Shinde Jaydeep M, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 12, Issue 12, December 2022, pp. 80-88

RESEARCH ARTICLE OPEN ACCESS

Experimental Investigation of Self-compacting Concrete with Low Fines Supplementary Cementations Materials

Shinde Jaydeep M *[1], K. Ravi*[2] and Vidya B R[*3]

[1]*Research Scholar, Department of Civil Engineering, Visvesvaraya Technical University, Resources Research Centre, Belagavi-590018,Karnataka,India*
[2]*Professor, Department of Civil Engineering, Sant Gajanan Maharaj College of Engineering, Mahagaon, Kolhapur-416503, Maharashtra, India*
[3]*Assistant Professor, Department of Civil Engineering, Amruta Institute of Engineering and Management, Bidadi-562109, Karnataka,India*

ABSTRACT
The low fines self-compacting concrete is a sustainable solution to boost productivity and efficiency which will helps engineers in construction industry. In this experimental investigation Low Fines Self-Compacting Concrete (LFSCC) is developed by using cementations content less than 380 kg/m³. In order to achieve economy and to develop ecological concrete the cement content is replaced by different percentage of Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS) and combination of FA+GGBS, which ranged from 10% to 50%. The fresh flow properties of LFSCC were investigated as per EFNRAC specifications. The various strength properties like compressive strength, splitting tensile strength and flexural strength are evaluated as per Indian standards specifications. From experimental results, all the mix combinations satisfied EFNARC specification in fresh state of LFSCC. The highest compressive strength of 37.44MPa was observed when cement was replaced with GGBS at 40%, which is 22.51% higher than the reference mix. Flexural strength and splitting tensile strength both decreased as the percentage replacement of fly ash increased. According to the overall findings, LFSCC can be considered for everyday concrete applications. Thus, Low fines SCC realizes a host of benefits such as economic, enduring, ecological and ergonomic.

Keywords*-Low fines self-compactingcconcrete,Flyash,GGBS,Compressive strength, Workability.*

Date of Submission: 04-12-2022 Date of Acceptance: 15-12-2022

I. INTRODUCTION

Self-consolidating concrete, also known as self-compacting concrete (SCC), is distinguished by its low yield stress, high deformability, and moderate viscosity. These properties are essential for ensuring the uniform suspension of solid particles throughout the transportation and placement processes (without external compaction). This concrete can be used to cast substantially reinforced sections, in areas where vibrators cannot be used for compaction, and in intricate shapes of formwork that would otherwise be impossible to cast, as well as to produce a surface significantly superior to conventional concrete. [1].Since the development of SSC in the 1980s in Japan, traditional veritable concrete should have been replaced to a greater extent by this technology's significant benefits. However, traditional SCC has disadvantages in the form of a high fines content and an imbalance between stability and fluidity due to the mix's sensitivity to changes in concrete elements. Also, the unit cost of SCC found to be 30-50% higher than the cost of conventional concrete [2]. The increase in cost may attributed to utilize large amounts of Portland cement (which will leads to thermal cracks due to excess heat of hydration) and use of chemical admixtures in SCC [7]. The extra cement content and fines required for the SCC, as well as the logistical costs (additional silos, additional mixing time, stricter quality control of the materials, etc.) increase production costs. Therefore, the cost per cubic meter of SCC becomes a constraint and therefore, SCC could never dominate traditional concrete [4]. Due to the fact that SCCs are manufactured with very disadvantages in the form of a high fines content and an imbalance between stability and fluidity due to the mix's sensitivity to changes in concrete elements. Also, the unit cost of SCC found to be 30-50% higher than the cost of conventional concrete [2]. The increase in cost may attributed to utilize large amounts of Portland cement (which will leads to thermal cracks due to excess heat of hydration) and use of chemical admixtures in SCC [7]. The extra cement content and fines required for the SCC, as well as the logistical costs (additional silos, additional mixing time, stricter quality control of the materials, etc.) increase production costs. Therefore, the cost per cubic meter of SCC becomes a constraint and therefore, SCC could never dominate traditional concrete [4]. Due to the fact that SCCs are manufactured with very effective super plasticizing additives and huge volumes of particles, which are essential for mixture stability, the end product has strengths more than 40 to 50 MPa, which are not always required by the project [29]. Thus, in today's world using SSC like an everyday concrete is not economically viable, especially in Ready Mix Concrete (RMC) industry by using high cement content. Use of mineral admixtures like as fly ash and GGBS, which are finely divided minerals added during the mixing phase, is one way to lower the cost of SCC [6]. The application of FA and GGBS in major civil engineering constructions is becoming more widespread. Aside from the economic and environmental benefits, several construction advantages have been reported [8], including: (a) improving fresh properties of concrete, such as better flow and easier compaction; (b) reducing heat of hydration evolution; and (c) decreasing chloride ion penetration, sulphate attack, alkali silica reaction, and so on [30]. Concrete can be made more durable and stronger by using fly ash as a substitute for cement, which is produced as a byproduct of thermal power plants. Fly ash minimizes the requirement for chemical admixtures that reduces viscosity [9]. SCC with replacement of Portland cement by FA up-to 50% can increase the versatility and robustness of SCC [10]. An innovative novel viscosity modifying agent (VMA) has been developed, that can reduce the overall fines content of the concrete and results in a substantial reduction in the unit cost of concrete (related to typical SCC) when mixed into a Polycarboxylate ether-based hyper-plasticizer. Hence, it is possible to realize dreams of a self-compacting concrete for day-to-day concreting applications in the range of grades 20MPa to 30MPa. In this direction a concept of SCC with low cementations content can be explored to achieve low grade concrete (20MPa to 30MPa) and also by maintaining the self-compacting properties at a lower cost which is nothing but Low Fines Self-Compacting Concrete (LFSCC) [11]. Low fines-based SCC can be produced with low cementations content in between 340 to 380 kg/m³ with hyper plasticizer based on Polycarboxylate ether (PCE) which is the need of present construction industry for lower grades of concrete with self-compacting properties for day-to-day applications [4].

The current experimental investigation focuses on the properties of SCC with different percentages of fly ash and ground granulated blast furnace slag replaced for cement, as well as by limiting the powder content to less than 380kg/m3. The current study's primary goal is to investigate the properties of LFSCC in both their fresh and hardened states.

II.LITERATURE REVIEW

Many researches have studied the SCC, with and without incorporating mineral admixtures. for its strength and durability characteristics, J. M. Khatib [12] examined the effect of addition fly ash (FA) on the characteristics of self-compacting concrete (SCC) and he came to the conclusion that by replacing 40% of the PC with FA, the strength will go up to 65 N/mm². Tarun R. Naik et al. [2] investigated the creation of high-strength, low-cost self-consolidating concrete with a 35-55 percent fly ash substitution. They have observed that VMA and PCE can be reduced as compared to normal dosage of SCC in their studies and found that cost-effective self-compacting concrete with 62MPa is feasible and it can be designed with 35% of high-volumes of fly ash. As a substitute for cement, Krishna Murthy et al. (13) have utilized mixtures of Metakaolin and Fly ash. They have created a simple tool for the creation of SCC mixes with 29 percent coarse aggregate, substitution of cement with fly ash and Metakaolin mixtures and controlled SCC mixes with a water/cementitious ratio of 0.36. Dinkar P. et.al. (22), examined self-compacting concrete made with portland pozzolana cement and various quantities of fly ash. In their studies they have replaced PPC in the range of 10 to 70% by FA. They found that replacing fly ash by 30% led to strength of up to 100MPa after 56 days. Mucteba Uysal et al. (7) conducted an experimental analysis to study the SCC's strength and durability capabilities with cement replacement by 5 different admixtures like marble powder (MP), limestone powder (LP), GBFS, FA and basalt powder (BP) was considered. They have investigated comparative study on workability of SCC, compressive test, density, ultrasonic pulse velocity (UPV) and resistance for sulphate attack of SCC. At 400 days, strength greater than 105 MPa was achieved by substituting 25% of PC with FA. On the other hand, a blend of 40% GBFS and 60% PC provided the best defense against attacks from salt and magnesium sulphide. The rheological and mechanical properties of SCC with low cement composition by adding metakaolin, fly ash has been studied by Fernando Pelisser et al., [5]. They accomplished SSC even though their compressive strength was only 28.6 MPa and their cement consumption index was 10.2 kg/m³. Their findings showed that when metakaolin and fly ash mineral additives are utilized, it is possible to manufacture low strength SCC with the required fluidity and concentrated binder use. Due to significant cost and environmental impact reductions, SCC becomes more effective. Experimental research was done to determine the compressive strength, carbonation, gas permeability of SCC made using FA and GGBFS by Shi Hui-sheng et. al., [27] and relationships between them were examined. The results of the tests showed that water–binder (w/b) ratios have a big effect on how FA with up to 60% replacement affected on different properties. However, the higher w/b ratios used in the tests did not improve any of the examined properties, including compressive strength, gas permeability in HPC. These qualities are highly dependent on w/b ratios and the types of admixtures used. According to the aforementioned literature review, significant study has been done on the creation of self-compacting concrete. Many of the self-compacting concrete mix designed at present contains higher fine contents which will have its own disadvantages and also proves to be uneconomical. In this direction there is a necessity of development of low fines self-compacting concrete for day-to-day applications in construction industry. Development of low fines self-compacting concrete is possible at present by using PCE. With an innovation of low fines SSC, it is possible to develop concretes in the grades of 20 to 30 MPa. Therefore, enough literature is not available at present on low fines self-compacting concrete hence further investigation is necessary.

III.METHODOLOGY

MATERIALS USED

The Portland cement grade 43 with a specific gravity of 3.15 was used in the experimentation work as per IS: 8112:2013[15]. Locally available artificial sand (M-sand) was used with specific gravity of 2.60 as per IS: 383-2002 [16]. Aggregate material composed of crushed stone with a maximum particle size of 12.5 mm and specific gravity of 2.74 as per IS: 383-1970 [17] was obtained from a local quarry. Class F fly ash was Pozzocreat 60 with a specific gravity of 2.2 and a colour of Light Gray. Ground Granulated Blast Furnace Slag (GGBS) with a specific gravity of 2.32 and an off white colour was used. The super plasticizer used is Poly-carboxylate Ether (PCE) Master Glenium Sky 8654.

PREPARATION OF MIXER

The characteristics strength considered is M20. The mix proportions are arrived as per the mix design IS:10262-2019 [18]. A total eighteen concrete mixes were designed in three groups. First group made with various percentage of replacement of fly ash as 0%, 10%, 20%, 30%, 40%, 50% by weight of total powder content. Second group made with various percentage of replacement of GGBS as 0%, 10%, 20%, 30%, 40% and 50% by weight of total powder content. In the third group, different amounts of Fly ash and GGBS were substituted, including 5% FA+5% GGBS, 10% FA+10% GGBS, 15% FA+15% GGBS, 20% FA+20% GGBS, and 25% FA+25% GGBS by weight of the total powder content. The total amount of powder in the mixture was 375 kg/m³ (in all mixes). The coarse aggregate in the total volume of concrete was kept constant at 966.66 kg/m³ and the fine aggregate content in concrete was maintained by volume (633 kg/m³ to 857.34 kg/m³) the w/p ratio was kept at 0.80 to 1.03. Water content of 180 kg/m³ along with a mix containing super plasticizer at 1% by mass of cementations materials.

CASTING OF SPECIMENS

The necessary material quantities were weighed in order to determine the mix proportions. Cement and fly ash have been blended separately in dry form, as well as coarse and fine aggregates, and afterwards mixed together in a blender to achieve a uniform mixture after adding the water. The fresh property tests, the casting begins immediately after the mixing. After 24 hours, the samples were taken out of the moulds and put in water for curing. The strength properties are evaluated as per the IS specifications at the age of 7days, 28days and 90days.

FRESH CONCRETE TEST

In order to assess the results of FA, GGBS and combination FA+GGBS on properties of LFSCC in fresh state the various fresh flow properties like Slump flow, V-funnel flow, J-ring flow, and L-box tests were conducted in accordance with EFNARC criteria [19]. In the present investigation, the LFSCC mixtures were created with all mineral admixture combinations and are designed to have slump flow values between 660 and 750 mm. To evaluate SCC's viscosity, V-funnel timings are taken into consideration. The L-box test is used to evaluate SCC's capacity to travel through constricted or reinforced regions without blockage or segregation.

STRENGTH PROPERTIES

Following are the strength properties evaluated for hardened concrete – Compressive strengths were measured at 7 days, 28 days, and 90 days of age as per IS No. 516:1959 [20]. The flexural strength test was conducted at 7 days and 28 days of age as per IS No. 516:2002 [21]. Ages of 7 days and 28 days were used to determine the splitting tensile strength as per IS No. 5816:1999 [22].

IV. DISCUSSION OF FINDINGS

THE IMPACT OF FLY-ASH

The slump flow measures the average diameter of concrete after the release of a conventional slump cone in two perpendicular directions. According to the slump flow test findings, all SCC mixtures displayed adequate slump flows in the range of 690–750 mm, indicating good flowability, as illustrated in Figures 1 to 4.

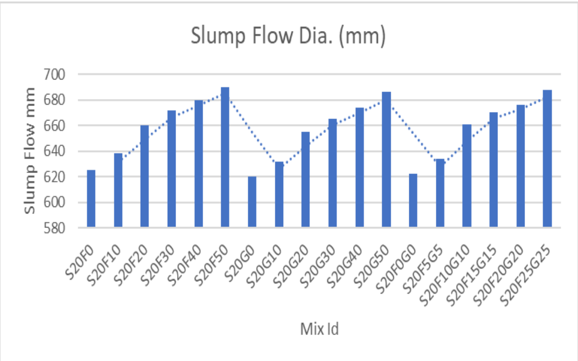

Fig.1 Slump Values of SCC Mix

LFSCC mixes with without FA indicated slump flow of 625mm. When percentage of FA increased from 10% to 50% the slump value varied from 638mm to 690mm for the same super-plasticizer content. The V-funnel flow time decreased from 15sec to 12.5sec, when replacements of percentage of fly ash from 10 to 50%. This indicates higher passing ability with higher percentage by fly ash. The results of J-ring test indicate 586mm to 623mm. In this case also higher flowability was observed with increasing fly ash content. In case of L-Box test, H2/H1 ratio was improved from 0.84 to 0.93 with increase in FA from 10% to 50%. This may be due fact that the surface area is decreased by the spherical geometry. Also, FA can disperse accumulation of cement particles which may cause higher flowability [7]. Also, compared to the other mineral additives, the FA particles were bigger and more spherical, which made the surface area smaller. Also, replacing some of the cement with FA increases the volume of the paste because density of FA is less than cement.

EFFECT OF GGBS

It is observed that the accumulation of GGBS has improved the fresh flow properties of LFSCC. Slump flow value increased from 632mm to 686mm when cement was replaced by 10% to 50% of GGBS as shown in Fig. 1 to 4. In case of V-funnel test, LFSCC mix with replacement of 50% GGBS the observed time is 11.8 sec and indicates higher passing ability as seen in Fig. 2. The results of J-ring test indicate 584mm to 620mm in this case also. Higher flowability was observed with increasing in GGBS content. In case of L-Box test blocking relation H2/H1 was improved from 0.82 to 0.92 with increase in GGBS percentage from 10% to 50%. The main reason which can be attributed for this is, in the initial stages water required for the GGBS is very low and more water content is available which improves workability.

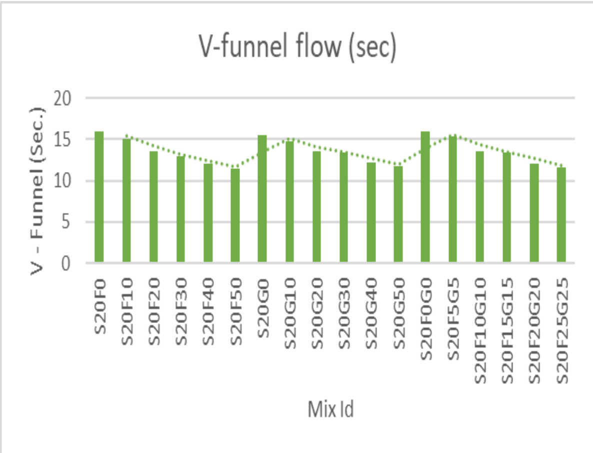

Fig.2 V-Funnel Flow Test

The surface area of the GGBS is glassy surface and its water absorption is minimum. Therefore, for the same water content more water available for workability purpose. Because of the bigger fineness and shape of GGBS particles it exhibits greater mobility. This might be the reason for the rise in slump flow and reduction in V-funnel time. Because of the increase in the mobility the observed flow in the L-box test is higher and hence decreases in H2/H1 ratio.

EFFECT OF COMBINATION OF FLY ASH V/S GBBS

In this case, it is observed that as proportion of combination of Fly Ash & GGBS increases, all the flow parameters increase. It has seen that, combined effect of combination of Fly Ash & GGBS plays better role in fresh flow state. In case of slump flow test, observations indicate that all SCC combinations demonstrated adequate slump flows in the range of 622–688 mm, indicating good flowability as shown in Fig.1 to 4. For V-funnel test, flow time decreased from 15.3sec to 11.6sec, when replacements of percentage of combination of fly ash and GGBS from 10 to 50%. The results of J-ring test, it indicates that the flow value ranges from 557mm to 623mm.

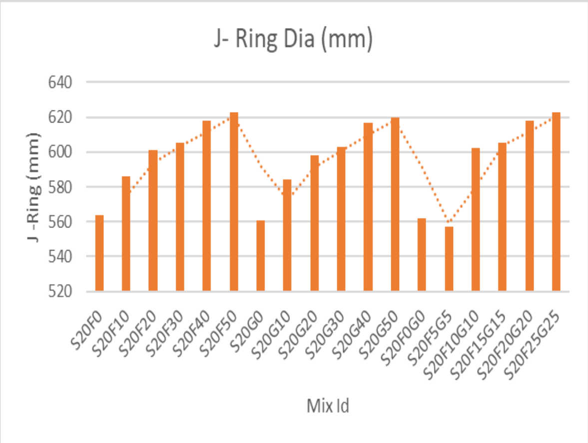

Fig. 3. J-Ring Test

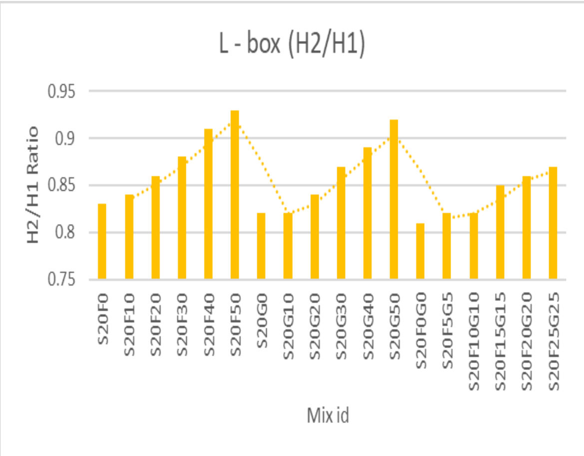

Fig. 4. L-Ring Test

In this case also higher flow ability was observed in increasing combination of fly ash and GGBS content. In case of L-Box test, blocking proportion H2/H1 was observed as 0.87 in case of replacement of 25%FA+25%GGBS. The reason is combined surface area of mineral admixtures reduces flow resistance & which will improve the workability.

EFFECT OF COMPRESSIVE STRENGTH

The compressive strength at 7 days, 28 days and 90 days curing were evaluated for all the mixes so as per IS specifications. The results of compressive strength of all mixes.

From the test results, the target strength of 20MPa and more was achieved in all mix proportions. When cement was replaced by fly ash in a range from 10 to 50%, the compressive strength went up to 30%, which is 22.9% more than it was in the reference mix (without any fly ash). After that, it was observed that compressive strength decreased as fly ash content increased. Similar observation was made by Lachmi (23) and obtained highest strength value at 40% replacement of FA in his studies. This is mainly because, up to 30% of replacement, the FA gets involved in secondary hydration process and contributes for the higher strength. After optimum value of 30% replacement, the strength gain was not significant and excess of Fly Ash (required more than that for secondary hydration process) acted as a just filler material. From the compressive strength results (Fig. 5, 6, 7), all compressive strengths have been found to rise with age of concrete. Similar observation was made by Khayat (28) when tested up to the 90 days curing.

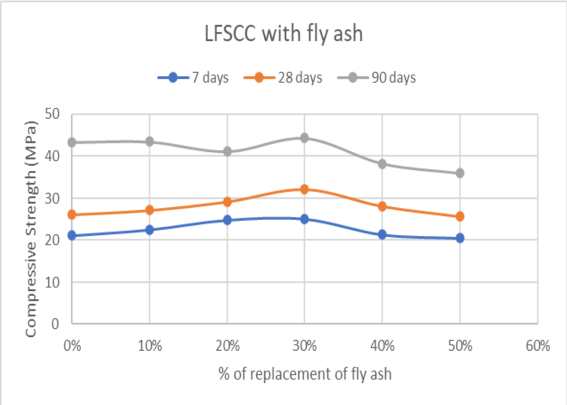

Fig. 5. Outcome of fly ash on compressive strengths of the hardened LFSCC

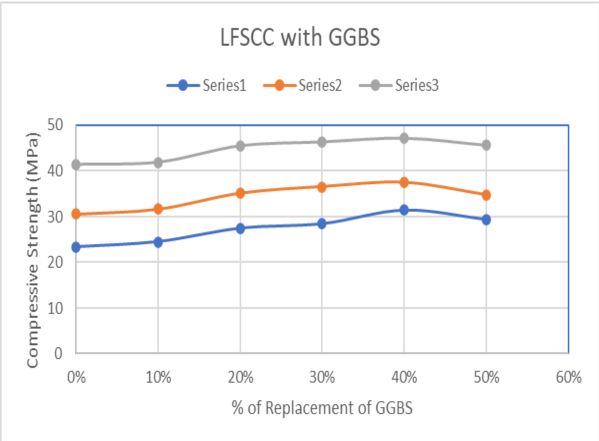

Fig. 6. Outcome of GGBS on compressive strengths of the hardened LFSCC

There was an enhancement of compressive up to 40% with replacement of cement by GGBS in the range of 10% to 50%, which is 22.51% higher in comparison to the reference mix. After that, it was discovered that a higher GGBS content led to a lower compressive strength. Increasing compressive strength is mainly attributed for strength contribution by GGBS due to supplementary hydration. Also, because the particles are smaller, they fit together better, making the paste denser. With the better particle filling with GGBS results in lesser voids and enhancement of the strength. However, one of the difficulties with GGBS is its slow gain in strength which requires longer curing.

In the case of replacing cement with a mixture of fly ash and GGBS in the range of 10% to 50%, there was an enhancement of compressive strength up to 20% replacement (10% Fly ash +10% GGBS) which is 19.72% higher as compared to reference mix. After that the compressive strength found to decrease with increase in combination of Fly ash and GGBS content. It was detected that compressive strength is in decreasing order due resulting in lesser bonding strength.

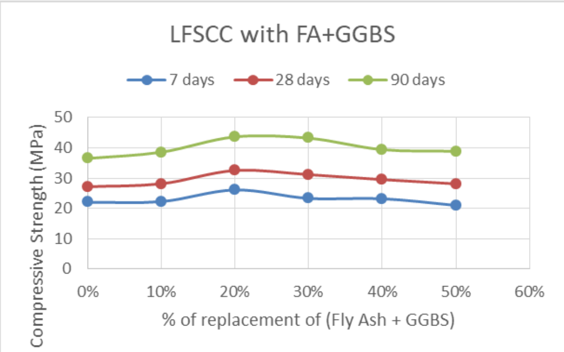

Fig. 7. Outcome of (fly ash + GGBS) on compressive strengths of the hardened LFSCC

From the compressive strength results (Fig. 5, 6, 7), it is detected that strength under compressive values increase with increasing age, and similar observation were made by Khayat [28] when tested up to the 90 days curing. It is also noticed that when the percentage replacement of fly ash increases, the strength values increase up to 30 percent of FA.

At higher values of replacement by fly ash, the strength values found to decrease. This may be attributed to fact that, up to 30% replacement the fly ash might have participated in pozzolanic action and at higher replacement it might have acted as just filler material. Similar observation made by Lachmi (23) and obtained highest strength value at 40% replacement in his studies.

SPLITTING TENSILE STRENGTH

The splitting tensile strength test results of LFSCC are listed and shown in Figs. 8, 9 and 10. It is noted that the splitting tensile strength of all LFSCC mixtures increases as the age of curing increases.

This may be owing to the fact that at greater volume of fly ash the bond strength becomes weak and hence decreases the tensile strength. Similar observations were made with when cement was replaced by GGBS and combination FA+GGBS.

Fig. 8. Splitting tensile strengths of LFSCC with FA

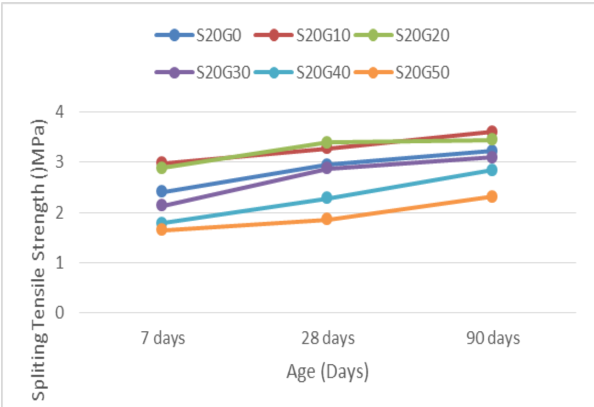

Fig. 9. Splitting tensile strengths of LFSCC with GGBS

However, in contradiction to compressive strength there is a decreasing in tensile strength with increasing percentage of fly ash similar observations were made by Rafat Siddique [24]. This may be owing to the fact that at greater volume of fly ash the bond strength becomes weak and hence decreases the tensile strength. Similar observations were made with when cement was replaced by GGBS and combination FA+GGBS.

However, in all situations, the split tensile strength is found to decrease as the % substitution of fly ash increases. In comparison to reference mix the decreasing split tensile strength is about 12% with 30% replacement of FA. The outcomes of the flexural strength tests conducted on LFSCC combinations are presented , and the variation of the results are shown in Fig. 9.

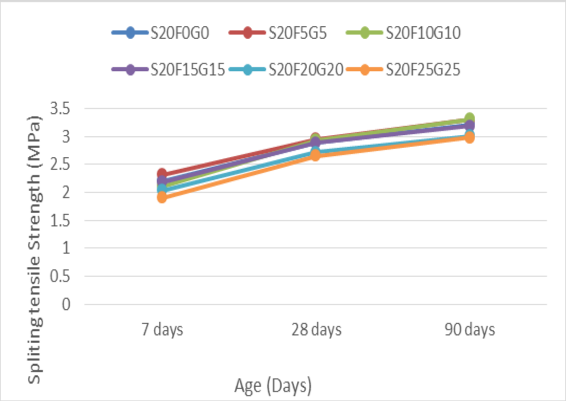

Fig. 10. Splitting tensile strengths of LFSCC with combination of FA+GGBS

When cement was replaced with mineral admixtures, all Flexural strength of LFSCC was found to decrease when compared to the reference mix (i.e. without mineral admixtures). Also, flexural strength decreased with increasing percentage replacement. The maximum flexural strength of 5.21MPa to 6.18MPa at 28days and 90days respectively was found with 10% replacement of cement by GGBS. However, all the flexural strengths was found to decreased with increasing all mineral admixtures FA, GGBS and combination of FA+GGBS contents. Similar observation was made by Mostafa Jalal in case FA replacement [6].

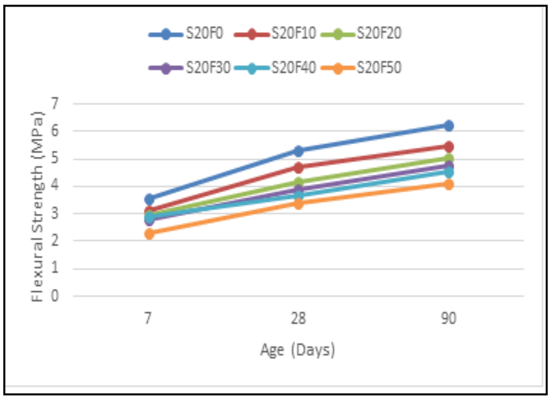

Fig. 11. Flexural Strengths of LFSCC

V.CONCLUSION

There is a necessity of developing low grade, economical self-compacting concrete which can be achieved by restricting powder content with optimum PCE. For everyday concrete applications, fly ash, GGBS, combinations of both fly ash and GGBS can be utilized as cement substitute materials to provide all self-compacting qualities with a lower strength. From the present study the LFSCC designed for target strength of 20 MPa satisfied all EFNARC specification in fresh state for all mixes. It was discovered that an increase in the percentage of cement replaced by FA, GGBS, or FA+GGBS led to an improvement in all of the fresh flow parameters. With the replacement of mineral admixtures, the compressive strength of LFSCC increased at a longer curing period (90 days) with a greater mineral content. FA, GGBS, and FA+GGBS all resulted in an increase in compressive strength when used to replace 30% to 40% of the cement. In general, it seems that up to 30% replacement of cement by fly ash and GGBS can yield economic efficient and ergonomic concrete with self-compacting properties. There was an increase in splitting tensile strength and flexural strength as the cure period increased. However, split tensile strength and flexural strength decreased as FA, GGBS, and FA+GGBS replacement increases.

Acknowledgements

The authors grateful to all staffs with interaction to my research articles and supported supervisor.

REFERENCES

[1]. Hajime Okamura, Masahiro Ouchi, *“Self-Compacting Concrete”*, Journal of Advanced Concrete Technology, Vol. 1, No. 1, April 2003, pp-5–15.
[2]. Seow Kiat Huat, Nilotpol Kar, Feng Qiuling, “The Asian Experience in Low Fines Self Consolidating Concrete (SCC) in Everyday Applications”, 36th Conference on our world

in Concrete & Structures, Singapore, 14-16 August 2011.

[3]. Naik TR, Kumar R, Ramme BW, Canpolat F, "Development of High-Strength Economical Self-Consolidating Concrete" Construction Building Mater 2012, Volume -30, pp-463–469.

[4]. Nilotpol Kar and David Firth, "Smart Dynamic Concrete – Economic, Ecological and Ergonomic" Proceeding of conference on IQA-CC Construction Materials Industry Conference, CMIC12, Melbourne, Victoria,19-22 Sept. 2012.

[5]. Pelisser, Fernando, Alexandre Vieira, and Adriano Michael. "Ef Fi Cient Self-Compacting Concrete with Low Cement Consumption" Journal of Cleaner Production 175: 324–32. https://doi.org/10.1016/j.jclepro.2017.12.084.

[6]. Şahmaran, Mustafa, Heru Ari Christianto, and Ismail Özgür Yaman, "The Effect of Chemical Admixtures and Mineral Additives on the Properties of Self-Compacting Mortars." CementandConcreteComposites28(5):432–40.

[7]. Uysal, Mucteba, and Mansur Sumer, "Performance of Self-Compacting Concrete Containing Different Mineral Admixtures." Construction and Building Materials 25 (11): 4112–20.https://doi.org/10.1016/j.conbuildmat. 2011.04.032.

[8]. McCarthy, M. J., and R. K. Dhir, "Development of High-Volume Fly Ash Cements for Use in Concrete Construction." Fuel 84 (11): 1423–32. https://doi.org/10.1016/j.fuel. 2004. 08.029.

[9]. Pathak, Neelam, and Rafat Siddique, "Properties of Self-Compacting-Concrete Containing Fly Ash Subjected to Elevated Temperatures." Construction and Building Materials 30: 274–80. https://doi.org/10.1016/j.conbuildmat. 2011.11.010.

[10]. Jalal, Mostafa, Alireza Pouladkhan, Omid Fasihi Harandi, and Davoud Jafari, "Comparative Study on Effects of Class F Fly Ash, Nano Silica and Silica Fume on Properties of High-Performance Self Compacting Concrete" Construction and Building Materials,90–104. https://doi.org/10.1016/j.conbuildmat.2015.07.001.

[11]. Bruno D'Souza, Hironobu Yamamiya, "Applications of Smart Dynamic Concrete" Proceeding ,International Conference on Sustainable Construction Materials and Technologies, 18 – 21 August 2013, Kyoto Research Park, Kyoto, Japan, pp-1-7.

[12]. Khatib, J. M. "Performance of self-compacting concrete containing fly ash" Construction and building materials 22.9 (2008): 1963-1971.

[13]. Krishna Murthy N, Narasimha Rao A V, Ramana Reddy I. Vand, Vijayasekhar Reddy M., "Mix Design Procedure for Self Compacting Concrete", IOSR Journal of Engineering (IOSRJEN),Volume 2, Issue 9, September 2012, pp-33-41.

[14]. P. Dinakar, M. Kartik Reddy, Mudit Sharma "Behavior of self-compacting concrete using Portland pozzolana cement with different levels of fly ash" Materials and Design 43 (2013) 161–169.

[15]. IS:8112-2013 "Indian Standard Recommended Specification for 43 grade ordinary Portland cement"

[16]. IS:383-2002, "Indian Standard specification for coarse and fine aggregates from natural sources for concrete"

[17]. IS:383-1970, "Indian Standard specification for coarse and fine aggregates from natural sources for concrete"

[18]. IS 10262-2019, "Indian Standard Recommended Guidelines for Concrete Mix Design, Bureau of Indian Standards, New Delhi, 1989.

[19]. IS: 516-1959. Methods of tests for strength of concrete. New Delhi (India): Bureau of Indian Standards.

[20]. IS: 516-2002, Flexural strength of concrete method of test. Bureau of Indian Standards, New Delhi, India.

[21]. IS: 5816-1999, Splitting tensile strength of concrete method of test. Bureau of Indian Standards, New Delhi, India.

[22]. Lachemi M, Hossain KMA, Lambros V, Bouzoubaa N. "Development of cost effective self-consolidating concrete incorporating fly ash, slag cement, or viscosity-modifying admixtures". ACI Mater J 2003;100(5):419–25.

[23]. Rafat Siddique "Properties of self-compacting concrete containing class F fly ash" Materials and Design 32 (2011) 1501–1507.

[24]. Ashish, Deepankar Kumar, and Surender Kumar Verma "An Overview on Mixture Design of Self-Compacting Concrete" Structural Concrete 20 (1): 2019,371–95. https://doi.org/10.1002/suco.201700279.

[25]. Xie Y, Liu B, Yin J, Zhou S. "Optimum mix parameters of high–strength selfcompacting concrete with ultrapulverised fly ash" Cem Concr Res 2002;32(3):477–80.

[26]. Hui-sheng, Shi, Xu Bi-wan, and Zhou Xiao-chen, "Influence of Mineral Admixtures on Compressive Strength , Gas Permeability and Carbonation of High Performance Concrete" Constructionzand Building Materials 23 (5): 1980–85. https://doi.org/10.1016/ j.conbuildmat.2008.08.021.

[27]. Khayat KH, Bickley J, Lessard M. "Performance of self-consolidating concrete for casting basement and foundation walls" ACI Mater J 2000;97(5):374–80.

[28]. Fernando Pelisser, Alexandre Vieira, Adriano Michael Bernardin. "Efficient self-compacting concrete with low cement consumption" Journal of Cleaner Production 175 (2018) 324-332.

[29]. Shi Hui-sheng, Xu Bi-wan, Zhou Xiao-chen. "Influence of mineral admixtures on compressive strength, gas permeability and carbonation of high performance concrete" Construction and Building Materials 23 (2009) 1980–1985.