PHYSICAL PROPERTIES OF TERNARY BINDERS; ADDITION CEMENTITIOUS MATERIALS AND MIXING

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ABSTRACT. The aim of this research is to replace cement with cementitious material. With the increase in use of cement more amount of CO_2 emission is done in the environment. So to reduce this CO_2 emission supplementary cementations materials are used as replacement of cement because of their environmental benefits. The aim of this research is to replace cement with ground granulated blast furnace slag (GGBS) and Nano silica. The water cement ratio is kept at 0.35 and replacement of GGBS is 50%of the cement content while Nano silica is replaced at 1%, 2%, 3%, 4% & 5% and physical properties of that material is tested. Mainly the tests are consistency test, initial and final setting time test, water absorption test and soundness test. All those tests are done according to Indian standards and in standard conditions. Results of those tests show that replacement of the cementitious material changes the physical properties of concrete and makes concrete more viable. Also because of the use of the cementitious material the bonding between mixtures will change which will effectively change the physical properties of concrete.

Keywords Ordinary Portland cement; Ground granulated blast furnace slag; Nano silica; Consistency; initial and final setting time; soundness

INTRODUCTION

Setting properties of concrete is the most important part in the field of concrete construction [3]. It helps in the development of different kinds of concreting operations such as transporting, placing, compacting and finishing of concrete. Placement of concrete in formwork depends on the setting time of concrete, which makes the concrete rigid. Nowadays production of new generation concrete like geopolymer concrete, self-compacting concrete, high strength concrete, and high performance concrete has been increasing throughout the world. For their better performance and to achieve better engineering properties, mineral admixtures such as fly ash (FA), silica fume (SF), ground granulated blast furnace slag (GGBS), metakaolin (MK),Nano Silica(NS) and rice husk ash (RHA) are normally added as partial replacement of cement for the better performance of advanced concrete. Since the different mineral admixtures possess different chemical and mineralogical compositions as well as different particle characteristics, they could have different effects on the properties of concrete inclusive of the setting characteristics. Knowledge of the setting characteristics is important in the field of concrete construction. This will help in scheduling the various stages involved in concrete construction operation such as transporting, placing, compacting and finishing of concrete. Such information is necessary when deciding whether or not to use a retarding admixture or accelerator.

The hydration product formation starts immediately once the water is mixed within the cement. The initial and final setting time of concrete can be determined by the rigid behaviour of the matrix. The initial setting time of the concrete refers to the beginning of hardening of the mixture and the final setting time refers to the sufficient hardness of the concrete mixture [9]. Studies have reported that with increase in Silica content within the binder, setting time also increases [3]. A study shows [4] that setting time of ternary blended concrete made of NS and GGBS shows delayed initial setting time in the range of 60–120 min.

Utilization of Nano Silica with GGBS gives an interesting substitute. Much research has been conducted on ternary binder using a combination with NS and GGBS [2]. A study also investigated the utilization of Nano Silica/or ground granulated blast furnace slag (GGBs) with Nano Silica. Using the Ground granulated blast furnace slag in binder, the setting time can be slightly extended. The effect of GGBS is more pronounced at high level replacement in binders. An extended setting time is an advantage, as it makes concrete remain workable for a longer period of time, therefore resulting in fewer joints and it is extremely useful in warm weather.

NS have a very high surNSce area, due to very high fineness of NS, the effects on setting time is different as compared to Cement and GGBS. Although there is an increase in both initial and final setting times at low replacement levels of NS, binary effects of other mineral admixtures investigated with Nano Silica (NS) and ground granulated blast furnace slag (GGBS), show an increase in setting times with an increase in replacement level.

The present study findings revealed that the combined quaternary effect of NS and GGBS with the replacement of OPC was unusual. With an increase in percentage levels of NS and GGBS the initial and final setting time also increases, whereas, with an increase in percentage level of NS in ternary binders, there is a decrease in initial and final setting time. A study [7] reported that initial setting time that estimated the time limit to handle the concrete and final

setting time designates the onset improvement of strength. It was also, examined that setting time of concrete depends on water/binder ratio, initial and curing temperature, dosage, type of mineral admixtures and composition of cement [8]. Some researchers have found that with the increasing percentage level of NS and GGBS, the setting time of concrete decreases [2].Reverse effect has been investigated in case of silica fume. It was investigated that SF increases the setting time with the replacement level [1]. The objective of this study is to investigate the combined effects of mineral admixtures in ternary binders, to our knowledge no other author has identify the setting time effects in quaternary binders with the utilization of mineral admixtures.

MATERIALS AND ITS SPECIFICATIONS

In this study materials used are OPC (ordinary Portland cement) of 53 grade according to IS12269:2013, Ground Granulated Blast Furnace Slag (GGBS) and Nano silica (NS) having particle size 15±5. Nano silica has been replaced by 1%, 2%, 3%, 4% and 5% by weight of cement while GGBS is replaced by 50% of cementitious material. Chemical and microbiological characteristics of those are shown below. Physical and chemical properties of all those are shown in table-1. In the present study, Super Plasticizer (SP) of Carboxylic Ether (CONFLOW SNS 2, Essence Construction) with specific gravity 1.21 was used. It was used to decrease the water demand while improving the workability of all the concrete mixes. The Super plasticizer dosage was adjusted for each mix to ensure that no segregation would occur. Also, the gravel used in this project has size less than 600 micron and coarse aggregate is with size less than 12.5mm according to ASTM.

Table 1 Chemical and mineralogical properties

Description	Water	OPC	GGBS	NS
Physical Characteristics				
Specific Gravity	1	3.15	3.14	2.4
Blaine's Fineness,cm^2/gm	-	2285	3250	1000000
Chemical characteristics				
Calcium oxide, Cao %	-	66.73	35.9	
Silicon dioxide, SiO_2 %	-	17.54	40.65	
Aluminum oxide, Al_2O_3 %	-	9.82	17.07	
Ferric oxide, Fe2O3, %	-	2.19	0.68	
Manganese oxide, MnO, %	-	0.02	0.03	
Magnesium oxide, MgO %	-	1.24	3.75	
Potassium oxide, K_2O%	-	0.48	0.56	
Sodium oxide, Na_2O%	-	0.22	0.19	
Loss of ignition %	-	0.9	0.08	

PREPARATION OF SPECIMEN

For the determination of initial and setting time of the cement, nano silica and GGBS mixture vicat apparatus was used and it was placed in mould according to IS 4031 Part -4 (IS 4031 Part 4). Mix proposition are given in the below table 1 and according to that we have taken out the initial and final setting time. Then the mix proportion is compared with the value in which only cement and 50%cement and 50% GGBS is used. The standard consistency is determined by adding different percentage of water content at different at different level till the mixture has certain amount of resistance.

Table 2. Percentage of Ingredients

					Kg/m^3			
Series	Nano Silica (%)	Cement	GGBS	Nano Silica	Coarse Aggregate	Fine Aggregate	Water	Super plasticizer
C	0	594	0	0	755.5	807.5	208	8.07
G	0	297	297	0	755.5	807.5	208	8.07
N1	1	291.06	297	5.94	755.5	807.5	208	8.07
N2	2	285.12	297	11.88	755.5	807.5	208	8.07
N3	3	279.18	297	17.82	755.5	807.5	208	8.57
N4	4	273.24	297	23.76	755.5	807.5	208	8.57
N5	5	267.3	297	29.7	755.5	807.5	208	8.98

Vicat apparatus was used to determine the consistency of different pastes. The test was done by taking different percentage of water in the cement, GGBS and Nano silica mixture. In this mixture the plunger of the apparatus is penetrated in mixture 5 to 7 mm above the bottom of the mould. Consistency was taken by taking and average of the three moulds. This test was done according to IS 4031(Part-4).

After the determination of consistency initial and final setting time of the mixture was determined. Initial setting time of was recorded as per IS 4031 Part-5. A needle of 1mm square is used to penetrate into the paste every 10 minute until the needle shows 5+0.5mm penetration in the mould. For determining final setting time the needle of vicat apparatus was replace with the needle of an annular attachment. The needle I released at every 30 minutes and when the needle makes an impression on the test block. The period between adding water in the paste to needle makes an impression on it is known as final setting time of paste. Averages of three tests are taken as initial and final setting time.

After determining initial and final setting time soundness of cement was carried out. Soundness of cement was carried out as per IS 4031 Part-3. In this test the mould is prepared and initially distance between them is measured. After that the mould is kept in boiling water

for 3 hours and distance between them is measured and from that soundness of cement is taken out.

RESULTS AND DISCUSSION

Standard consistency

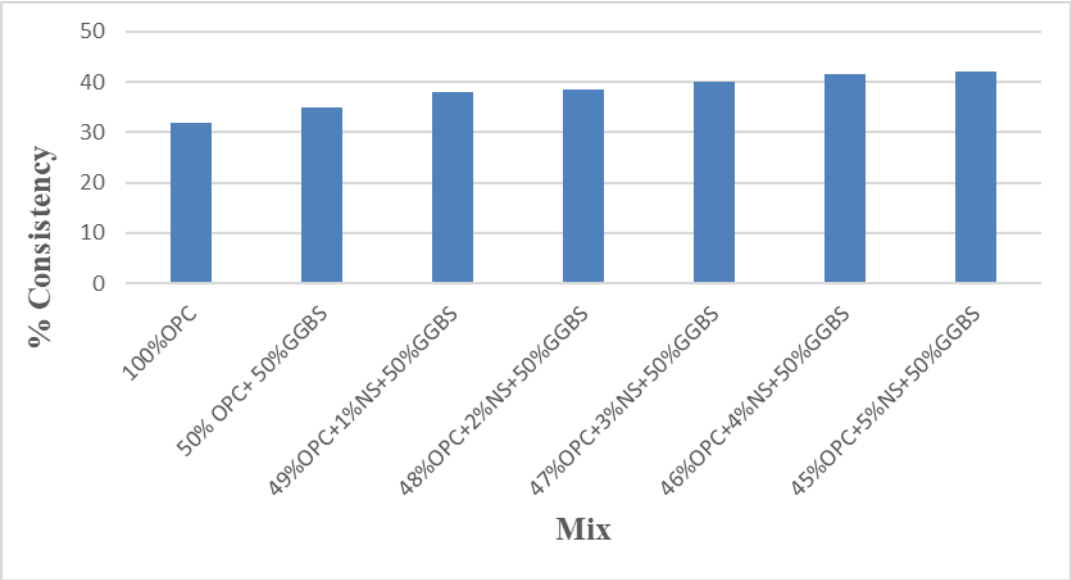

Figure-1 Standard Consistency of binary and ternary mixes

Results for standard consistency at different percentage level of Nano silica are shown in

Figure-1. According to a study with the replacement of OPC with other cementetitious material like Nano silica, the water requirement increases because of the fineness of the material [9]. It is also determined from study that because of GGBS with NS the water demand is reduced because of the some of the properties exhibited by GGBS [6] but because of fineness of Nano Silica the water demand is increased a little. Studies also say that GGBS does not require more amount of water but after adding Nano silica this binary material will turn into ternary material which requires more amount of water and its consistency starts increasing.

Initial and Final Setting time of Binary and Ternary Mixes

Setting time of the ternary mixtures containing cementitious material is shown in figure 2 & 3. According to study [9] due to the use of GGBS is to provide greater retardation in the initial and final setting time of the high strength concrete. From the study it is derived that setting time of OPC-NS reduces when Nano Silica is added in it but when GGBS is added it will increase the setting time of the concrete which we can see from figure 2 & 3. The main reason behind the retardation of setting time is due to the excessive fineness of the Nano Silica [12,13].

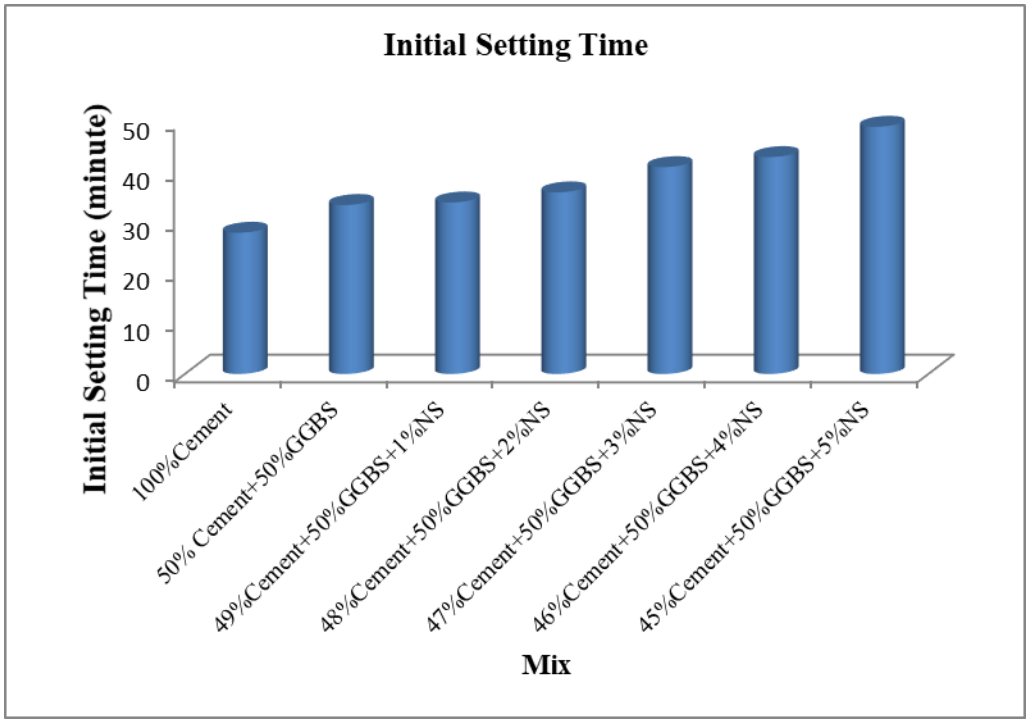

Figure 2 Initial Setting Time

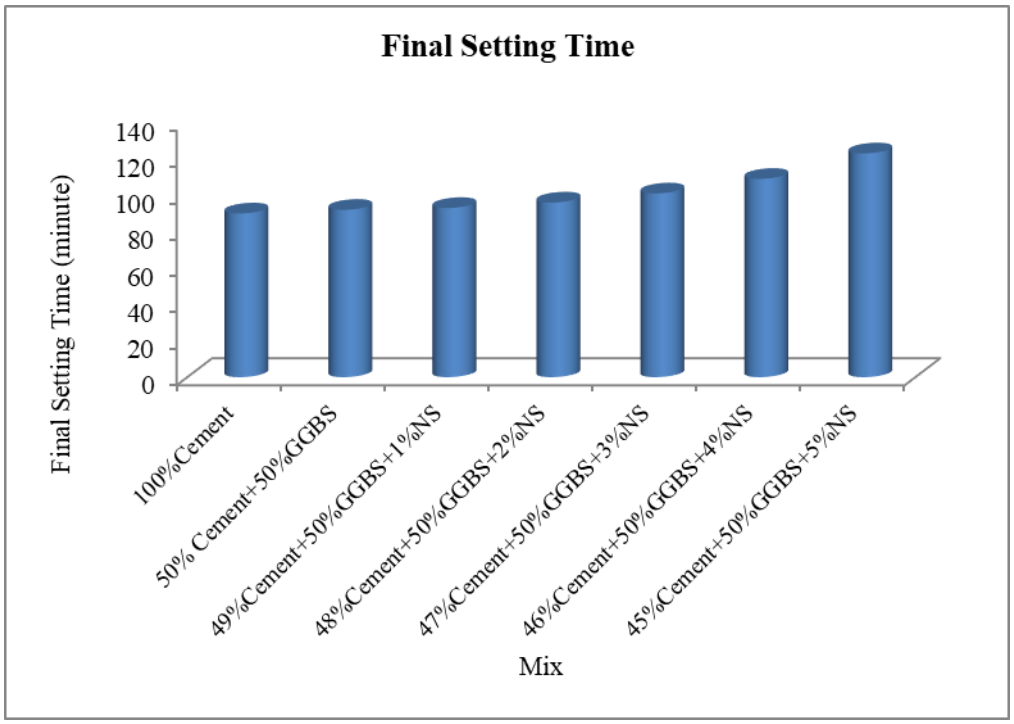

Figure 3 Final Setting Time

Due to the use of GGBS the hydration process longer times and retards the setting time and also due to the fineness of Nano silica it takes more time, but it comes in the expected limit of 600 minutes according to IS 4031 Part-5.

Expansion of Binary and Ternary Mixes

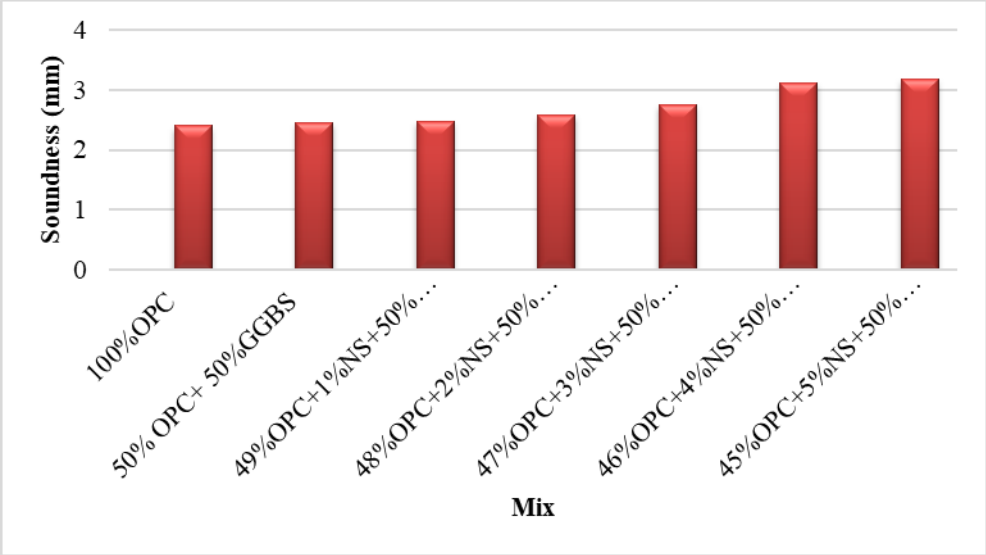

Figure 4

Soundness of cement refers to the free magnesia and lime present in the cement slakes very slowly and change in volume after setting. The le-chatalier apparatus expansion and % replacement with Nano silica was plotted in figure 4. With the increase in the content of Nano Silica the soundness of cement increases that is the length between the two increases with the increase in Nano Silica [9].

Water absorption

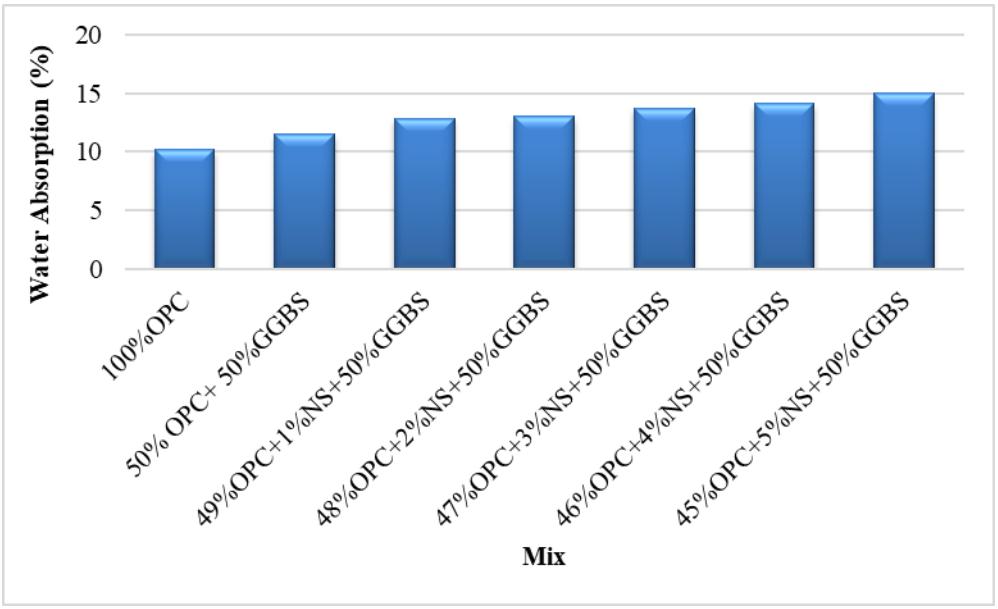

Figure 5 Water Absorption Test

Water absorption of water refers to the water absorbed by concrete cube when they are put for the curing [20]. With the use of GGBS the water absorption can [11] be decreased and also as Nano silica is also used in it so that will be more fine than the GGBS which will also increases water absorption in concrete.

CONCLUSION

1. Replacement of OPC by 50% with GGBS increases the initial and final setting time of the concrete but when increased consistency was in standard limit and similar to OPC.

2. Standard consistency in ternary binder (OPC–GGBS–NS) increases with increasing percentage levels of NS, owing to the high surNSce area of NS and high levels of water demand. These findings revealed that by controlling the percentage level of NS in binder, both water and standard consistency requirements can be addressed.

3. 50% replacement of OPC with GGBS has little control on consistency, but partial replacement of OPC by NS and GGBS has increased consistency. This shows that the high surface area of Nano Silica requires high amount of water. Setting time of the ternary binders increases with the replacement of OPC.

4. Higher amount of NS in ternary binder. The GGBS and NS are highly reactive, and small size of particles speeds up the reaction with calcium hydroxide.

5. Overall effect of NS and GGBS on standard consistency, an initial and final setting time in quaternary binder is to retard the setting time. The influence of increasing the levels of GGBS is to provide greater retardation in the setting time, due to less content of C3A.

6. This type of concrete is very useful for manufacturing RMC concrete where longer time is required for the placing.

7. As the cost of this concrete is too high compare to normal concrete this type of concrete is not used in small projects.

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