushed out of coal-fired boilers along with the flue gases. The ingredients of fly ash vary substantially which depends upon the type as well as source of the coal that is burnt. Almost all fly ash contains considerable quantities of SiO_2, Al_2O_3 and CaO as the constituents. In relation to the sustainable development, it is imperious that additional cementitious materials must be utilized to substitute the huge amounts of cement in the construction industry.

On the other hand, red mud is a by-product of Bayer's process employed in alumina production. To significantly increase the utilization of fly ash and red mud which are by-products and being wasted, and to have a substantial influence on the powder content of concrete, it is essential to utilize the concrete incorporating huge quantities of fly ash and red mud as replacements of cement. Such concretes as per the literatures show good performance as compared to the normal concrete, and can be made cost effective and efficient [1][22][23][24][25][26]

III. LITERATURE SURVEY

Various researchers had worked on the different properties of the SCC and also with supplementary cementitious materials and waste materials which is called SCHPC. But as such the research on consumption of waste plastic bags in concrete has been carried out in very few areas.

The summary of the researches being carried out by various researchers is mentioned in Table 1.

Brief literature on the properties of waste polythene gives very limited information utilization of waste polythene in SCC. The information available till date is insufficient to study the effects of waste polythene on different properties of self-compacting concrete.

Table 1: Summary of the research on self-compacting high performance concrete using various admixtures

S.No.	Researcher(s) (year)	Work carried out
1.	**Persson (2000) [3]**	• Assessed the mechanical properties (strength, elastic modulus, creep and shrinkage) of SCC and also for NCC. • Used 8 mix proportions with w/b ratio ranging from 0.24 to 0.80. • Half of the mixes were SCC and other half NCC. • In the creep study, the loading age varied in the ranges of 2 and 90 days. • Results revealed that elastic modulus, creep and shrinkage of SCC did not differ to a great extent as compared to NCC.
2.	**Bouzoubaa and Lachemi (2001) [22]**	• Experimentally evaluated the performance of SCC manufactured with the help of high volumes of fly ash using 9 SCC mixtures and one normal concrete. • The content of the cementations materials was kept to be constant i.e. 400 kg/m^3. • The water/cementitious material ratios ranged between 0.35 and 0.45. • The cement replacement was 40%, 50%, and 60% by Class F fly ash. • The SCC mixes developed 28-day compressive strength ranging from 26 to 48 MPa. • Economical SCC mixes was effectively established by including high volumes of Class F fly ash.
3.	**Felekoglu et al. (2006) [4]**	• 5 mixes with diverse blends of w/c ratio and different dose of super plasticizer were carefully prepared and tested.

		• Results revealed that the optimum w/c ratio for manufacturing SCC was in the range of 0.84 to 1.07 by volume. •
4.	**Grdic et al. (2008) [5]**	• Carried out an investigational study on the properties of SCC mixed with various kinds of additives such as fly ash, silica fume, hydraulic lime and a mixture of fly ash and hydraulic lime. • Results revealed that adding of fly ash to the mix containing hydraulic lime is fairly advantageous leading to a significant enhancement of the behaviour of SCC fly ash hydraulic lime concrete. • of SCC fly ash hydraulic lime concrete had reduced filling capacity and fluidity than other mixes.
5.	**Liu (2010) [6]**	• Investigated SCC with up to 80% replacement of cement by fly ash in mixtures attuned to show constant fresh concrete properties. • Results revealed that SCC with up to 80% cement replaced by fly ash was likely to be manufactured. • To keep the filling ability constant, replacement of cement with fly ash was accompanied by an increase in water/powder ratio and a decrease in the dosage of superplasticiser. • It was revealed through the experiments conducted that fly ash had negative impact on passing ability, consistence retention and the strength.
6.	**Malagavelli and Rao (2010)**	• Used High Density Poly Propylene (HDPP) fibres and Polyethylene Terephthalate (PET) fibres in concrete slabs. • Noticed rise in ultimate load carrying capacity of the concrete, compressive as well as flexural strengths in comparison to the high performance concrete.
7	**Bhogayata et al. (2011) [7]**	• Experimentally investigated the viability of polyethylene post-consumer waste used for food packaging along with fly ash. • They added plastic waste in fibre arrangement from 0% to 1.5% by volume of concrete plus variation of fly ash from 0% to 30% by volume of concrete. To assess the impact of chemical attack, different curing conditions were used and the corresponding alteration in the compressive strength of concrete mix were found out.
8.	**Rai et al. (2012) [8]**	• The study was conducted on the concrete mixes in which there was a partial replacement of fine aggregates by waste plastic flakes in changing percentages by volume of concrete. • The concrete mixes both with and without superplasticizer were tested at room temperature. The results revealed that there was a decrease in workability and compressive strength because of the partial replacement of fine aggregates by waste plastic and this reduction was minimal without super-plasticizer and was improved with the addition of super-plasticizer.
9.	**Kanellopoulos et al. (2012) [14]**	• Found out the durability of SCC by employing the following tests: sorptivity, porosity and chloride ion permeability • The test results of SCC were then compared with the corresponding parameters of normal concrete. • Results indicated a correlation between the different durability indicators for the definite filler additives utilized in the mix designs. The correlation was used to evaluate the durability of SCC without the necessity to count on time intensive artificial weathering experimental

		process.
10.	**Ghernouti et al. (2015) [10]**	• Tested the fresh as well hardened properties of SCC comprising of plastic bag waste fibres (PBWF). • The preparation of the fibres were carried out by recycling of the waste material such as plastic bags. • The study was carried out on 14 mixtures of SCC having 0.40 of w/c ratio. Out of these, 12 SCC mixtures with plastic bag waste fibre by fluctuating the length of fibres (2, 4 and 6 cm). • Test results revealed that mixtures based on PBWF with a length of 2 cm, met the conditions of self-compactability irrespective of the fibres content.
11.	**Massana et al. (2018) [21]**	• Studied the impact of binary and ternary mixtures of nano-silica and micro-silica on the durability of a HPSCC. • 10 blends were made: one without additions as control mix, three with 2.5%, 5% and 7.5% of nano silica, three more with 2.5%, 5% and 7.5% of micro silica and three using both admixtures, with 2.5%/2.5%, 5%/2.5% and 2.5%/5%, of nano silica and micro silica, respectively. • The highest compressive strength is attained in the ternary admixture with 2.5%/2.5%.
12.	**Ghorpade et al. (2018) [27]**	• Studied chloride resistance of waste plastic fibre reinforced SCC. • SCC mixes with fluctuating percentages of waste plastic fibres 0.0%, 0.25%, 0.5%, 0.75%, 1.00%, 1.1%, 1.2%, 1.3% and 1.4% were established for M40 grade concrete. • The concrete cubes and cylinders were immersed in 5% magnesium chloride solution for 30 days, 60 days and 90 days. • The degree of chloride attack was assessed by estimating the decrease in compressive strength, split tensile strength and percentage loss of weight of the specimen. • Results revealed that maximum compressive strength and split tensile strength were attained for 1% replacement with plastic fibre. • Percentage loss of weight, loss in compressive strength and chloride penetration reduced as the percentage of fibre was enhanced.
13.	**Mohammed et al. (2019) [28]**	• Studied mechanical strength of concrete for pavement quality when mixed with rice straw ash (RSA) and micro-silica (MS). • 9 mixes were made by partial replacement of OPC with micro-silica (2.5%, 5%, 7.5%, and 10%), RSA (10%) and RSA-MS composite (5%–5%, 5%–7.5%, 10%–5% and 10%–7.5%). • Maximum enhancement was seen when OPC was partially replaced by 7.5% of micro-silica and 5%–7.5% in case of RSA-MS composite. • All the mix revealed improved strength in comparison to the normal mix.
14.	**Al-Hadithia et al. (2019) [12]**	• PET fibres with an aspect ratio of 28 were added from waste plastic to SCC. • One control mix was developed using which all other mixes were developed. • 8 SCC mixes containing diverse volumetric ratios of plastic fibres percentages (0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75%, and 2%) were developed. • The behaviour of SCC slabs under impact loading was assessed. • A substantial enhancement was seen in the resistance to impact load and energy absorption capacity of slabs containing PET fibres. The increase in the time of maximum deflection for the concrete mixes containing PET fibres improved significantly showing an improvement in the

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		capacity of SCC to absorb further energy under low velocity impact.

IV. DISCUSSION AND CONCLUSION

After critically reviewing all the literatures, following points have been drawn for discussion point of view.

- Very less volume of research work is available on utilization of waste polythene in conventional concrete as well as SCC.
- No substantial work has been done on utilization of waste polythene with micro silica in SCC but some researchers used it in conventional (normal) concrete.
- A few studies have stated positive results towards the mechanical properties (compressive strength and flexural strength) of concrete while no literature is available taking into account its initial cost and the durability of such concrete.

Thus, there is a wide scope of study related to utilization of waste polyethene, red mud, fly ash and micro-silica and other related additives in SCC. This will help to assess the various mechanical, physical, micro-structural and durability properties of SCC with different additives.

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