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"Optimizing Self-Compacting Concrete Performance through Recycled Coarse Concrete Aggregates: A Review"

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ABSTRACT

Self-compacted concrete (SCC) is very advanced concrete which has higher fluidity without separating and are capable of filling every side and corner of the structure with its own weight. It does not require any kind of vibrations to compact the concrete without affecting its mechanical properties. It is considered to have many advantages incomparison with ordinary concrete like improved& fast construction activity and reduced costetc. It is preparedsimilar manner that of ordinaryconcrete. Cementitious materials are replaced in SCC with wastematerials from industries and agricultural. Different types of materialhave been tried to prepare SCC with enhanced properties. In many countriesSCC has been acceptedreasonably in civil construction.In above point of view, it becomes important to focus on review on preparation SCC in which withcementitious material is replacedwith some other waste products.These waste products reinforce the SCC.Present paper is a review of enhancement of properties of SCC using different adhesive with objective to compile available literature tounderstand the various properties of SCC when cementitious material is replaced with some other waste products.

INTRODUCTION

Major problem faced by civil engineers in last decades is the durability of civil structure and it is due to poor durable property of concrete used in making structures. Proper compression is important to make durable concrete structures. Compressionin normal concrete is achieved by using different vibrating devices; by which concrete segregation is done by excessive vibration of the concrete. It is not easy to ensure uniformity of concrete material quality and suitable density in the case of reinforced crowded places. Durability complications in concrete arise if concrete does not provided sufficient coverage for reinforcement. So, compression of concrete becomes very difficult in such situation. Therefore, it becomes important to prepare or manufacturesuch concrete which is capable of to be compressed its own. Solution to this problemis found in a special concrete whichis capableof self-compress byweighing it at each place of the structure and in the crowded reinforcement without any outer vibrations. Such concrete is termed as Self-Compacting Concrete (SCC). The concept of SCC meets almost requirements to overcome these problems. SCC is very advanced concrete which has higher fluidity without separating and are capable of filling every side and corner of the structure with its own weight. It does not require any kind of vibrations to compact the concrete without affecting its mechanical properties.

SCC was first manufactured in Japan in 1980s to enhance corrosive property of concrete due to the lake of skilled workers, the homogeneity and compaction problem of concrete in the edges into an adaptable structure to improve the durability of concrete and structures. After that, all Europeancountries started working on this. European countrieshave been working dynamically in the field of research regarding SCC.Now-a-day, significant research work is being performedall over the world to improve the resilience of SCC with its basic properties such as durability and strength. The first seminar on applications of SCC was organized by North America in November 2002. In present time, many researchers are working on SCC in many research organization, universities and R&D societies. Whereas, advantage of use of SCC have been reported by many researchers.

REVIEW OF LITERATURE

As reported in literature cementitious materials are widely used in civil construction work. Many researchers investigated effect of addition of cementitious materials on various properties of SCC in fresh and hardened state.

Ravindrarajah and Tam (1985) studied effect of using recycled concrete aggregates with different properties on durable properties and strength of concrete. The outcomes of the experiments conducted at RCA showed the sg of the recycled aggregate has a lower value while the adsorption capacity has much more value than ofnatural aggregate. Recycled CA has low protection from mechanical activities. The accessible approach for predicting the MOE based on the compressive strength describe that regular concrete has a higher MOE than recycled CA.

Zerpino et al. (2008)studied the different levels of compressive strength of three types of concrete. Each form includes a ref. concrete made from natural coarse aggregate and two recycled aggregate concrete formed from two diff. forms of aggregate obtained bycracking high-strength and normal-strength concrete. The beams and rollers were used to do the bending strength test andCompressive strength test respectively. In addition, failure traits were analyzed by specific goal to determine extent of the broken aggregates. RAC screen smoothly reduces the resistance (1-15%), lowers the MOE (15-18%) and significantly reduces breakdown energy (30-45%) and thus in the size of the area rupture, compared to concrete produced from natural coarse aggregate.

Tam et al. (2009)examined the physical and chemical responses of cement paste adhering to recycled concrete and regular concrete. Use two blending methods called the two-stage blending way, the normal blending way, and diff. techniques. Four types of physical and chemical responses of concrete samples, such as dihydroxylation of CH, drying of $C_3S_2H_3$, C_6S_3H development and substitution of iron at different temperatures, were separately observed. The outcomes of the differential calorimetry showed that there was a low increase in the strength of the concrete sample prepared from recycled aggregate compared to the concrete sample formed without using recycled concrete. In both cases, results of the two-stage mixed approach are exposed to improve the quality of refrigeration and air conditioning.

Reddy et al. (2009)discovered the possibility of producing new concrete using RCA in the manufacture of SCC. In this way, the durable properties and mechanical properties of self-ramming concrete were checked. To find waterabsorption, acid attack resistant and SCC resistance, three types of concrete (M20, M40 and M60) were made using recycled concrete aggregates instead of natural aggregates in different proportions (0%, 25%, 50% and 100%). The results of these tests indicate that the SCC resulting from the substitution of 25% of the RCA does not show any antagonistic impact on the characteristics of the SCC.

Ranganath et al. (2010) evaluated effect of cement and paste dust content in SCC mixtures. Experiments were conducted on 63 mixtures with a fixed volume of water changing from 180 L/m3 to 220 L/m3 for three diff. paste contents. For each adjustment of probes, the water/water ratio and water content essentially remain constant. Various tests are performed to check the quality of SCC, like asV-funnel tests, settling flow, and J-ring tests, and the results showed a directly proportional relationship b/w SCC flow characteristics and core size.

Liu (2010) examined the variability of cement supplanting with fly ash of up to 80% in self- pressing concrete, while keeping all new properties constant. An examination of the relationship b/w SCC stiffness properties was performed. The results showed that replacing cement with fly ash up to 80% is attainable in SCC. Replacing cement with fly ash increases the water/dust ratio (W/P) and reduces the dose of the superplasticizer, while the packing capacity of the SCC remains constant. They also show that fly ash negatively affects the consistency maintenance, flowability and hardening property ofconcrete, for eg. Strength investigation between Naturally Vibrated Concrete (NVC) and SCC shows that both have nearly similar material properties. This efficient completion of works can lead to the use of a more fly ash in SCC.

Madandoust& Mousavi (2012) used metakaolin as replacement material of cement from 0 to 20% in 0.32, 0.38 and 0.45 w/b ratios. The addition of metakaolin in cement increased the workability and rheological properties of SCC. A remarkable enhancement (27%) in compressive strength and tensile strength was observed in 14 days. The use of metakaolin reduced water absorption of SCC less than 3%. 10% metakaolin has been recommended as optimum and effective cement replacement.

Phathak& Siddique (2012) worked on influence of high exposing temperature on compressive strength, tensile strength and durability of SCC by replacing cement by 0% to 50% fly ash at different exposing temperature. It was observed from the study that the tensile strength was significantly reduced with temperature and percentage of fly ash but compressive strength was found to be decreased.

Oshago et al. (2012) investigated the effect of RCA used with fly ash in concrete as an alternative to ordinary aggregates for fractures and aggregates. The engineering assets were analyzed for durability variables of concrete containing OPC and fly ash with different stretches of recycled concrete aggregate, such as 100%,50%, 30% &0%. The results obtained showed that although planting a larger amount of recycled concrete aggregate can reduce the protection against ingress of chloride and carbonization of concrete, practically similar contour strength can be achieved for the control mixture.

Viacava et al. (2012) performed a study to investigate the feasibility of the SCC's medium strength prepared using cement kiln dust both theoretically and practically. They replaced cement with 20%, 30% cement kiln dust with 0.38 and 0.42 water/binder ratios. It has been observed from the study that the SCC having 35MPa strength can be produced with 30% of cement kiln dust and 0.42 of water/fines ratio.

Mohammed et al. (2013) prepared SCC with limestone powder and fly ash. They investigated effect on micro-structural and hydration properties of SCC using X-ray diffraction, scanning electron microscopy, mercury intrusion tests, image and thermogravimetric analysis. It has been found that the compressive strength of SCC was enhanced. The microstructure of SCC was different in both the cases i.e. limestone powder and fly ash.

Raharjo et al. (2013) investigated thirty three mixtures of SCC containing limestone powder and fly ash as partial replacement. The mixtures also contained iron slag. Compressive strengths of SCC have been determined at 3, 7, 14, 28 and 56 days. It was observed that concrete with 30% fly ash and 20% silica fume has maximum compressive strength.

Vanjare&Mahure (2013) observed in their study workability, compressive strength and flexural strength of SCC have been enhanced with increased percentage of cement kiln dust. The optimum dose of cement kiln dust is suggested 10% in terms of strength properties.

Wang & Ling (2013) investigated the properties of fresh and hardened SCC experimentally with 0% to 30% weight by weight furnace slag as replacement of cement. The effect of slag was investigated in terms of slump flow, shrinkage and compressive strength and that the slump flow varies 550 mm to 700 mm with 15% of slag and exhibit maximum compressive strength.

Ranjbar et al. (2013) performed an experimental study on influence of natural zeolite on different properties of SCC. They replaced from 0 to 20% of cement with natural zeolite. The results showed increase in passing ability and viscosity of SCC with natural zeolite but flow ability became less. More increment of natural zeolite decreased slump flow. The UPV values were not affected by addition of natural zeolite at high compressive strength. Water absorption of SCC with NZ was decreased with passage of time.

Shobana et al. (2013) replaced cement with 10%, 12.5% and 15% silica fume. Slump flow, V-funnel, J-Ring, L-Box, U-Box tests have been performed to measure the fresh properties of SCC. UPV and compressive strength tests were performed to evaluate mechanical characteristics of SCC. Enhanced properties of SCC both in wet and hardened state have been observed in that study. Based on study, maximum 6% silica fume is suggested for best results.

Nuruddin et al. (2014) prepared SCC by replacing cement with microwave incinerated rice husk ash fly ash. They investigated the effect of fire flame on it. The weight and compressive strength of SCC reduced with temperature. High temperature improved spalling effect of SCC.

Ahmed et al. (2015) evaluated the work of ternary SCC mix manufactured using some industrial debris such as inorganic fillers that including cement kiln dust, limestonedust, bagdust, metacholine and crushed steelslag, all combination along pozzolanic cement. Study was conducted to evaluate the optimal chemical mixture doses to meet the requirements for self-compatibility of SCC. But the strength of the SCC mixture containing dirt in the bag was observed to be lower than that of the other SCC mixture at early and later ages. Furthermore, the significant protection against spoilage shown by generated SCC blends indicate that the super-SCC blend could be formed using these industrial debris as inorganic fills.

Jalal et al. (2015) investigated rheological properties of SCC experimentally by partial replacement of cement with silica nano particles, silica fume and fly ash. Improvement in rheological properties of SCC with fly ash was observed. The mixture of silica fume and nano silica particles together found to enhance both mechanical and rheological properties of SCC.

Palomar et al. (2015) examined enhancement in microstructure, stiffness and mechanical properties of SCC using micro silica, methacholine and nanosilica, with limestone filler. The hardness, compressive strength and density were found to be reduced until the supplanting of the cement with limestone putty reached 50%, while the vapor permeability and porosity of the paste increased over the control concrete. The use of active additives naturally reduces the volume and the presence of big Portland crystals at the interface of the concrete transition zone and increased compressive strength, but there were no changes in hardness. The water vapor porosity and the paste porosity were reduced by the use of active additives, which increased the strength of the concrete. The strength and porosity of the paste increased without filling, while its absence decreased depending on the pozzolanic effect of AMA. The processing conditions at a young age also affected the mechanical properties and micro-structure of the dough, developing increased sample evaporation, reducing porosity, nick and WVP, although the mean pore diameter increased.

Tennich et al. (2015) worked on optimization of different compositions of SCC by “Concrete LabPro2” software followed by experimental study. SCC was prepared with waste of marble and tiles mineral admixture. Result revealed that prepared SCC has good fluidity and resistance to segregation. UPV compressive strength and spilt tensile strength tests reflected good strength properties which are suitable to SCC with these admixtures. It has also been observed that SCC with marble waste has lower strength than the SCC with lime stone.

Silva et al. (2015) examined the carbonization nature of concrete prepared from recycled aggregates of demolition and construction waste. It learns from diff. viewpoints of the effect associated with the use of RCA, for example, the volume, source and level of substitution, as well as the effect of processing conditions and the type of chemical additives and mineral additive. In this study, a statistical examination was carried out to determine the effect of using more content of recycled aggregate on the carbonization modulus and carbonation depth. The accelerated carbon protection of a reinforced air condensing compound under normal carbonization conditions was predicted by accelerated carbonization tests. The test results concluded that the carbonization depth increases with the increase in the substitutional level, while recycled aggregates, structured concreteand natural aggregates all have the same relative mixing composition. Both recycled aggregate and concrete prepared with ordinary aggregate show comparable relationship in carbonization depth and compressive strength.

Leung et al. (2016) investigated properties of SCC prepared by mixing fly ash and silica fume by sorptivity test to determine the surface water absorption. Significant reduction in water absorption was observed by adding 20% or more fly ash. Absorptivity was also found decreased. When SCC is prepared with both silica fume and fly ash, the decrease in water absorption is not as much; but, compressive strength increased is more.

Lee et al. (2016) reviewed the accessible RCA optimization approach and state their pros and cons in order to encourage the identification and promotion of reasonable RCA optimization strategies. The toughness and mechanical properties of RCA can be reasonably and effectively improved by carbon therapy of RCA. Besides improving the properties of recycled CA, the carbonization approach of RCA also provides an environmentally friendly, well-disposed technique.

Najim et al. (2016) replaced cement partially with cement kiln dust and observed high performance of SCC. Cement was replaced by weight 0%, 10%, 20% and 30% keeping other constitutes as it is. The results revealed that flow ability and mechanical properties decrease with increasing percentage of cement kiln dust. Maximum strength of SCC was achieved with 20% cement kiln dust while high performance of SCC was observed with 30% cement kiln dust. Cement kiln dust reduced the dynamic modulus of elasticity and increased the damping capacity.

Dinesh et al. (2017) replaced cement partially with fly ash and silica fume both. They replaced from 5% to 25% of fly ash and 2.5% to 12.5% of silica fume. Silica fume increased fresh and hardened properties of SCC. Lower compressive strength of SCC was observed with fly ash.

El-Mir &Nehme (2017) prepared SCC with high percentage of waste perlite powder, slag of blast furnace and metakaolin. The results identified a pronounced pozzolanic effect of WPP on concrete microstructure. This effect caused enhancement in compressive strength and durability performance of SCC.

Takahashi et al. (2017) presented another way to mix ordinary aggregates and RCA to increase the amount of recycled aggregate in recycled concrete and to improve RAC performance. This examination investigated the engineering properties of recycled concrete using a novel strategy and standard approach with varying amounts of substitution of recycled aggregates. The new strategy has updated the new and hardened properties of recycled concrete in contrast to the regular strategy. Using a new technology for concrete with recycled aggregate, the fraction of recycled aggregate can be brought to 50% in concrete, while the traditional strategy restricts the measurement of recycled aggregate to be less than 30%.

Vivek&Dhinakaran (2017) prepared SCCwith three mineral admixtures silica fume (5% to 25%), metakaolin (5% to 20%) and ground granulated blast-furnace slag (25% to 100%). The results obtained have been compared with normal concrete. Water-binder ratio was obtained at 2.3% and 0.15% weight of cement respectively. It has been observed that optimum values as partial substitute to cement found to be 50% ground granulated blast-furnace slag, 10% silica fume and 20% metakaolin.

Durgun&Atahan (2018) investigated the effect of the size of colloidal silica nanoparticles (CNC) on the microstructural and elastic properties of the SCC mixture. The size of the CNS samples was taken as 5, 17 and 35 nm to reduce the total amount of dust in the vicinity of the self-pressing concrete. With the help of colloidal nanosilica, the measurement of dust (fly ash) content in the composition of the SCC mixture was reduced and replaced with aggregates. Compression resistance testing was performed at 28 and 120 days of age with a mixture that meets the fresh characteristics of SCC. In addition, the elasticity coefficients for a concrete sample were estimated. The decrease in strength cannot be restored by using colloidal nanosilica with low fly ash content in a mixture. The hardness of CNS-containing SCC mixtures with fly ash provides the best hardness, although the increase in the absolute contentof aggregate is not significant. The development of a thick C-S-H gel was demonstrated by microscopic examinations.

Guardia et al. (2018) studied the early age and hardening properties of SCC containing various types of fillers such as nanosilica, microsilica and limestone filler by varying the processing temperature and relative humidity. It was concluded that temperature altered the response speed and development of early life characteristics, while relative humidity affected the rate of shrinkage and evaporation in the green state and the hardness and porosity in the annealed state. The order of the processing states and the type and size of the addition molecule influence the microstructure and evolution of the pore network in SCC.

Mohan and Mini (2018) examined the greening and hardening properties of SCC with cement replaced by complementary cement materials for example ultra-fine blast furnace slag and silica fume in various dimensions. The SCC mixture was obtained by determining the percentage of water binder and changing the doses of the superplasticizer (SP) to add it to the cementitious material. In addition to engineering properties, SCC blends gave high strength and durability when mixed with silica fume and alkaline in a dose of 10%. Therefore, silica fume gave the best result in the case of durability and mechanical examinations of different mixtures. The Design of Experiments (DOE), a statistical technique, provides assurance of an optimal silica-coffin-containing mixture. The DOE results provided optimal doses of alkaline and silica fume at 8% and 6% separately, which also achieved SCC property by varying the dose of the superplasticizer. The geometrical properties initially obtained for the mixture were in agreement with the DOE results.

Nguyen et al. (2018) tried to improve the properties of low cement SCC by dolomite powder and concluded that dolomite powder did not affect the setting properties of SCC. However, significant effect was observed on the properties of SCC blended with mixture containing slag, OPC & FA. Flow ability and compressive strength of SCC was enhanced with dolomite powder adjustment in ternary blended mixes of SCC.

Abid et al. (2019) worked on underwater abrasion of steel fiber-reinforced self-compacting concrete. In this paper, six SCC mixtures were prepared with different design grades of 30, 40 and 50 MPa and different micro-steel fiber contents of 0, 0.5, 0.75 and 1.0%. Four fresh SCC tests were adopted, while abrasion and control tests were conducted at ages of 7, 28 and 90 days. The ASTM C1138 tests showed that increasing the mixture strength by 20 MPa improved the abrasion resistance more effectively than the inclusion of 1.0% of steel fiber. Same has been compared to the 30MPa plain SCC, the 90-day abrasion resistance improved by 78% for SCC with 50MPa strength, while the inclusion of 1.0% of micro-steel fiber enhanced the resistance by only 26%.

Niewiadomski&Hola (2020) worked on process of compressed self-compacting concrete modified with nanoparticles assessed by acoustic emission method and proved this method as failure for the same. The obtained results were used to calculate the fatigue strength of all the concretes that were tested in the paper. Based on the achieved results, it can be concluded that the durability and safety of structures made of self-compacting concrete with the addition of SiO_2 and TiO_2 nanoparticles that are subjected to repeatedly variable loads will be higher when compared to structures made of concrete without these additives.

Wang et al. (2022) studied engineering properties of low-pH self-compacting concrete for concrete plug. The test result shows that adding SF and FA could effectively prolong the setting time. Using only SF, the initial setting time of the mix increased up to 4.2 h with the addition of 40% SF, while the combination of 40 wt% SF + 10 wt% FA could also increase the initial setting time to 3.92 h, which was much longer than 2 h working time requirement. Furthermore, at 90 days of curing, the pH value of each mixture was lower than 11, while the compressive strength enhanced to 118–132% compared to the control group. This addition could increase compactness, which leads to relatively strong sulfate resistance. The compressive strength could be enhanced by increasing the cementitious materials, which in turn, increases the pH and dry shrinkage.

CONCLUSION

Literature review reveals that a variety of waste materials is used as replacement cementitious material in SCC. Most of the studies have been performed to investigate the effectof additive materials on flow ability, compressive, tensile strength and flexural strength. Durability is also one of the most important studied parameters.In most of the cases flowability, passing ability and segregation resistance decreasesprogressively while compressive, tensile strength and flexural strength increased remarkably with replacement of cementitious material in SCC. In some studies waste materials obtained from different resources have also been used as replacement cementitious material. Enhancement in these properties varies with different percentage of replacement cementitious material.

Therefore, it has been concluded from the study that different properties of SCC can be improved by replacing cementitious material with other waste products such as fly ash, ultra-fine blast furnace slag and silica fume, dolomite powder, non silica, micro silica and limestone etc.

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