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Review

Durability performance of Green Concrete Incorporating Various Wastes: A Review

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ABSTRACT

The present manuscript stands for the review on the topic of durability attribute of concretes developed by means of green conception with incorporation of a variety of solid industrial waste slag from Ground Granulated Blast Furnace, silica fume, rice husk ash, pulverised fly ash, glass powder waste as well as materials that have undergone recycling in order to know its degree of sustainability. It is highly sought-after to transform these types of waste into a precious adding up materials in place of Ordinary Portland Cement (OPC) in building-up of Green concrete with affordable cost and more essential with a little carbon footprint. How far these Green concept concretes have succeeded in context to its durability characteristic is the principal focus of this review study. There prevails an enormous demand for cost-effective construction materials for offering enough residences and infrastructure networks to get rid of the burgeoning population on the planet earth. The centre of attention is to make researcher, engineer and infrastructure related peoples, as well as construction industry au courant of absorbing the, dissipate materials and their promotion as an acceptable, sustainable and cost-effective building materials. The apposite standards of durability and still excellent researches on the sustainability of this novel Green concept concrete will encourage for espousal of gargantuan construction and infrastructures projects globally. Looking to the above facts, it can be predicted that the said Green technology bestows the impression to have dazzling potential and its approval in construction industries which establishes it as the most promising future edifice material.

1 Introduction

An insurgency of concrete technology is eye-witnessed by human beings since ancient Roman's concrete, Opus Caementicium, to contemporary Ordinary Portland Cement(OPC) concrete where OPC is a chief binder. A booming population of the world necessitates more and more infrastructure that in turn calls for a gigantic mass of concrete. Eventually, the gargantuan magnitude of OPC turns out to be requisite for manufacturing of concrete.

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The OPC production gulped down restrained resources from nature like coals in order to acquire violent energy and elevated temperatures prerequisites and Limestones as the key raw materials. The contemporary technique of OPC production is not just intense energy consuming along with the necessity of very high temperature, but also releases embodied primary greenhouse gas CO_2 into environment shooting up quandary of global warming escorting to a range of coupled environment evils. The annual escalation of production of OPC is roughly 3% [1]. To produce 1 ton of OPC, the atmosphere has to be ready to face an almost equal amount of CO_2 emissions, and that is the catastrophe associated with the present process of OPC production [2-4].

Each year, approximately 1350 Million tons of CO_2-emission is reported on its own across the earth by OPC production [5-7]. Unbelievably, it is roughly 7% of the entire quantity of greenhouse gases! [8-14]. That is why, Mehta [15] have advocated employment of a lesser amount of restricted natural resources, lower down energy, and mitigation of CO_{2-} emissions, in order to produce environmentally being concrete. As well, a falloff in the deleterious impacts of leftover industrial wastes can be overcome by extenuating the rate of consumption of naturally occurring ingredients. These types of industrial wastes may embrace material that has believed to be valueless by industry, factory, mining operation or mill, etc. at a particular stage in the processes of production viz., Slag from Ground Granulated Blast Furnace Slag, Copper and Steel Slags, Ferrochrome Slag, ISF Slag, i.e., imperial smelting furnace Slag,foundry waste sand, Coal bottom Ash, volcanic ash, Ash of bio-waste, Palm oil clinker, etc.that are accountable for transforming limited fertile lands into the piles of unwanted materials. The ground-breaking technology with Green concept concrete has endowed with assurance through the development of varied Green concrete incorporating wastes as substitute aggregates. Manufacturing of Green concrete is a perception that protects the environment in context to natural ingredients, mix proportion and design, construction and preservation of structures of concrete [16]. These diverse wastes play a part either as supplementary cementitious materials or as a switchover of aggregate such as industrial, agricultural, marine waste, bio-waste, municipal wastes, and E-wastes, etc. can be added after subjected to recycling.

Consequently, a modern Green concrete technology has progressed one stage in advance now and has magnetised researchers and engineers, particularly, from construction and infrastructure industries not merely for its supporting environmental attitude but also the potential developments of diverse Green concretes. On the other hand, more the global industrial production equals more wastes, creating health perils, contamination of soil, air and water as well as answerable to landfills since they are materials of sans systematic applications such as municipal solid wastes; Fly, Bottom, and volcanic ashes; silica fumes; Foundry Sands; Slags; rice husks, etc. are mostly found to employ blended in the manufacturing of Green concrete devoid of impacting its vital attribute of durability [17, 18]. It means merely that novel, sustainable, reasonably priced, adaptable Green concretes can be prepared with acceptable and at times excellent durability through a tactic of "best from the wastes" which is the call for the present age. In short, an incorporation of diverse wastes such as low calcium fly ash [17], Ground granulated blast-furnace slag (GGBS), [18], calcium rock, silica, phosphate and organic minerals, Metakaolin, mineral powder, [16] and high calcium fly ash, red mud with fly ash and micro silica [19, 20] could be employed for the said purpose. This seems to be a systematic, practical and feasible elucidation to the crisis of landfills and accompanied pessimistic impacts, cost-saving with low carbon footprint and conservation of natural resources and significantly a fall in contamination of soil and groundwater by consuming such type of waste materials to manufacture new-fangled useful products. These endeavours will unquestionably restrain the intense load of the landfills on the planet. Indubitably, Green Concrete is demonstrating the excellent potential to prove itself a construction material of foremost preference in the days to come.

2 Supplementary Cementitious Waste Materials And Methods

A saving of natural resources and energy, as well as lessening of solid wastes, mitigation of greenhouse gases, and alleviation of pollutants of air and water, can be made with the help of recycling of waste building materials and by their subsequent consumption as additional material in developing green concrete. The infrastructures and construction industries are very thoroughly familiar with the advantages of employing waste and recycled materials. Fillers with pozzolanic properties, i.e. possessing high silica content can demonstrate technical benefits to developing concrete, facilitating significant cement replacement [21].

Utilization of these waste materials brings ecological and economic advantages. Various researches have been carried out on the applications of apposite recycled materials able to be used again and the techniques necessary to do so. The applications of fly ash, slag, foundry sand, bottom ash, rubber tire fibers, asphalt pavement, silica fumes, recycled aggregates derived from construction and demolition waste, cement kiln dust, glass, plastics, empty palm fruit bunch, roofing shingles, citrus peels, swine manure, animal fat, and carpet, etc. in concrete have been investigated.

2.1 Fly Ash

Fly Ash (FA) or coal-fired ash is one of the significant industrial source materials used in the development of green concrete owing to its excellent properties and chemical compositions. It is profusely found as coal-fired ash from power generating thermal plants run by coal and other coal-based industries. It means, it is chiefly a by-product from thermal power plants as remains of burnt coal. Nevertheless, its consumption is very inadequate up until now causing a landfilling problem. As estimated in1998, the world coal ash production is above 390 million tonnes per year, but its exploitation is less than 15% [22]. China and India are likely to increase fly ash production in future. It is estimated that only these two countries may be responsible for fly ash production of about 780 million tonnes per year by 2010 [23]. Hence, attempts to make use of this by-product material in developing green concrete are significant to produce the best from the waste. In spite of the specifications and its profuse present, Fly ash has limited applications so far. Heavy metals viz. mercury, lead and, arsenic is found tied up with this powdery substance. It may employ as an alternative to another resource of industrial origin or use or processes like the production of cement and concrete, underground void filling roadway and use in pavement, infiltration barrier, structural fill and cover material. It can partially substitute OPC owing to its benefits like reduced bleeding and cracking at an early age, lower water necessitates for the same workability, long-term strength gain, lower evolution of heat and segregation can be achieved by using it as partial replacement of cement. Fly ash permits normal replacement of 25-40 % with high Calcium content. Almost up to 75% of OPC in concrete to construct driveways, roads and parking lots. It contains SiO_2, Al_2O_3, Fe_2O_3 and so when reacting with calcium hydroxide it forms a C-S-H gel in the form of a by-product which acts as good filler with augmented strength, corrosion and reduced permeability demonstrating augmented sulphate resistance along with reduced alkali-aggregate reaction.

2.2 Ground Granulated Blast - Furnace Slag

In earlier periods, the by-product obtained from the blast furnaces during the production of ground iron slag and steel as well as iron was considered useless. But, it has now been found useful in the fields of, environmental applications, agriculture and in the construction as well as infrastructure industries. Its chemical composition varies depending upon the raw materials employed. Course aggregate which made air cooled is utilized in asphalt mixes, concrete, as filling material in embankments, road base material and as treatments for the upgrading of soils. The flexural and compressive strength of concrete found enhanced owing to use of GGBFS. The low-density property of expanded slag permits a better mechanical binding with hydraulic OPC paste. Its suitability for use as an adsorbent is purely due to its particle size, surface area, bulk density, apparent porosity and water holding capacity. It contains silicates, aluminates, CaO and MgO in chemical composition. Its application as slag cement in a concrete mixture is quite useful. Concrete structures exposed to a very high temperature of more than 450°C, are often encountered with the dilemmas like dehydration, development of cracks, permeability issues, and spreading caused due to heat. These changes in concrete structures are the effects of their decrease in strength and boosting in porosity. A view of [24] is that the slag cement added up as partial substitution of cement up to 40%, is found to have enhanced flexural and compressive strengths than that of standard concrete modified by OPC. The concrete structures modified with GGBFS and containing iron slag as addition can be considered as a sustainable building material for pipes, pavements, foundations as well as for marine-based applications.

2.3 Silica Fume

Silica fume or micro silica is also a by-product procured from industries that employing the smelting process for the production of an alloy of ferrosilicon as well as silicon metal. This ultra-fine powder contains greater than 85 to 90% silica. The shape of particle size is found spherical while the size of the particles demonstrated on an average is 150nm which is 100 to 150 times smaller than OPC particles. Landfilling by silica fumes and the environmental apprehensions necessitated its systematic consumption. The most significant application is its use as a mineral admixture with concrete but also used as filler. Compressive strength, abrasion resistance, and bond strength of OPC concrete enhance by its use as an additional material due to its characteristic properties. Siddique and Singh [25] reported that when silica fumes react pozzolanically with free $Ca(OH)_2$ of fresh concrete, it results into the enhancement of strength of the concrete by making an additional C-S-

H gel. This decreases the permeability and refined pore structure. In aggressive environmental conditions, this leads to advancement concerning resistance to sulphate attack.

3 Durability Properties Of Concrete

So far, the durability of concrete incorporating various wastes has not been studied much and hence, it is essential to study this topic further in detail. Nevertheless, some studies on the subject have resulted in fruitful upshots.

3.1 Porosity and Absorption of Water

A level of maximum substitution of cement is found 6.60 % with a view to avoiding adverse effects on the concrete performance on account of enhanced water exigency of the supplementary cementitious materials as established by Yang et al. [26].

In addition, outcome for water absorption of specimens are presented in Fig. 1. When basic oxygen furnace slag and RHA are partially substitute OPC, the water absorption augmented noticeably and was high than that for reference control specimen. Also, they examined water absorption of ternary blends cement incorporating rice husk ash and Basic oxygen furnace slag (BOFS) which is found in a lesser amount than ternary blend cement modified with fly ash as well as that of derived from Limestone by Shafigh et al. [27].

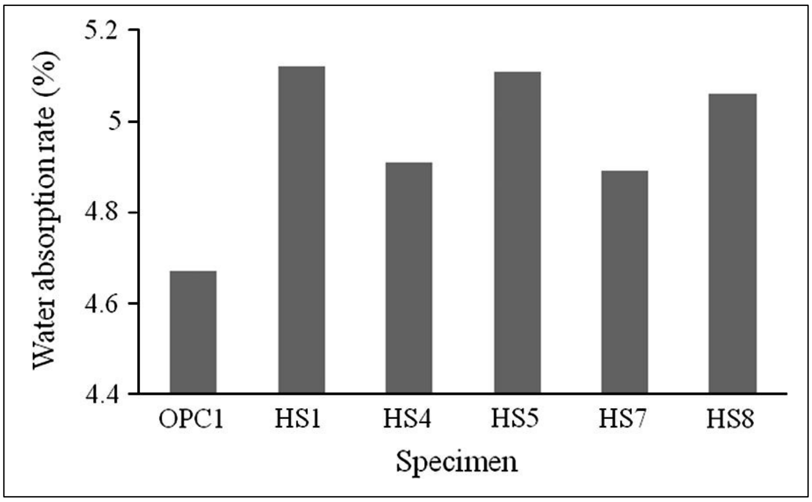

Fig. 1- Water absorption rate of specimens [26]

Water absorption found decreasing with an augment made of powder of recycled glass waste representing a decrease in the bulk density as monitored by Parghi and Alam [28]. Addition of cement results in a lessening of water porosity and absorption by green concrete as noted by Aliabdo et al. [29]. Aliabdo et al. [30], have studied that the water absorption and a decrease in void ratio with the addition of powder of glass waste are owing to the filling of pores as well as pozzolanic nature of powder of waste glass. Research works by Binici [31] made known that absorption of water decreases as the temperature of alkali activation augmenting but the decrease displayed is found varying as to the type of material. Absorption of water and apparent porosity differs as per various time periods of curing as well as fly ash to cement ratios according to Tian and Zhang [32]. This simply means that an apparent porosity, supplementary cementitious materials to cement ratio, and absorption of water of the supplementary cementitious materials employed in a green concrete influence their mechanical properties. Effect of fly ash content on apparent porosity is shown in Fig. 2. Fig.2 revel that the apparent porosity diminishes with time due to the hydration process of the cementitious material progressively fills in the voids, which augmented the density and decrease the apparent porosity. Effect of fly ash content on water absorption is demonstrate in Fig. 3. It can be seen that, all the mixes show similar water absorption (16.5%) at 28 days.

Also, a note from Hesami et al. [33] suggested that decline in porosity as to boosting amount of rice husk ash and polyphenylene sulfide (PPS) recycled glass waste combination, fibres of glass as well as steel, irrespective of water to cement ratio, advocated by them as best possible rice husk ash content between 8 to 10% along with water cement ratio of 0.33.

Polypropylene (PPF), as well as wastes of rubber tire fibers, can be applied to diminish absorption of water by rice husk ash modified cement composite as established by Momtazi and Zanoosh [34].

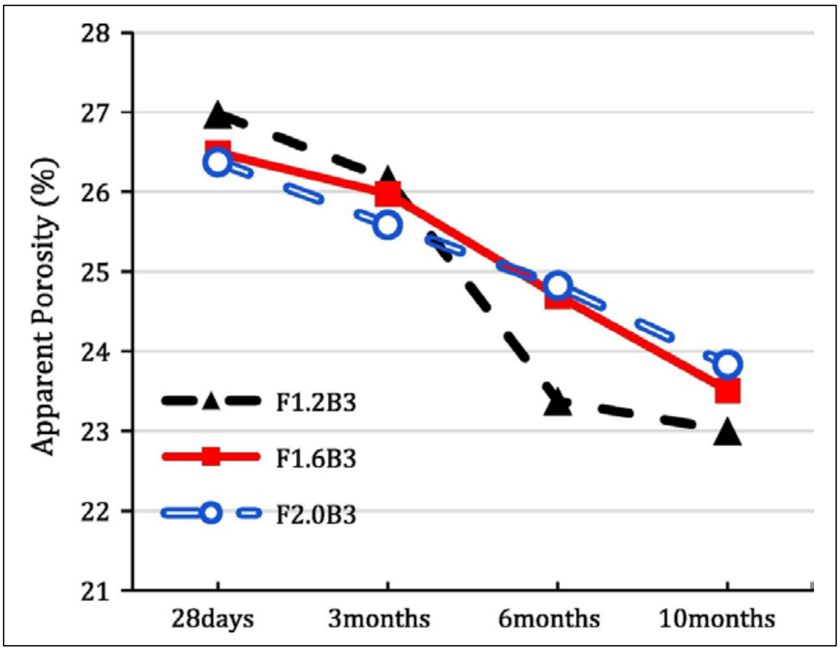

Fig. 2- Effect of Fly ash on Apparent porosity [32]

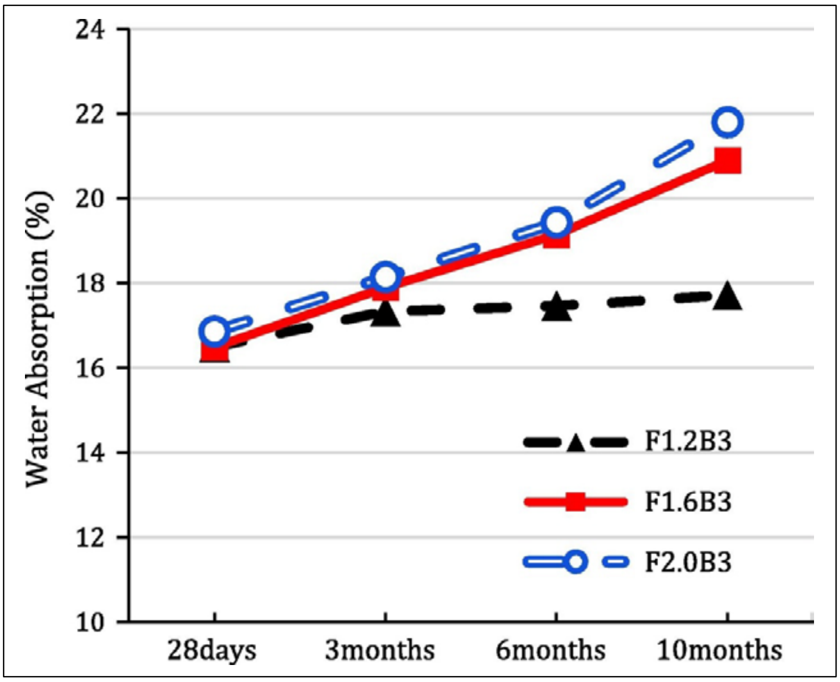

Fig. 3- Effect of Fly ash on Water absorption [32]

3.2 Alkali-Silica Reaction [ASR] and Chloride Ion Penetration

Enhanced resistance to chloride penetration in case of bacterial rice husk ash concrete as suggested by Siddique et al. [35] is compared with results achieved by Boğa et al. [36] with 10% rice husk ash substitution of cement which is the optimum value.

Gastaldini et al. [37] made known that low chloride penetration is achieved at low water to cement ratio of 0.5 as compared with 0.65 and found that chloride penetration control of rice husk ash is higher compared to silica fumes (see Fig. 4). Fig.4 , observed that the total passing charge diminish with augmented curing period, substitution levels of cement by RHA or SF, and rising testing age.

An addition of 25% recycled glass particle having a size less than 300μm in combination with 10% fly ash and 10% silica fumes to manufacture superior mortar with alkali-silica reaction expansion is less than 10% specified by ASTM C1260 as suggested by Parghi and Alam [28]. The further additional decrease in alkali-silica reaction expansion having augmented content of waste glass used for natural sand substitution with age of curing is noted by Abdallah [38]. The decrease in accessible alkali is owing to the consumption of lime made by the silica in the waste glass which is grounded finely. Silica fumes demonstrated approximately 14.3% and 40% resistance to chloride penetration which is more than rice husk ash at the same cement substitution ratio of 10% and 5%, water to binder ratio of 0.6 and curing age of 3 days as monitored [37].

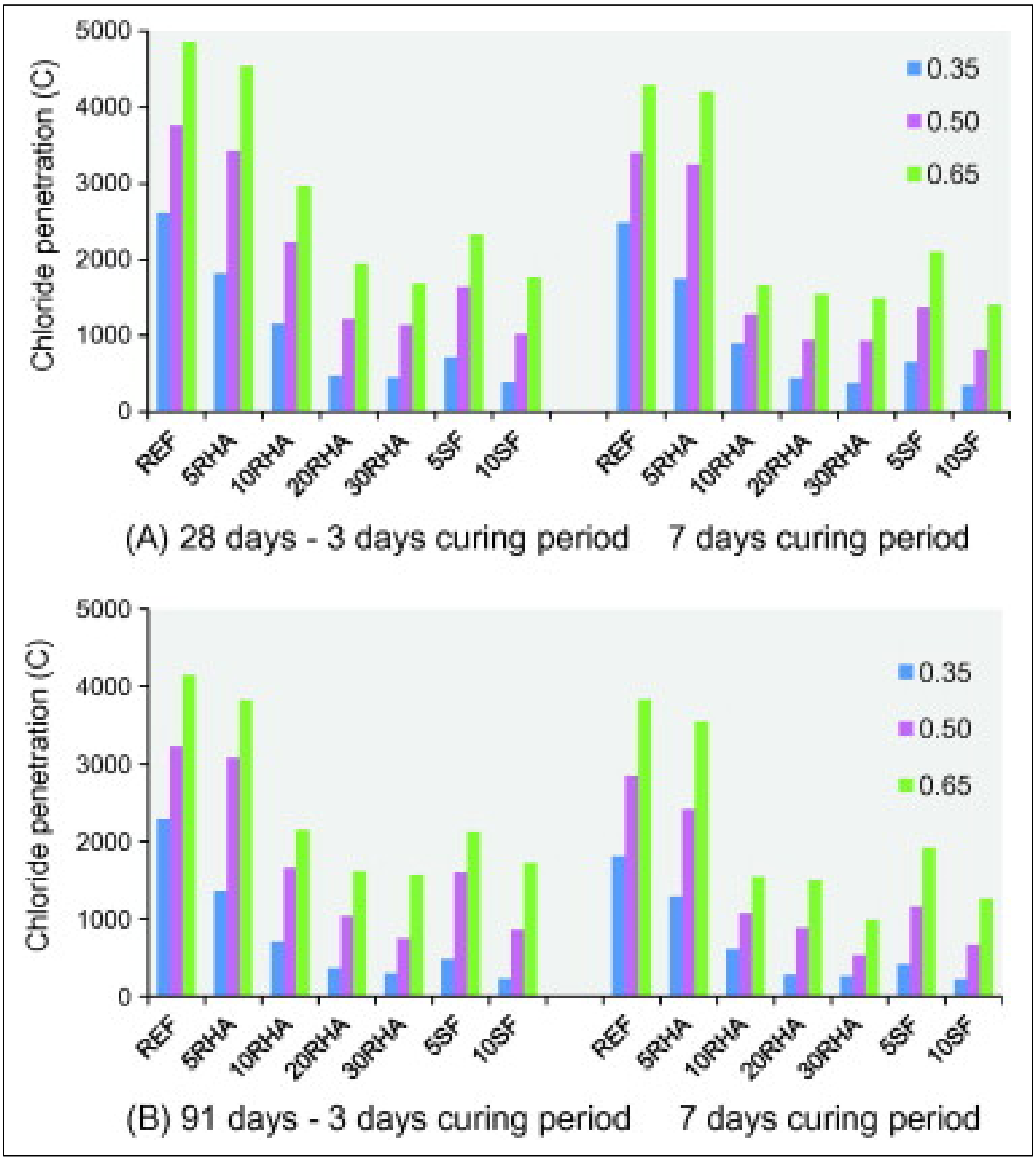

Fig. 4- Chloride penetration results [37]

As noted by Hassan et al. [39], silica fumes attained the lowest chloride penetration as compared to fly ash and cement at early ages. Resistance to chloride penetration of 26.7%, 38.5%, and 49.6% at 5%, 10% and 15% silica fumes substitution of cement is noted according to Rostami and Behfarnia [40].

Zareei et al. [41] encountered 78.4% decrease in chloride penetration in High-Performance concrete incorporating 25% rice husk ash substitution of cement and 10% micro silica from 4306 coulombs to 928 coulombs. [42] 52.36% decrease met with in chloride penetration from 19 mm to 9.5 mm by the utilization of fly ash in self-compacting concrete having 60% fly ash and 10% silica fumes. A concrete cover of 20 mm is insufficient to guard steel reinforcement against chloride encroachment even in high-quality self-compacted concrete as noted by them. Silica fumes and a waste of glass are effectual to reduce alkali-silica reaction as noted by Matos and Sousa-Coutinho [43]. A decrease of 76.85% is met with at 20% waste glass content. In a mortar, powder of waste glass represented 52.47% decrease in chloride diffusion. An optimum of 10% of waste glass content is suggested to attain the best possible properties of durability [44]. An improved chloride binding capability with increasing Ground granulated blast slag content is found which can be affected by the presence of sulphates according to Siddique and Bennacer [45]. Chloride penetration resistance to 81.9% using 60% ground granulated blast slag substitution of cement at the water to cement ratio of 0.55 from 10271coulombs to 1864 coulombs as noted by Cheng et al. [46] (See Fig.5). Fig.5 demonstrate Chloride penetration results indicate the maximum total charge-passed obtained in mix A and the lowermost total charge-passed in mix C specimen, which represent utmost chloride-ion penetration resistance. Refinement of the pore, as well as densification of concrete, is responsible for enhancement in resistance to chloride penetration. The cracking formation can be controlled by restricting unrestrained shrinkage of concrete mix as noted [47].

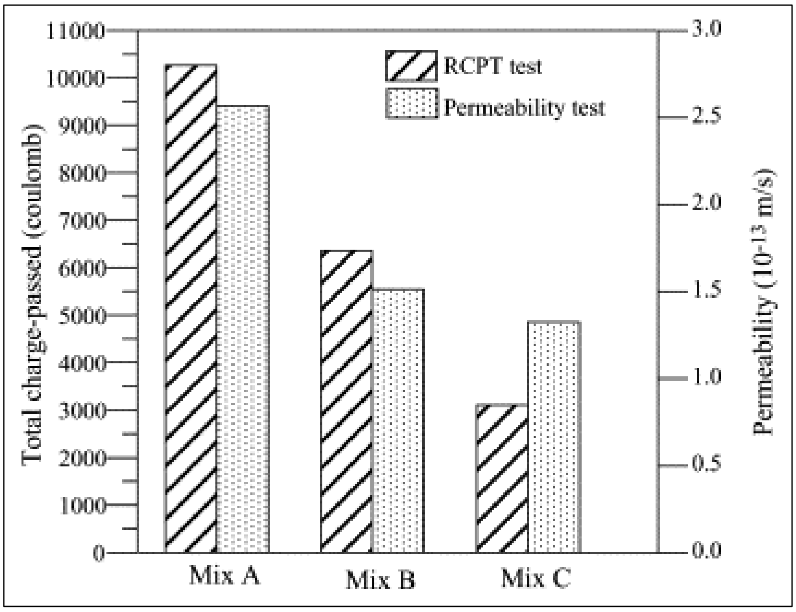

Fig. 5- Total charged passed for chloride penetration [46].

The outcome demonstrated that fly ash displayed the highest drying shrinkage compared to that of nano silica and ground granulated blast slag cement. Chloride penetration is monitored to decrease with growing age of curing, augmenting cement substitutions with rice husk ash and silica fumes but decreased with augmenting water to binder ratio. A mix of nano-rice husk ash (2.5%) and micro rice husk ash (12.5%) achieved the best possible resistance to chloride penetration as recorded by Balapour et al. [48]. Their combination obtained resistance to chloride penetration of 71.2% at 90th day as compared to controlled mix. This value is superior to 36.2% denoted by 2.5% nano-rice husk ash when employed unaccompanied. Order of preference in terms of resistance to chloride penetration can be concluded from the above results as follows:

ground granulated blast slag > rice husk ash > silica fumes > fly ash > waste of glass.

Nevertheless, experimental data are necessitated confirming this order of preference for resistance to chloride penetration employing the analogous experimental conditions viz., same cement substitution levels, water to cement ratio, the age of curing at testing, amongst others for specific comparison objectives. Durability problem of concrete is due to the reaction of silica with alkali pore solutions, i.e. Alkali-silica reaction, which forms so many resultant reaction products, causing deleterious cracking in concrete [49]. The factors affecting any supplementary cementitious materials to diminish alkali-silica reaction depend upon chemical composition,i.e., SiO_2 and alkali; percentage and type of supplementary cementitious materials; kind of alkali-aggregate reaction as well as fineness and kind of alkali-contents of cement [50]. Supplementary cementitious materials trim down alkali-silica reaction in the course of pozzolanic kinetics that decreases the permeability of concrete [51]. In accordance with Fapohunda et al. [49], found with a divergent opinion about the effects of rice husk ash on the alkali-silica reaction in concrete. On the other hand, Hasparyk et al. [52] suggested the quantity of incorporation of rice husk ash between 12 and 15% to control the reaction of alkali and silica. In alkali-silica reaction, a researcher Le [53] noted that rice husk ash acts as micro-reactive aggregate responsible for producing numerous alkali-silica reaction products. Zerbino et al. [54] have resolved this by noting down that rice husk ash can slow down or encourage alkali-silica reaction depending upon the size of its particles. Consequently, the authors suggested that care should be taken in the selection of equipment, cement, and mixing cycle, as well as an adaptation of the process of mixing. In another study up to three-year duration, they monitored unwavering mechanical properties with alkali contents (Na_2O) of less than 3 kg/m^3. Their results are substantiated by one more study which made known that rice husk ash which is produced by controlled ignition displayed higher alkali-silica reaction inhibition effect compared to leftover rice husk ash produced through uncontrolled burning [55]. In mitigating alkali-silica reaction expansion in a mortar. A researcher Le [53] found rice husk ash less effective than silica fume. He suggested making use of rice husk ash with a fine particle size less than 5.7 µm to lessen alkali-silica reaction expansion. When 20% replacement of cement by silica fumes, fly ash, waste of glass, Rice husk ash from controlled burning and raw rice husk ash, the alkali-silica reaction expansion were found 0.01%, 0.02%, 0.02%, 0.06% and 0.23% respectively. This corresponded to a percentage decrease of 88.9%, 66%, 83.8% and 37.8% of fly ash, waste of glass, rice husk ash and rice husk ash [54, 56, 57]. Moreover, Oberholster and Westra [58] also noted that silica fumes represented better than fly ash in extenuating alkali-silica reaction. At 20% replacement of cement, they achieved alkali-silica reaction values of 0.03%, 0.02% and 0.2 for silica fumes, cement and fly ash. The said results correspond to alkali-silica reaction decreases of 85% and 65% respectively concerning the control. This proves the superiority of silica fumes over fly ash in extenuating alkali-silica reaction. In one more study, Buck [59] noted that alkali-silica reaction amounting 0.15% and 0.47 at 30% ground granulated blast slag replacing cement and 0% (control), which corresponds to alkali-silica reaction decrease of 68.1%. Consequently, the results mentioned indicates the probable ranking of the supplementary cementitious materials in terms of alkali-silica reaction mitigation is,

silica fumes > fly ash > rice husk ash > ground granulated blast slag > waste of glass > rice husk ash

Nevertheless, it is essential to confirm this order of ranking by confirmatory laboratory and field investigations. Lindgård et al. [60] pointed out that supplementary cementitious materials with low calcium content but rich in silica are found the most effective in mitigating alkalinity of pore solution and consequently alkali-silica reaction expansion. The authors suggested satisfactory, trustworthy, accelerated and inexpensive methods of testing which resemble to field conditions like alkali content, humidity, and temperature. Alkali-silica reaction expansion is noted to decline in concrete when waste of glass is employed as fine aggregates owing to decrease in accessible lime [57]. Alkali-silica reaction diminutions of 66%, 41.7% and16.7% are achieved at 20%, 15% and 10% substitution of fine aggregate by the waste of glass. Alkali-silica reaction expansion is studied between 25 and 100% substitutions of cement [61]. It is also found to depend upon the waste of glass content and its color. They suggested making use of fly ash and Lithium carbonate for a decrease of alkali-silica reaction expansion. On the contrary, özkanandyüksel [62] believe that the color of glass has no major influence on alkali-silica reaction as well as elevated temperature resistance. They also supported applications of fly ash and ground granulated blast furnace slag to lessen alkali-silica reaction expansion.

3.3 Characteristics of resistance to fire and chemical attack

Karri et al. [63] examined the effects of the acid attack on concrete incorporating ground granulated blast furnace slag at various curing durations employing two grades of concrete (20 and 40 Mpa). Compressive strength found enhanced of some of the concrete. This may be owing to chemical reactions between an acid and ground granulated blast furnace slag as well as other constituents of concrete. It is suggested that the substitution of ground granulated blast furnace slag cement should not go beyond 40% with regard to durability parameters. Acid seems to endorse pozzolanic reactions in the concrete modified with ground granulated blast furnace slag. At less than 300°C, silica fumes found to influence notably on residual compressive strength. At elevated temperatures of 100, 200, 300 and400°C strength retention is noted as 84.1%, 85.2%, 68.8% and 26.8% at 10% silica fumes substitution of cement in silica fumes. At 6% cement substitution, their strength retention is found higher than the corresponding values of 84.1%, 85.2%, 68.8% and 26.8% as displayed [64]. A fading of interfacial transition zone

(ITZ) is responsible for the strength loss to deteriorate of the bonding between paste and aggregate as well as chemical decomposition of hydration products. At 200 ° C., strength revival of 1.3–3.7% is also monitored in all concrete. Strength retention of 94.5%, 60.9%, and 47.3%, for silica fumes and 103.6%, 46.4%, and 48.2%, for rice husk ash at 200° C, 400° C and 600° CAs noted by Bernal et al. [65]. The outcome demonstrated that rice husk ash displayed lower strength retention than the silica fumes. After the temperature of 800°C, only rice husk ash based system had kept hold of assessable strength. Rashad [66] noted compressive strength of 45.92 MPa for high volume fly ash concrete with 70% substitution of cement by fly ash at 400° C. While Bernal et al. [65] noted it by maintaining the same criteria to 67 MPa and 52 MPa for silica fumes and rice husk ash in alkali-activated pastes at the constant temperature which is found higher compared to Rashad’s observations for compressive strength.

Furthermore, the bump up in compressive strength owing to the densification of the matrix is monitored at 400° C in all the mixtures. Additionally, high volume flyash concrete displayed enhanced fire performance as compared to neat concrete while incorporation of ground granulated blast slag demonstrated pessimistic effects on compressive strength at elevated temperature. Low thermal stability at elevated temperatures between 800 and 1000°Cis demonstrated by fly ash based Geopolymer which is due to substitution of the amorphous structure by crystalline sodium-feldspars and the enhancement in the average size of pore [67]. Fly ash (class F) based concrete manufactured by employing Sodium activator, and the compressive strength found of 30, 33, 37, 38, 14 and 12 MPa at 200, 400, 600, 800, 1000and 1200°C correspondingly. Whereas on the other side, fly ash-based concrete manufactured by employing potassium silicate displayed weakening of compressive strength after 1000°C. That means, fly ash (class F) based concrete is unsuitable to use in refractory insulation utilizations due to the great declines in compressive strength and vast shrinkage in between 800°C to 1200°C. High strength concrete incorporating silica fumes ð15.4%þ and fly ash (38.5% of cement content) accounted the decline in the compressive strength of 74.4% from 97.3 to 24.9 MPa at a higher temperature of 800°C [68].

On the other side, the usual concrete demonstrated 54.7% decrease in compressive strength at the constant temperature. The weakening of compressive strength in both high strength and usual concrete is due to dissimilarity in the structure of pore. In the case of high strength concrete incorporating 9% silica fumes weight of cement, compressive strength had noted marginal strength loss between 100 and 400°C while there was a noteworthy loss occurred between 55 and 80% after the temperature of 400°C [69].

Janotka and Nürnbergerová [70] examined the strength weakening in the range of 100 and 200°C in the case of high strength concrete modified by silica fumes with a content of 7.53% by weight of cement at the water to cement ratio of 0.32 and is found due to coarsening of the structure of pore.

Kong and Sanjayan [71] worked on fly ash based Geopolymer concrete pastes and noted that 6% strength enhancement at compressive strength of 62.8 MPa and 11% mass loss at a high temperature of 800°C, as compared to the unexposed specimens. The compressive strength supplement is due to the presence of a large volume of micropores, low moisture loss, and higher solid to liquid ratio. The most significant parameter for fire resistance and strength development in concrete is fly ash to activator ratio and the advised best possible amalgamation of Na_2Sio_3=KOH of 2.5 and fly ash=activator of 2.5. A boost in strength of concrete at high temperatures is assigned to both polymerization kinetics and sintering. In one more study, Kong and Sanjayan [72] made known that the rate of expansion of aggregate and their size are the effectual parameters that affect the green concrete performance at a higher temperature. Smaller aggregates of less than 10 mm size have been found encouraging spalling and widespread cracking while larger aggregates of more than 10 mm found to be stable. In the case of fine glass powder mortar, Pan et al. [73] found strength loss of 15% at a temperature less than 500°C while for strength loss of 56% is ranging from 500 to 800°C. The strength loss is assigned to decrease in Calcium hydroxide of Geopolymeric mortar that softens glass content and greater inappropriateness between sand particles and paste. The thermal resistance of cement paste and paste incorporation with glass powder are confirmed in Fig.6. It can be seen that the thermal capacity of the cement paste is 1.047 W/mK, while thermal resistance are found as 1.013, 0.911 and 0.707 W/mK, for 5Glass I, 10Glass I and 20Glass I pastes respectively.

Poon et al. [74] noted that pulverized fly ash followed by ground granulated blast slag displayed enhanced performance at a higher temperature as compared to silica fumes in concrete and can be employed in the cases where there is a high risk of fire. The best possible percentage of substitutions of cement by fly ash and ground granulated blast slag in high strength concrete to keep hold of the highest strength and durability are 30% and 40% respectively [74]. In the case of concrete incorporating silica fumes with more than 5% cement substitution should be keep away owing to produce volatile spalling.

The order of preference for compressive performance based on the results at higher temperature can be demonstrated as follows:

fly ash>groundgranulatedblast>slag > silica fumes.

Average strength loss in fly ash and silica fumes based high strength concrete and ground granulated blast slag based concrete are 44% and 60% respectively.

Rashad et al. [66] observed increasing residual strength at higher temperatures when ground granulated blast slag is employed as sand substitutions in the case of alkali-activated slag mortar. Residual strength loss met with at 800°C are 33.45%, 51.91%, 69.49%, and 90% as well as at 25%, 50%, 75%, and 100%, substitution of sand correspondingly. An augmentation in residual strength at 200 and 400°C are 19.31%, 79.26%, 89.73%, and 100.95%, as well as 20.89%, 64.28%, 71.86%, and 82.58% whereas at 25%, 50%, 75%, and 100%, substitution of sand correspondingly. Microcrack is found to be absent in the alkali-activated slag mortar all through the high-temperature tests.

Tanyildizi and Coskun [75] studied lightweight concrete with the incorporation of 0,10, 20, and 30% substitution of cement by fly ash at a higher temperature of 200, 400 and 800°C. The range of compressive strength found between 38–48 MPa, 35–38 Mpa and 14–23 MPa as noted at 200, 400 and 800°C. Retained strength percentage observed ranging from 91.09–98.95%, 80.23–92.6% and 36.13–43.64% at 200, 400 and 800°C correspondingly. The loss of compressive strength is due to the loss of water of hydration at higher temperatures. The percentage of splitting tensile strength retained found ranging from 87.84–91.85%, 81.94–85.55% and 23.55–43.15%, at 200, 400 and 800°C correspondingly. With a view to achieving optimum compressive strength and splitting tensile strength, the optimum fly ash content suggested is 30%. Concrete mix incorporating fine waste glass are found with the highest compressive strength compared to a coarse waste glass containing concrete and amalgamation of both fine and coarse waste glass incorporating concrete [76]. The best possible waste of glass content to have the greatest compressive strength at both ambient and higher temperature is 10% aggregate substitution for three amalgamation varieties. The compressive strength of the three concrete came together at about 700°C owing to nearness to melting point temperature of waste glass, i.e., between 700 and 800°C and the exclusion of size effect in the soften condition of the glass aggregates. Compressive strengths of concrete incorporating fine waste of glass attained 40.5, 35, 55, 42, 34.5 and 22 MPa at 20, 60, 150, 300, 500 and 700°C. Pulverized fly ash concrete demonstrated relative strength enhancement at 450and 650°C, however, durability got worsen from 250°C [77]. The enhanced width of it, coarsening of the toughened cement paste and augmented total porosity is responsible for compressive strength loss. Rice husk ash is found more effectual than fly ash in resisting sulphate attack of binary cement mortars. Astonishingly, the rice husk ash mortar had gone through strength enhancement of 7% as compared to 0% for fly ash after 90 days immersion in 5% sodium sulphate solution and at 20% cement substitution [78].

Nevertheless, fly ash found with greater strength enhancement of 8:8% as compared to rice husk ash which is accounted for 24.6% strength decrease both at 40% cement substitution after 90 days. The best possible rice husk ash and fly ash substitution of cement, to make sure of compressive strength retention and development, is 20% and 40% correspondingly.

Chatveera and lertwattanaruk [79] have suggested 20% rice husk ash substitution of cement to achieve durability enhancement in concrete and improvement in resistance to acid attacks. The enhanced resistance to rice husk ash is due to a physical and pozzolanic effect, the densification of its microstructure as well as the presence of oxide of Aluminium (Al_2O_3) [55]. Strength enhancement is noted as 25% rice husk ash substitution of cement with 0.1N H_2SO_4 [80]. A variety of chemicals viz., H_2SO_4, HNO_3, Acetic acid, H_3PO_4, Na_2SO_4, and $MgSO_4$ are used to examine chemical resistance to fly ash and silica fumes [81]. Further, they noted that silica fume exhibits better resistance at higher cement substitution from 15%. Silica fumes displayed lower strength loss of 16.6% and 17.8% as compared to 23.5% and 38.9% for fly ash at 15% and 22.5% cement substitutions correspondingly. Chemical resistance to fly ash gets affected by its fineness. Compressive strength increased from 41.5, 53.5, 56, and 61.5 MPa for growing Blaine fineness of 3000, 3900, 4800 and 9300 cm^3 to g [82]. The best possible substitution level to obtain chemical acid resistance varies depending upon the kind of acid as well as alkaline solutions engaged [83]. It appears that chemical acid resistance to fly ash is more effectual at higher substitutions as compared to silica fumes. The sulfate resistance is due to stopping of the ingress of sulfate ions into concrete, resulting in the small formation of Gypsum [84]. The level of resistance to chemical attack augments with growing cement content, lowering of water to cement ratio and the applications of cement with tricalcium aluminate ($Ca_3Al_2o_6$) content of less than 7% [85]. Chemical resistance to ground granulated blast slag depends upon high reactivity in the presence of lime, accessibility of Calcium in the pore solution and its distribution in the specimen [86]. Ground granulated blast slag performed far better than fly ash on its exposure to leaching and sulphate attack [87]. The authors noted that hydration of tricalcium silicates C_3S and C_2S in cement resulted in the formation of portlandite, which when released, facilitates ingress of sulphate ions and produce expansive products like gypsum and ettringite. Similarly, ground granulated blast slag performed better than fly ash in resisting attack from $MgSO_4$ [88]. Up to 50% ground granulated blast slag can be utilized in concrete to obtain good properties against sulfate resistance, to diminish carbonation as well as thermal cracking [89]. Concrete incorporating up to 70% ground granulated blast slag demonstrated good resistance to thaumasite form of sulphate attack and their resistance is enhanced with the adding up of small amounts of $CaCO_3$ or calcium sulfate [90, 91]. Ground granulated blast slag displayed stronger resistance to sulphate attack as compared to fly ash, and the optimum cement substitution for ground granulated blast slag is 40% [92]. However, ground granulated blast slag has a good resisting capacity.

O'connell et al. [93] pointed out that ground granulated blast slag should not be employed in wastewater infrastructures as it is not able to resist the high levels of sulphate and sulphuric acid attack. Waste glass enhanced the durability of concrete incorporating waste glass by retaining weight stability during sulphate attack [94]. Additionally, field studies of more than six years demonstrated the uninterrupted enhancement in mechanical performance of slabs and walls made with the waste of glass concrete [95]. Glass fume prepared from particles of a waste of glass are monitored to display higher resistance to sulphate attack [96].

Ganjian and pouya [97] noted that OPC concrete performed far better than silica fumes concrete when exposed to the tidal environment while a mixture of silica fumes and ground granulated blast slag displayed inferior performance. Makhloufi et al. [98] noted that mortar prepared with quaternary blends including ground granulated blast slag demonstrated enhanced sulphate attack resistance than OPC concrete.

Aziz et al. [99] noted that up to 30% ground granulated blast slag enhanced the durability of sulphate resisting cement and can be employed for the production of extremely durable concrete. The enhancement is due to a decline in total pore volume, free lime content, total chloride, total sulphate contents and, subsequent augment in the resistivity towards sulphate and chloride ions. The above results indicate the preferable ranking of the supplementary cementitious materials concerning sulphate attack as follows:

Waste of glass > silica fumes > ground granulated blast slag > fly ash > rice husk ash.

Even though, more laboratory and field investigations are essential to confirm and to verify the ranking.

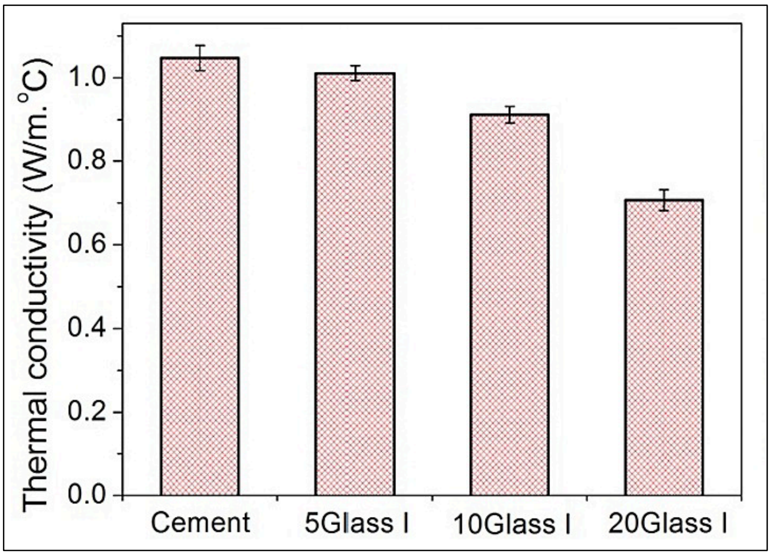

Fig. 6- Thermal conductivity of pastes [73]

4 Conclusion

Employment of diverse industrial wastes as ingredients substitution has been reviewed in this manuscript. Durability properties of dissimilar Green concrete is conversed and compared to their conventional counterparts. Summarily, when sand is substituted by class F fly ash, imperial smelting furnace slag, copper slag, concrete demonstrates enhanced durability and strength attributes, but the value of slump augments since the rate of substitution increases in the case of slag and the slump value declines while class F fly ash used. A petite research work found reported on the topic of palm oil clinker and ferrochrome slag as a replacement material for sand and hence advance researches are essential in the said field. A range of Green concept concrete and mortar and their incorporations with various wastes and solid wastes materials from agricultural, industries, bio-waste, recycled materials, and some other substitute ingredients has been found acceptable in terms of durability property hence, green composites technology is attracting researchers, engineers and construction industry related people more and more with positive impact as reviewed by some limited studies. An improvement in sustainability, a diminish in cost, solutions to environmental crisis and conservation of natural resources from degradation, excellent resistance to fire and chemicals are some of the significant features of it. An application of these wastes in Green composites displays not only enhanced durability as well as strength but also enhanced the microstructures. Sustainable and apposite wastes, as well as demolished building materials in concrete, save the lands from filling and degradation of expensive and constrained natural resources of ingredients like river Sand, Limestones, Coals, etc. Nevertheless, its impactful application in upcoming days, business-relaxed alertness such as Sustainability, durability, easy to get to, it's quality, cost-effectiveness, an exhibition of low environmental impact on account of mitigated carbon footprints maintaining all essential specification of ‘‘Green Concrete. An appropriate standard along with cross-disciplinary collaborations between construction stakeholders are essentially required on an urgent basis, to encourage acceptance of green concrete in construction industries. To diminish the necessity of OPC, more manifestations of the project and advance researches to develop optional binders by using green source materials is to be made. Owing to its, technological, financial and ecological gains, green concept concrete is strongly recommended for construction and infrastructure industries. Their use as additional materials in structures is recommended to obtain more strength, enhanced workability, and excellent durability. Global promotion of applications of green concrete in large-scale infrastructure and construction projects will facilitate its acceptance worldwide. The promotion of the green concept should materialize by not only governments or authorities but also by media and people related to construction fields. Awareness strategy for consumption of these “waste for the best” should be pursued to gain the full attention towards this novel, innovative, and eco-friendly technology by inventors, researchers, engineers, ecologists, conservationists, and people associated with construction and infrastructure industries across the globe.

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