International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 03 - Issue 07 || July 2018 || PP. 57-62

Performance of Ternary Blended Concrete Exposed to High Temperatures

Poornachand Pamu[1], Kasi Rekha[2]
[1]*(Post Graduate Student, Department of Civil Engineering, VITAM College of Engineering Visakhapatnam, Andhra Pradesh, India)*
[2]*(Asst. Professor, Department of Civil Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia)*

Abstract: The objective of this paper is to study the behavior of two types of ternary blended concretes after subjecting to elevated temperatures. Ternary concrete mix 1consists of Portland cement (65%) + fly ash (30%) + silica fume (5%) and mix 2 consist Portland cement (65%) + GGBS (30%) + silica fume (5%). The final mix adopted was 1:1.93:3.39 with w/b ratio 0.42 to achieve the M30 grade concrete. The mechanical properties of ternary blended concrete at 7 and 28 days were measured and compared with normal concrete after exposing to temperatures between 100 and 800^oC at an interval of 100^oC. The specimens were tested after 3 hours of exposure for its mechanical properties by cooling them to room temperature. The results showed that the ternary blended concrete have better resistance to elevated temperature compared to normal concrete.

Keywords: Ternary blended concrete, elevated temperature, fly ash, ggbs, silica fume, mechanical properties, weight loss.

1. INTRODUCTION

Concrete is the most popular artificial construction material on the earth. Cement plays a major role of binding in concrete. Every one ton of cement production is producing one ton of CO_2 into atmosphere and hence there a need to reduce the usage of cement in construction industry. The usage of supplementary cementetious material such as silica fume, fly ash, ground granulated blast furnace slag, rice husk ash etc. may give solution for reducing the usage of cement. These are the by-products of industry, which may cause environmental threat on disposal as land-fills.

Besides, the concrete may be exposed to high temperatures during accidental building fire, an operating furnace or nuclear reactor. The behavior of concrete exposed to elevated temperatures causes physical changes, includes large volume changes due to thermal dilations, thermal shrinkage and creep related to water loss[1]. The volume changes can results in large internal stress and lead to micro cracking and fracture[2].

Hence the present study aimed to study the behavior of ternary concrete after exposing to elevated temperatures. The fly ash and silica fume are used to partially replace the ordinary Portland cement at different percentages.

The objective of this paper is to study and compare the weight loss and compressive strength of ternary blended concrete with normal concrete, after subjected to elevated temperatures.

2. LITERATURE REVIEW

Deepa A Sinha et al [3], studied the effect of ternary blends on the strength and workability characteristics of concrete. The cement was partially replaced with fly ash (FA), silica fume (SF), ggbs, and metakaolin (MK) with different combinations. The authors tested the combinations such as (FA+SF), (FA+GGBS) and (FA+MK) are (25+5), (20+10) and (15+15) and also studied the combinations of (FA+SF), (FA+GGBFS) and (FA+MK) at (10+20), (5+25) and (0+30).The compressive strength and flexure strength of the above mixes at 7,28 and 90 days curing periods were determined. The authors concluded that Silica fume gives highest Strength in Flexure after 28 and 90 days. Up to 30% replacement of cement with fly ash can give higher strength than normal concrete at 28 & 60 days. Replacing levels of cement with 15% FA +15%MK, 10%FA + 20% SF, 10% FA + 20% GGBS performed better than the reference mix for 28 & 90 days.

Khatib.J.M et al [4], conducted research on the influence of partial replacement of GGBS and Metakaolin on concrete. The portland cement was partially replaced with 0-80% of GGBS and 0-20% of MK with fixed water binder ratio 0.50 for all mixes. In mixes M1, M2, M3 and M4 portland cement was partially replaced with 0%, 40%, 60% and 80% GGBS (by mass), respectively, and no MK was included. On the other hand, in mixes M5, M6, M7 and M8, the cement was partially replaced with respectively 0%, 30%, 50% and 70% GGBS and 10% MK. In mixes M9, M10, M11 and M12, the cement was partially replaced with 0%, 20%, 40% and 60% GGBS and also contained 20% MK. The results showed that GGBS up to 60% and MK up to

20% replacement to cement increase the compressive, flexural strength and young's modulus at early age of hydration.

Mohamed Heikal et al [5], studied the effect of substitution of silica fume (SF) and fly ash (FA) on the behavior of Cement pastes exposed to elevated temperatures. Composite Cement were exposed to temperature at 250ºC, 450ºC, 600ºC and 800ºC for 3 hours. The physical – mechanical characteristics like porosity, bulk density, compressive strength were determined at all temperatures were investigated. The authors concluded that the composite cement paste made from 10% of silica fume and 10% fly ash have good fire resistance than the normal concrete.

Balakrishnaiah D et al [6], examined the residual compressive strength of ternary blended concrete consists of ordinary Portland cement (OPC), fly ash and silica fume. The OPC was partially replaced by 15% fly ash (FA) and 5% silica fume (SF) with water binder ratios of 0.55, 0.45 and 0.35. The specimens were subjected to elevated temperatures 200°C, 400°C and 600°C for 4, 8 and 12 hrs duration. After heating of the samples in the furnace, the samples were allowed cool to room temperature and then tested for compressive strength. The authors concluded that a gradual reduction in compressive strength was found with increase in temperature from 200°C to 600°C for exposure duration of 4 hours. The percentage decrease in weight loss is higher for higher exposure time and the loss of weight is less for lower w/b ratios. The ternary blended concrete has shown improved resistance for higher temperature for lower water/binder ratios.

3. MATERIALS

3.1. CEMENT : Ordinary Portland cement (OPC) of 53grade confirming to IS: 12269-1989 [7] is used in the present study.

3.2. FLY ASH: Class F fly ash was used in experimental work and the specific gravity of fly ash is found to be 2.1. The particles are in the form of solid spheres with sizes ranging from less than 1 µ to 100 µ and an average diameter of 20 µ.

3.3. SILICA FUME: The specific gravity of fly ash is found to be 2.2. SF particles are very fine with particle sizes about hundred times smaller than that of average size of OPC particles.

3.4. GGBS: The specific gravity of GGBS is found to be 2.2.The particle sizes are less than 45 µ.

3.5. SAND: The locally available river sand conforming to zone-II of IS 383-1970 [8] has been used as fine aggregate. The fine aggregate are clean, inert and free from organic matter, silt and clay. The fineness modulus is 2.69, specific gravity is 2.62 and the water absorption is 0.4% for the sand used throughout the investigation.

3.6. COARSE AGGREGATE: Conventional coarse aggregate was used from an established quarry satisfying the requirement of IS 383:1970 [8]. The fineness modulus is 6.07 & 7.35, specific gravity is 2.76 & 2.64 and the water absorption is 0.4% and 0.5% respectively for 10mm and 20mm coarse Aggregate.

4. METHODOLOGY

I. An attempt is made in this paper to study the effect of high temperatures on a ternary blended concrete containing fly ash, silica fume and GGBS. The Concrete mix was designed for the granite aggregate in accordance with IS 10262-2009[9] for the grade of M30. Two different types of ternary blended concretes, such as mix1 : Portland cement (65%) + fly ash (30%) + silica fume (5%) and mix2 : Portland cement (65%) + GGBS (30%) + silica fume (5%) were cast, cured and tested for its compressive strength after exposing them to elevated temperatures between 100 and 800^{o}C for the duration of three hours. Fig. 1 shows the bogie hearth furnace for heating the specimen. The specimen will be taken out after exposing to different temperatures and tested for its mechanical properties after cooling them to room temperature.

II.

Figure 1: Cubes after Exposing to 800^{o}C in Bogie Hearth Furnace

5. MIX PROPORTIONS AND SPECIMEN CAST

Table 1 shows the mix proportions for different mixes used in this study. Normal concrete, mix 1 and mix 2 are designated as C100, C65F30S5 and C65G30S5 respectively. Table 2 shows the number of cubes casted for different temperature exposures.

Table 1: Mix Proportions of Different Mixes

	MixDesignation	Cement kg/m^3	Fly Ash kg/m^3	GGBS kg/m^3	Silica Fume kg/m^3	Sand kg/m^3	CoarseAggregate kg/m^3	w/b
1	C100	365	-	-	-	704	1237	0.42
2	C65F30S5	255.5	109.5	-	18.25	689	1210	0.42
3	C65G30S5	255.5		109.5	18.25	708	1219	0.42

Table 2: Number of cubes cast for different temperature exposures

Mix Designation	27^{o}C	200^{o}C	400^{o}C	600^{o}C	800^{o}C
C100	6	6	6	6	6
C65F30S5	6	6	6	6	6
C65G30S5	6	6	6	6	6

6. RESULTS AND DISCUSSIONS

6.1. WEIGHT LOSS

Fig. 2 shows the comparative analysis of percentage weight loss of different mixes at various temperatures. The weight loss expressed as the percentage of weights of each concrete exposed to different temperatures to the weight of respective concrete at room temperature. The weight loss increased with the increase in temperature. From Fig. 2, it can be observed that Mix 1 i.e. C100 concrete exhibited higher loss of weight compared to ternary mixes C65F30S5 and C65G30S5. The weight loss in Mix 2, i.e., C65F30S5 is less. Hence, from the results it can be concluded that the weight loss in fly ash mixed ternary concrete is less when compared to the remaining mixes. This lower weight loss in fly ash mix concrete may attributed to good bond.

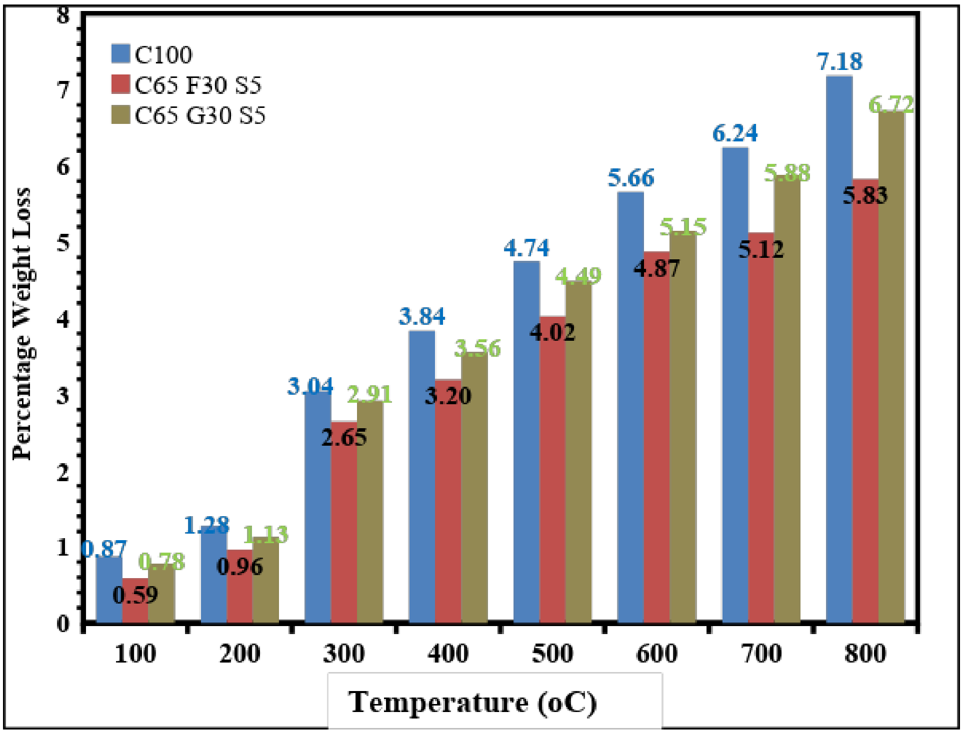
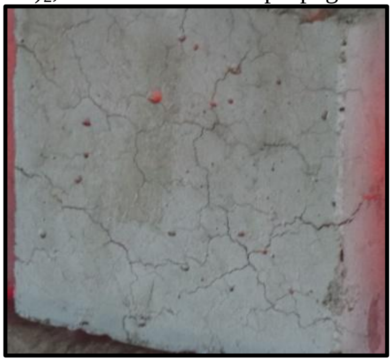


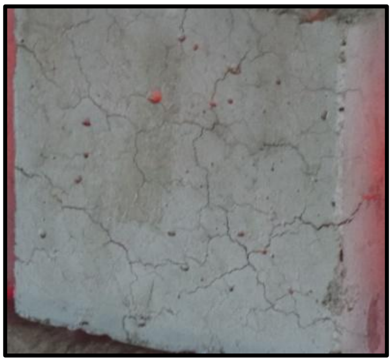
Figure 2: Comparison of Percentage Weight Loss for Different Mixes at various temperatures

6.2. SURFACE CRACKS

Fig. 4 shows the cracks appeared on the surface of the different concrete mixes at 800^{o}C. No cracks were visible on any mix for temperatures up to 600°C. All the mixes showed prominent cracks at 800ºC. C100 concrete showed prominent and prolonged cracks when compared to the other mixes. Mix 2, i.e, C65F30S5 showed comparatively less surface cracks. The less cracks in C65F30S5 concrete may be because of the reduction of Ca $(OH)_2$, which reduces the propagation of cracks.



C100



C65F30S5

C65G30S5

Figure 4: Surface Cracks on Different Mixes at 800^{o}C

6.3. RESIDUAL COMPRESSIVE STRENGTH

Fig. 3 shows the percent residual compressive strength of different mixes. The residual compressive strength increased up to 200ºC and there after it reduced with the increase in temperature. The increase in compressive strength at 100 and 200ºC in all mixes may be because of accelerated hydration. From 200 to 300ºC, all the mixes exhibited a gradual fall and is ranging between 28 to 32%. All the mixes lost almost 50% strength at 400ºC and around 80% strength at 800ºC. From Fig. 3, it can be concluded that the both ternary mixes, i.e; C65F30S5 and C65G30S5 performed well at high temperatures by showing higher residual compressive strength at every temperature. The additional cementitious materials formed due to secondary hydration reaction could be the reason for the higher bond strength in ternary concretes. It can further be concluded that the behavior of mix 2 i.e; C65F30S5, is better than the other two mixes at every temperatures. The higher residual strength in mix 2 may because of good bond between the aggregate.

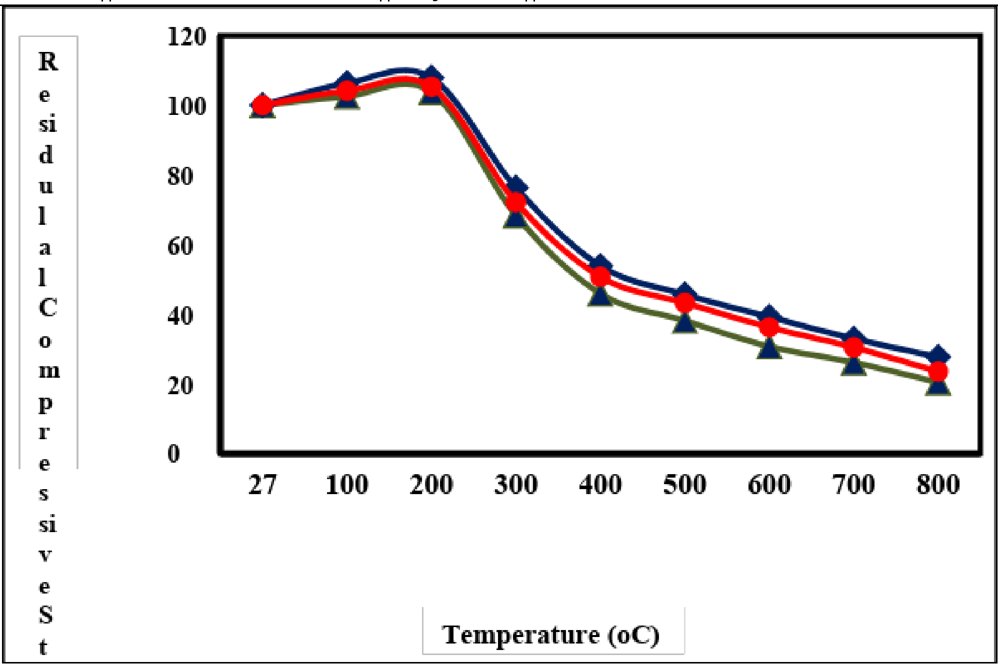


Figure 3: Percentage Residual Compressive Strength of Different Mixes at different temperatures

7. CONCLUSIONS

- The percentage weight loss increased with increase in temperature for all the mixes. Mix2, i.e, C65F30S5 exhibited a lower percentage weight loss when compared to the other mixes. This lower weight loss is may be due to the presence of fly ash.
- The surface cracks in C65F30S5 were less compared to the other two mixes which is because of the presence oflower $Ca(OH)_2$.
- The residual compressive strength of ternary mixes showed higher residual compressive strength than the normal concrete (C100) at all temperatures.
- The residual compressive strength of all the mixes exhibited a rising to falling trend at the temperature of 200^oC. Beyond 200^oC, all the concretes exhibited falling trend.
- The Mix2, i.e, C65F30S5, exhibited higher percentage residual compressive strength than the other mixes at every temperature.
- The behaviour of Mix2, i.e, C65F30S5, is better when compared to the other mixes at high temperatures.

REFERENCES

[1] K.SrinivasaRao, M. PothaRaju, P.S.N.Raju, "A study on variation of compressive strength of high strength concrete at elevated temperatures", 29th Conference on Our World in Concrete & Structures: 25 - 26 August 2004.

[2] Sule E, Mohammed A. K, Sani R.O and Makwin. H.L, "The Effect of Metakaolin on Compressive Strength of Rice Husk Ash Concrete at Varying Temperatures"-Civil and Environmental Research-ISSN 2225-0514, Vol.6, No.5, 2014.

[3] Deepa A Sinha, "Comparative mechanical properties of different ternary blended concrete"- Indian Journal of Research, ISSN 2250-1991, and Vol: 1, October 2012.

[4] J.M. Khatib a, J.J. Hibbert, "Selected engineering properties of concrete incorporating slag and Metakaolin", Construction and Building Materials, VOL- 19 (2005), pp-460–472.

[5] Mohamed Heikal.H, El-Didamony,T.M, Sokkary, I.A.Ahmed, "Behavior of composite cement pastes containing micro silica and fly ash at elevated temperature" construction and building materials,Vol-38,pp-1180-1190.

[6] Balakrishnaiah. D, Dr. SrinivasaRao. P, Adinarayana. D, "Residual Compressive Strength of Ternary Blended Concrete at Elevated Temperatures"-International Journal of Engineering Research & Technology ISSN: 2278-0181, Vol-2 Issue 9, September – 2013.

[7] IS:12269 – 1989(reaffirmed in 1999), "Specifications for 53 Grade Ordinary Portland Cement", Bureau of Indian standards, New Delhi.

[8] IS: 383- 1970 (reaffirmed in 1997), "Specifications for Coarse and Fine Aggregate from Natural Sources for Concrete", Bureau of Indian standards, New Delhi.
[9] IS:10262-2009, " Recommended Guidelines for Concrete Mix Design", Bureau of Indian standards, New Delhi.
[10] IS 2386 (Part 1)-1963, " Specifications for Methods of Test for Aggregates For Concrete", Bureau of Indian Standards, New Delhi.
[11] IS 516-1959, "Method of Test for Strength of Concrete", Bureau of Indian Standards, New Delhi.
[12] ISO: 834-1975, "Fire Resistant Tests - Elements of Building", International Standards Organization, Geneva, Switzerland.

Author's Profile

Pamu Poornachand, obtained B. Tech from Nagarjuna University, Guntur. Presently he is pursuing M. Tech from Jawaharlal Nehru Technological University, Kakinada. He has a total 16years of experience in construction industry with different designations. His research interest includes usage of recycled materials in concrete, special concretes etc.

Kasi Rekha, obtained B. Tech from Jawaharlal Nehru Technological University, Andhra Pradesh in the branch of Civil Engineering. She obtained her Master's degree, M. Tech in Advanced Construction Technology from Pondicherry University and Ph. D in Structural Engineering from GITAM University. She has total 13 years of experience in teaching as Assistant Professor. Her research interest includes Recycled aggregate concrete, concrete at high temperatures, special concretes with industrial slags etc.