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Mechanical Properties of Quaternary Blended Concrete using Nano Silica

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Abstract- Alternatives to cement as binding material is gaining importance due to increased demand of concrete and since we all know it performs better. We can use the other alternatives to it such as SCMs (supplementary cementitious materials) and also some of these supplementary cementitious materials are byproduct/waste products of other industries. These SCMs will be partially replaced which will imparts higher strength to concrete. The use of SCMs which are in finer in size which densifies the pore structure which leads to increased mechanical and durability properties. This research investigates effect of SCMs like Metakaolin (MK), Flyash (FA) and Nano silica (NS) when used in quaternary blended concrete. In this research, three trial mixes were carried out. For these three trials mixes, the compressive strength is tested at 28 days and it was determined that, for the OPC @60%, MK proportion of 10%, FA @ 30%, and NS @ 3% found to offer the increased strength. For the optimum proportion, casted the samples and compared them with control concrete (only OPC), measured the compressive strength, split tensile strength, and flexural strength as well. 2.29 percent was an observed increase in the compressive strength and 8.4 percent was the increase in split tensile strength. On the other hand the flexural strength was increased by 7.27 percent when the comparison was made with the control concrete. Due to the addition of supplementary cementitious materials this increment is possibly attributed and this leads to the denser and refined micro-structure and also due to the compactness of interfacial zone of transition, we possibly witnessed this increment.

Keywords- Quaternary Blended concrete, High strength concrete, Flyash, Metakaolin, Nano Silica, Supplementary cementitious Materials, Mechanical Properties.

I. INTRODUCTION

Concrete is used extensively all across the globe as a strong construction item needing cement in larger quantities for the concrete manufacture. The SCMs can be replaced partially for cement in making concrete that inturn reduces the cement requirement upto certain extent. By using SCMs high performance and high strength can be produced by reducing Water /Binder ratio and at lower W/B the mixes are very stiff and this problem can be addressed with usage of new generation high range water reducers(Bharatkumar et al.2001). In recent years many researches have shown usage of nanomaterial in concrete which improves mechanical and durability of concrete (Li LG et al. 2019; Li LG et al. 2018; Sikora et al. 2020). Widely used nanomaterial is nanosilica (NS) because of its pozzolonic and pore filling effect which makes concrete impermeable. Usage of Nanomaterial in combination with other industrial waste materials will improve the performance of concrete (Li LG, et al 2019). The use of NS has shown enhancement of compressive strength than control mix upto 6% (Berra et al. 2012; Said et al. 2012). The widely used SCMs such Flyash (FA), Metakaolin, fume of silica, GGBS (Valipour in 2013). With other supplementary cementitious materials, the Metakaolin is used as an initial and partial replacement and as a result of it, the comprehensive strength increases and permeability decreases. This was observed in 2017 by Kumar et al. There are so many investigative workers especially in the past decade have tried to use the substance Metakaolin as an initial and partial cement replacement and they have successfully obtained the durability as well as other mechanical features. (El-Din et al. 2017; Sabir et al. 2001; Salimi et al. 2020; Ženíšek et al. 2016). In 2017, it was demonstrated by Lenka and Panda that for MK if there is only 10 percent of enhancement in the level of concrete, the comprehensive strength is likely to increase. Similar outcomes were seen when some other investigative workers tried to determine the impact (Dinakar and Manu 2014; Parande et al. 2008; Wild et al. 1996). There is a reduction in the process of absorption of water due to the use of supplementary cementitious materials and also the resistance to chloride permeability increases as well. With the help of binary effect of MK and FA, the possible changes were investigated by Sujjavanich et al in 2017 especially as far as replacement at different levels is concerned. It has been reported by the investigators in the past that when a mixed proportion is used consisting of 10 percent of the MK and FA substitute, we can get a denser and stronger microstructure as far as weight of the total binder is concerned. Increased in the mechanical strength and durability properties was seen with the help of different SCMs like FA, MK & NS and the concrete obtained was high performing (Rabinder et al.2021).

II. MATERIALS AND METHODOLOGY

1. Materials

OPC 53 Grade cement is used in this investigation and this confirms to the use of IS: 12269-1987. The Hyderabad industries, Hyderabad offered the Flyash for this investigation. M/s Astraa chemicals, Chennai offered Metakaolin and Nano silica for the investigation. The Flyash was characterized as class F flyash. As coarse aggregate, the crushed granite was used and size of this crushed granite used was 20 mm which is obtained from local source having sp.gravity is 2.6. The Fine aggregate is of river sand passing 4.75mm sieve used available locally. The fineness modulus of Fine aggregate is 2.27 and sp.gr is 2.57. The constant water/ binder ratio of 0.28 is maintained. As the low W/B is used to decrease the flow properties of concrete, new generation super plasticizers are used. In this research super plasticizer of FOSROC AURAMIX500 is used. The superplasticizer used @ 1.5% for quaternary Blended concrete. Higher dosage of superplasticizer was used as SCMs used, as supplementary cementitious materials were very fine materials which demands more water than without SCMs. For control concrete only 0.5% superplasticizer was used.

2. Methodology

As per IS: 10262-2019 for the grade of M65, the mix design was done. Percentages were varied for the trial mixes and these are mentioned as OPC(55%,60%&65%) and MK(15%,10%&5%) and FA fixed percentage is taken as 30% and 3% of NS was used according to the adopted literature. These mixes were coded as TM1 (OPC @55%, Flyash@30%, Metakaolin @15% & NS@3%), TM2 (OPC @60%, Flyash@30%, Metakaolin@10% & NS@3%) and TM3(OPC @65%, Flyash@30%, Metakaolin@5% & NS@3%). In dry state, the materials were mixed and this is done for the equal or uniform mixing of all the materials inside it and this mixing is done for the period of two to three minutes. Super plasticizer was used and water is added. The water is added to mixture and all materials were mixed for the period of about seven minutes to obtain a homogenous mixture. In terms of vee-bee time, the workability is also estimated and we determined it to be 11-12 seconds. The cube of 150 x 150 x 150 mm was the size of specimen used for the estimation of compressive testing of strength. The moulds were taken after the period of 24 hours and demoulded and kept in water at room temperature for curing until the tests are conducted. The trial mixes specimens were tested at 28 days. Figure 1 mentions the outcomes and from this figure, it is very clear that for TM2 (OPC @60%, Flyash @30%, Metakaolin @10% & NS @3%) proportion was provided highest compressive strength. Samples of different sizes were casted for the optimum proportion of OPC, FA, MK and NS. To make 1 cum of concrete, the quantities of materials needed are mentioned below in the following table 1. For compressive strength as per IS: 516, the cubes were taken with sizes 150 x 150 x 150 were casted and tested. For testing of the split tensile strength according to IS: 5816, the cylinders with sizes of 150 diameters and 300 mm height were casted. And for the testing of the flexural strength as per IS: 516, the beams of sizes casted were of size 500 x 100 x 100.

Table 1 Quantities of Materials in kg for 1 Cum of concrete

	OPC	Flyash	MK	NS	Water	SP	CA	FA	W/B Ratio
Quaternary Blended Concrete	300	150	50	15	140	7.5	1213	543	0.28
Control Concrete	464	-	-	-	130	2.5	1213	543	0.28

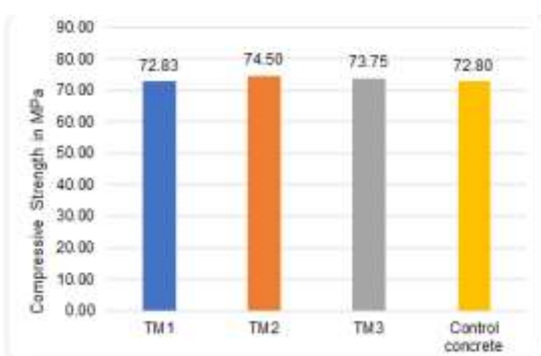

Figure 1 Results of compressive strengths for Trial mixes

III. RESULTS AND DISCUSSION

1. Compressive Strength

For three samples, the average compressive strength of concrete quaternary blended at 28 days of age was seen to be 74.50 MPa. The average compressive strength of these samples at the age of same 28 days for the control concrete were estimated at 72.80 MPa as shown in fig 2. As compared to the control mix, the increase in the quaternary concrete strength was seen to be 2.29 percent. The role of activator is played by the finer materials and the role of reactivity of pozzolonic materials. Due to the fineness of the materials activating the reactivity increase for Supplementary cementitious material is seen to be much more after the enhancement of hydration and this is due to the material fineness that increases its reactivity. Zhang and chen in 2019 also had similar findings as well. Due to the filler effect, the effect of MK is observed because formation more C-S-H gel (Baioumy and Ibrahim 2012; Mardani-Aghabaglou et al. 2014). It is also suggested by the studies in the past that greater compatibility is there when NS is used for the concrete development and especially if the concrete has higher comprehensive strength (Rabinder et al.2021). Making dense concrete packing, in which highly well-refined microstructures with larger surface to volume ratio for the nanostructure particles are used, is a crucial function of NS inclusion(K Nandini et al 2021), (Snehal K, B B Das, (2022)).

2. Split Tensile Strength

For a quaternary blended concrete, the split tensile strength is found to be 5.89 MPa and 5.40 MPa for the control concrete as shown in figure 3. As compared to the control concrete, the quaternary blended concrete has higher split tensile strength of 8.4 percent. Better pore filling of supplementary cementitious materials is the cause of this increase in strength which leads to compact interfacial zone of transition Rabinder et al in 2021 also had the similar findings.

3. Flexural Strength

For quaternary blended concrete, the flexural strength is recorded to be 6.30 MPa and 5.84 MPa for the control concrete as shown in figure 4. For quaternary blended concrete, the increase in strength is 7.2 percent more than that of the conctrol concrete. This may be attributed to better interlocking since excess amount of C-S-H gel formed when supplementary cementitious materials such as Flyash, Metakaolin, and Nano silica.

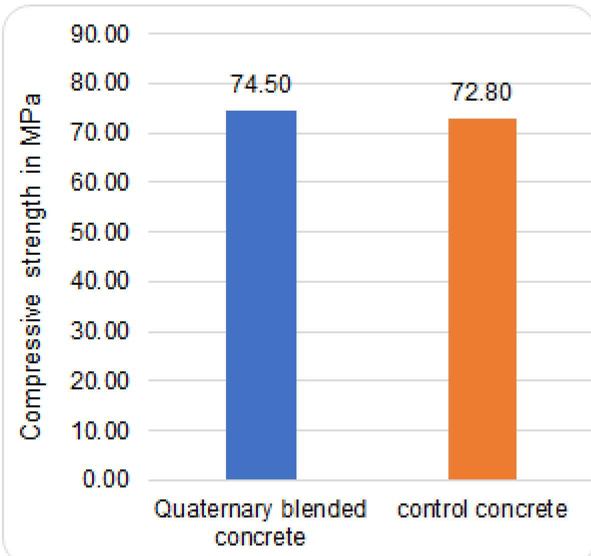

Figure 2 Compressive strengths of Quaternary blended concrete and control concrete days

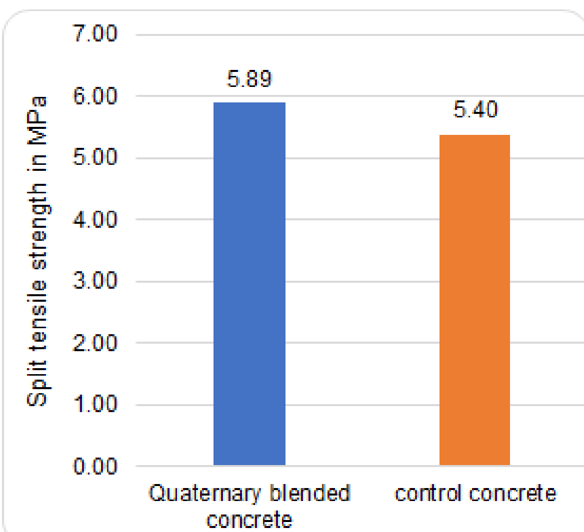

Figure 3 Split tensile strengths of Quaternary blended concrete and control concrete at 28

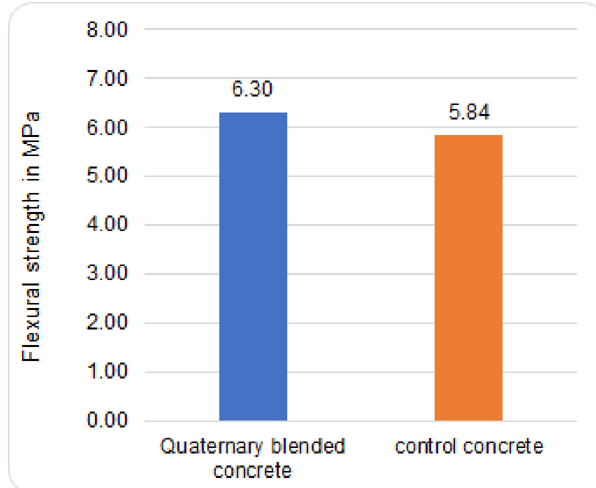

Figure 4 Flexural strengths of Quaternary blended Concrete and control concrete at 28 days

IV. CONCLUSION

The investigations were made to determine the quaternary blended concrete and its impact when supplementary cementitious materials are added such as Flaysh, Nano silica and Metakaolin. The impact of these particles is tested on the compressive strength, split tensile strength as well as flexural strength. Following observations were recorded on the basis of the experimental outcomes:

- The trial mixes outcomes indicate that when we used at different proportions, the optimum composition of quaternary blended concrete consists of 60%OPC, 10% MK, 30 % FA and 3% NS, which yielded maximum compressive strength.
- The extent of the increase in quaternary blended concrete compressive strength was 2.29 percent more as compared to the control concrete.
- For the quaternary blended concrete, the split tensile strength was marked as 8.4 percent higher as compared to the control concrete.
- The flexural strength increased and for the quaternary mix, this was found to be 7.2 % higher as compared to the control concrete.

REFERENCES

1. Berra M, Carassiti F, Mangialardi T, Paolini AE, Sebastiani M (2012) Effects of nanosilica addition on workability and compressive strength of Portland cement pastes. Constr Build Mater Elsevier Ltd 35:666–675.
2. Bharatkumar BH, Narayanan R, Raghuprasad BK, Ramachandramurthy DS (2001) Mix proportioning of high performance concrete. Cem Concr Compos Elsevier 23(1):71–80.
3. Baioumy and Ibrahim, Mineralogical Variations among the Kaolin Deposits in Malaysia, Annual International Conference on Geological & Earth Sciences (GEOS 2012).
4. Bureau of Indian Standards IS: 10262-2019 , Concrete Mix proportioning.
5. Bureau of Indian Standards IS:516, Method of test for strength of concrete.
6. Bureau of Indian Standards IS:5816, Method test Split Tensile strength of concrete.
7. Dinakar P, Manu SN (2014) Concrete mix design for high strength self-compacting concrete using metakaolin. Mater Des Elsevier 60:661–668.
8. El-Din HKS, Eisa AS, Aziz BHA, Ibrahim A (2017) Mechanical performance of high strength concrete made from high volume of Metakaolin and hybrid fibers. Constr Build Mater Elsevier 140: 203–209.
9. Kumar R, Mohd Yaseen AYB, Shafiq N, Jalal A (2017) Influence of metakaolin, fly ash and nano silica on mechanical and durability properties of concrete. Key Eng Mater [Internet] 744:8–14.
10. K Nandini, V Ponmalar, Effect of Blending Micro and Nano Silica on the Mechanical and Durability Properties of Self-Compacting Concrete Silicon 13, pages 687–695 (2021)-Springer.
11. Lenka S, Panda KC (2017) Effect of metakaolin on the properties of conventional and self compacting concrete. Adv Concr Constr 5(1):31–48.
12. Li LG, Zheng JY, Ng PL, Zhu J, Kwan AKH (2019) Cementing efficiencies and synergistic roles of silica fume and nano-silica in sulphate and chloride resistance of concrete. Constr Build Mater Elsevier 223:965–975.
13. Li LG, Zheng JY, Zhu J, Kwan AKH (2018) Combined usage of microsilica and nano-silica in concrete: SP demand, cementing efficiencies and synergistic effect. Constr Build Mater Elsevier 168:622– 632.
14. Mardani-Aghabaglou A, Inan Sezer G, Ramyar K (2014) Comparison of fly ash, silica fume and Metakaolin from mechanical properties and durability performance of mortar mixtures view point. Constr. Build Mater 70:17–25 .
15. Parande AK, Babu BR, Karthik MA, Kumaar KKD, Palaniswamy N (2008) Study on strength and corrosion performance for steel embedded in metakaolin blended concrete/mortar. Constr Build Mater Elsevier 22(3):127–134.
16. Rabinder Kumar, Nasir Shafiq, Aneel Kumar & Ashfaque Ahmed Jhatial(2021) Investigating embodied carbon, mechanical properties, and durability of high-performance concrete using ternary and quaternary blends of metakaolin, nano-silica, and fly ash. Environmental Science and Pollution Research, Springer 28, 49074–49088 (2021).
17. Sabir BB, Wild S, Bai J (2001) Metakaolin and calcined clays as pozzolanas for concrete: a review. CemConcr Compos Elsevier 23(6):441–454.
18. Salimi J, Ramezanianpour AM,MoradiMJ (2020) Studying the effect of low reactivity metakaolin on free and restrained shrinkage of high performance concrete. J Build Eng Elsevier 28:101053
19. Sikora P, Rucinska T, Stephan D, Chung S-Y, Abd Elrahman M (2020) Evaluating the effects of nanosilica on the material properties of lightweight and ultra-lightweight concrete using image-based approaches. Constr Build Mater Elsevier 264:12024.
20. Said AM, Zeidan MS, Bassuoni MT, Tian Y (2012) Properties of concrete incorporating nano-silica. Constr Build Mater Elsevier Ltd 36: 838–844. metakaolin and fly ash on properties of concrete. Constr Build Mater Elsevier 155:830–837.
21. K Snehal, BB Das (2022) Pozzolanic reactivity and drying shrinkage characteristics of optimized blended cementitious composites comprising of Nano-Silica particles

Construction and Building Materials, 316, 12579.

22. Sujjavanich S, Suwanvitaya P, Chaysuwan D, Heness G (2017) Synergistic effect of metakaolin and fly ash on properties of concrete Construction and Building Materials Volume 155, 30 November 2017, Pages 830-837.
23. Valipour M, Pargar F, ShekarchiM, Khani S (2013) Comparing a natural pozzolan, zeolite, to metakaolin and silica fume in terms of their effect on the durability characteristics of concrete: a laboratory study. Constr Build Mater Elsevier 41:879–888.
24. Wild S, Khatib JM, Jones A (1996) Relative strength, pozzolanic activity and cement hydration in superplasticised metakaolin concrete. Cem Concr Res Elsevier 26(10):1537–1544.
25. Ženíšek M, Vlach T, Laiblová L (2016) Dosage of metakaolin in high performance concrete. Key Eng Mater [Internet] 722:311–315.
26. Zhuang C, Chen Y (2019) the effect of nano-SiO2 on concrete properties: a review. Nanotechnol Rev [Internet] 8(1):562–572.