Effects of Fly Ash, Coarse Aggregate, Ground Granulated Blast Furnace Slag and Curing on the Strength of Self-Compacting Concrete (SCC)

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Abstract - *Self-compacting concrete (SCC) is a highly flowable concrete that can be poured into a form without the use of mechanical vibration. For decades, SCC has been portrayed as the most progressive advancement in concrete construction. In the construction industry, SCC has numerous advantages; the removal of compaction work lowers the const of placement, reduces construction time, and thus increases productivity. This review paper focuses on how different factors, such as fly ash, coarse aggregate, ground granulated blast furnace slag (GGBS), and curing, affect the strength of SCC.*

***Key Words*: Self Compacting concrete, Coarse aggregate, fly ash, curing, GGBFS, Strength.**

1.INTRODUCTION

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SCC (self-compacting concrete) represents a turning point in concrete research. SCC is a non-segregating, highly flowable concrete that scatter into position, tries to fill the formwork, and surrounds the reinforcement with relatively low mechanical vibration. Prof. Okamura and his team created SCC in 1986 at the Tokyo college of Technology in Japan to improve the nature of development. In 1988, the “High-Performance Concrete” model of SCC for basic applications was done, before being renamed “Self-Compacting High-Performance Concrete”. A board was framed at the college of Tokyo, Japan to take into account the qualities of SCC, recounting a critical concrete workability test. [1]

SCC is regarded as among the most prominent examples of concrete advancement in the last ten years. Due to its excellent properties, SCC may result in a substantial progress in the natural state of concrete structures and create new areas for the utilization of concrete, which are accomplished by a fantastic coordination of deformability and resistance of segregation. The use of SCC in the development phase has lots of advantages, including a reduction in placement costs and a reduction in construction time, resulting in increased productivity. SCC results in less noise throughout casting, improves working conditions, and allow for longer setting times in urban areas. Because of the streamlined and outstanding surface completion without blowholes or other surface imperfections. [2] The term “Self-Compacting” refers to the material’s fresh concrete properties, as a result, various mix compositions' level of consistency, deformability, and viscosity were routinely explored. Self-compacting concrete, unlike traditional vibrated concrete, requires a high level of powder content to produce a homogeneous and cohesive mix. Jagadish et al. [3]

Powder in the range of 450-650 kg/m3 of concrete is common in SCC, as stated in the report. Filler addition (both reactive and inert) is frequently included in SCC to preserve and enhance workability, and also to control cement concrete and lessen hydration heat, due to its rheological requirements. Mineral admixtures such as fly ash, ground granulated blast furnace slag, silica fume, and others can successfully replace a portion of this powder substance. [4] Despite the reality that SCC is made up of essentially having similar parts as regular concrete mixture, the concrete composition needed to attain the desired “Self-Compacting Properties” differs significantly. SCC, on the other hand, must have a greater level of segregation resistance while also having a high deformability. As a result, SCC has a vastly greater substance of ultra-fine substances. Fly ash contains numerous advantages in this application, including lowered water needs, improved workability, and increased compressive strengths at later curing times, which is impossible to attain with more Portland concrete. Chemical admixture is always necessary when making SCC to improve workability and reduce segregation. SCC has a lower coarse aggregate content and a lower water-to binder ration than regular concrete. To avoid gravity segregation of larger particles in the new concrete, SCC contains a lot of fine particles, such as blast furnace slag, fly ash, and lime powder. [5-7] In the design and execution of concrete mixes, aggregate size, shape, and surface play a critical role. The aggregate size has a direct impact on the density, voids, quality, and workability of concrete mixes. It also affects concrete mix properties such as powder content, air voids, powder-filled voids, consistency, flow values, durability, and weakness life, among others. It can be deduced that practically all mix properties are influenced by the size and proportion of course and fine aggregate in the mix.

2. Effects of Fly Ash on the Strength of SCC

FA is produced when coal is burned in thermal power plants and is considered an essential waste. During coal combustion, the mineral pollutions combine and exceed. With time, this intertwined material cools and solidifies into spherical particles, which are commonly referred to as FA. FA is commonly used as a low and high-volume replacement for PC in concrete (vibrated and non-vibrated). The primary goals of its application are to reduce CO2 emissions from the cement industry and to improve the workability of concrete [8-16]. In contrast to ordinary PC-based concrete, the use of FA in high volume ($\geq 30\%$) explicitly in mass concreting applications such as dams, piers, bridge abutments, and so on, results in low heat of hydration [17-20]. FA molecules range in size from 10 to 100 m, with the majority of the general size falling under 35 m [21-22]. The surface territory of FA particles is generally between 300 and 500m2/kg, but the base and most extreme estimates of surface zone range from 170 to 1000 m2/kg individually. Furthermore, FA's specific gravity ranges from 2.1 to 3.0[23]. Fly ash is primarily silicate glass, with silica, alumina, iron, calcium, and magnesium as minor constituents. Sulfur, sodium, potassium, and carbon are minor constituents. According to ASTM C618-12(a), fly ash is classified as either Class F or Class C, and its placement is based on the chemical composition. The color of Class F-FA has been observed to be light grey. The strengthening substance of silica, alumina, and iron oxide in FA, which must be at least 70% and half for Class F-FA and Class C-FA, respectively, is the major delimiter for differing characterization. Similarly, the Canadian Norms Affiliation categorized FA based on the calcium oxide measurement (CaO). It demonstrates that when CaO is less than 10%, FA is classified as low-calcium (Class F), whereas when CaO is greater than 10%, FA is classified as Class C. (CSA, 1982). Class F-FA, in particular, contains calcium ranging from 1% to 12% in the form of calcium hydroxide, calcium sulphate, and smooth segments mixed with silica and alumina. Class C-FA, on the other hand, has a calcium oxide content of 30 to 40% [23-25]. Indian Standards (IS-1727(1967)) have adopted the same recommendations for various classes of FA. SCC mixes are prepared for various evaluations ranging from 30 to 70 MPa and include all required rheological properties such as flow ability, filling capacity, passing capacity, and segregation resistance. The addition in compressive strength at early curing periods (12h to 28 days) for various grades of SCC mixes has been established, and the relationships have been compared to the IS Code formula for conventional concrete according to IS: SP 23-1982. $f_{ct}=f_{c28}$x t/ (4.2+0.85 x t).is the proposed condition for compressive strength. For various grades of SCC, the level of strength development is a little greater than the standard strength of regular concrete for similar grades. The quality of all grades of SCC at 12h is found to be over 10% of the 28-day strength, and 1-day strength is around 18-20% of the 28-day strength. For the elasticity of all grades of SCC, $f_{ct} = 0.0843f_{ck}+0.818$. is used to create a single connection. The rate error of the proposed connection in comparison to the exploratory results is found to be under 3.7 percent on average, demonstrating the equation's reliability [26].

3. Effects of Coarse Aggregate on the strength of SCC

Coarse aggregate is made up entirely of naturally occurring materials, such as rock, which forms as a result of the parent rock, and includes natural rock, slag, expand clay, and shale (light weight aggregate) as coarse aggregate, other recognized inert materials with comparable properties, such as hard, strong, and durable particles, can be used, adjusting to the particular requirements of this materials generously held on IS Sieve No: -4 with increasing coarse aggregate size, SCC's fresh properties deteriorate. The compressive, split tensile, and flexural strengths of SCC are highest when the coarse aggregate used in the mix is 20 mm in size. The increase in strength is legitimately proportional to the coarse aggregate size. In comparison to conventional concrete, SCC provides strengths over a longer period of time. SCC mix necessitates a high level of powder. To give the concrete mix soundness and fluidity, use a smaller amount of coarse aggregate, a high-reach superplasticizer, and VMA. SCC fills the for5mwork and typifies the reinforcement without the use of vibration, allowing for compaction to be achieved solely through gravity's activity, resulting in an amazing surface finish. SCC can be obtained for a wide range of fly ash or concrete materials as long as the paste volume determined by the water cement ratio remains constant. SCC was the increase in strength with age. Following 28 days, SCC's rate of strength gain increased with age. The propensity of the mix to segregate increase as the size of the coarse aggregate increase. In any case, SCC properties can be achieved for extremely high levels of fly ash content (for example, up to %). [27] When using crushed aggregate with a similar W/P proportion and superplasticizer measurement, the flowability of SCC decreases as the largest size of coarse aggregate increases. At (28,56,90) days of testing, using percent metakaolin as a partial replacement by weight of cement results in a decrease in flowability, an increase in viscosity, and an improvement in strength. Concrete mixes made with crushed limestone have higher strength and elasticity than concrete mixes made with crushed rock, and crushed rock concrete mixes have more vigor and versatility than uncrushed gravel concrete mixes. SCC mixes with the largest coarse aggregate size of 10mm have better mechanical properties than mixes with the largest coarse aggregate size of 20mm. [28.]

4. Effects of different curing conditions on the strength of SCC

Curing is a method of controlling the rate and severity of concrete dampness misfortune during cement hydration. It could be either after it has been installed (or during the assembly of concrete products), allowing the cement to hydrate. Because cement hydration takes days, if not weeks, instead of hours, it takes a long time. If the concrete is to achieve its expected strength and durability, it must be allowed to cure for a reasonable amount of time. Curing may also include temperature control, as this affects the rate at which cement hydrates. The curing period may be determined by the expected properties of the concrete, the purpose for which it will be used, and the surrounding conditions, such as the temperature and relative humidity of the surrounding environment. Curing is primarily intended to keep the concrete clammy by preventing the loss of moisture from the concrete during the strength-building process. Curing can be done in a variety of ways, and the best methods for curing may be determined by the site or development strategy. The compressive strength of SCC increased from 33.8 MPa to 36.4 MPa, from 50.2 MPa to 52.6 MPa, and from 57.9 MPa to 63.3 MPa at curing times of 3,7, and 28 days, respectively, under various initial water-curing periods and curing conditions. The flexural strength of SCC increased from 4.97 MPa to 5.46 MPa, 7.53 MPa to 7.86 MPa, and 8.68 MPa to 9.24 MPa at curing times of 3.,7, and 28 days, respectively, under various initial water-curing conditions and curing conditions. SCC with a 7-day underlying water curing period has the highest compressive and flexural strength. SCC under full room water FR curing has a higher compressive and flexural quality than SCC under continuous full standard (FS) or continuous full water (FW) curing. The strength picking up the rate of SCC with a 7-day underlying water-curing period and SCC under FR restoring is higher [29]. Preliminary steam curing may help to increase compressive strength. Higher initial compressive strength is due to advanced hydration, C-S-H gel, and CH crystalline arrangement at higher temperatures; however, extreme compressive strengths at 90 years old were nearly equivalent. Because a portion of the compressive strengths obtained from 16h of absolute steam curing duration were not exactly the undertaking requirements, a shorter total steam curing term of 18h appeared to be the best routine among the regimens in this study. [30]

5. Effects (GGBS or GGBFS) on the strength of SCC

GGBFS is made by cooling fluid iron slag (a byproduct of iron and steel production) in water or steam, which produces a gleaming, granular material which is then dehydrated and finely ground. GGBFS contains CSH (calcium silicate hydrates), a strength-enhancing compound that improves the concrete's strength, toughness, and appearance. Because of its pozzolanic nature, ground granulated blast furnace slag (GGBFS) could be an incredible resource for modern construction needs, as slag concrete can perform if properly designed, GGBFS is increasingly being used as a cementitious material and fine filler in the production of High-Performance Cement (HPC), Roller Compacted Concrete (RCC), and self-compacting concrete (SCC), among other things. In any case, to achieve the required high performance in any of these concrete composites, slag must be proportioned properly so that the subsequent concrete meets the structure's quality and execution model requirements. GGBFS is one of the most widely used SCMs in SCC mixtures as a halfway cement or totals substitute. GGBFS is widely available, and its annual production is estimated to be around 25 million tons. Almost a third of GGBFS is used to expand the production of concrete for the structure area. The impact of GGBFS on the properties of SCC has been studied extensively, and it has been determined that the expansion of GGBFS increased the rheological properties of concrete. The use of GGBFS reduces the amount of superplasticizer that is expected to be acquired in a slump flow similar to that of Portland cement concrete. SCC fresh properties are acceptable when industrial slag is used in large quantities. GGBFS, on the other hand, had no effect on the flowability and stability of SCC. The yield pressure and viscosity of the concrete paste are reduced when GGBFS is used. Similarly, Sethy et al. (2016) found that increasing the slag content reduces plastic viscosity and results in extremely low yield pressure for all of the substitutions teste. In any case, GGBFS's association with the SCC lowered mechanical properties at a young age. After a 28-day cure period, this decrease could be overcome. In addition, using GGBFS in SCC improved drying shrinkage, chloride ion penetration, water ingestion, sulphate assault resistance, and corrosion resistance. The use of GGBFS as a cement substitute reduced compressive strength at an early age, but at later ages (56 and 90 days), the strength was equal to or greater than that of reference concrete. The highest compressive strength was achieved by combining SCC with 15% GGBFS. [31].

6. CONCLUSIONS

For various grades of SCC, the level of strength development is a little greater than the standard strength of regular concrete for similar grades. The strength of all grades of SCC at 12h is found to be over 10% of the 28-day strength, and 1-day strength is around 18-20% of the 28-day strength. SCC's flowability decreases as the largest size of coarse aggregate is increased, and crushed aggregate with a similar W/P ratio and superplasticizer dosage is used. The compressive strength of GGBFS as a concrete substitute was reduced at an early age, but at later ages (56 and 90 days), the strength was equivalent to or higher than that of reference concrete. The highest compressive strength was achieved by combing SCC with 15% GGBFS. Initial steam curing may result is caused by higher temperature, while ultimate compressive strengths at 90 years old were similar.

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