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Resistance to Deterioration and Water Absorption by Ternary Blended Concrete with Ceramic Powder and SiO_2

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Abstract: This paper presents the behavior of ternary blended concrete made using ceramic powder obtained from waste ceramic tiles and micro silica in aggressive environment involving H_2SO_4 and NaCl curing mediums. Waste ceramic tiles were collected and were ground to ultra fine size using dry ball mill and the sizes were checked with X-Ray Fluorescent (XRF) to bring a fine powder with size less than that of cement particles. The ground ceramic powder was added in 4, 9 and 14 percentages by weight of cement to obtain a high strength concrete mix of M50 grade. Micro silica was also added in the mix in a small percentage of 1% by weight of cement to accelerate the early age strength making the mix ternary blended. To find the rate of deterioration cube specimens were cast and cured in water for 28 days and then in diluted H_2SO_4 and NaCl for a period of one month. Resistance to water absorption was also studied by casting cylinder specimens. The exact percentage of ceramic powder that can be added with the OPC (Ordinary Portland Cement) to provide enough resistance to deterioration and water permeability were identified. Concrete with ceramic powder 9% and micro silica 1% provided enough resistance to deterioration both in acid and base medium. In resisting water absorption the mix which contained 14% ceramic and 1% micro silica showed better resistance to water absorption.
Key words: Ceramic powder, micro silica, H_2SO_4, NaCl, XRF, ternary blended, OPC.

1. Introduction

The performance of conventional concrete under normal conditions is extremely well, but when exposed to aggressive environment a concrete with higher compressive strength is required. According to IS 456-2000 [1], the various exposure conditions that a structure can come across in its life time were classified as mild, moderate and severe, very severe and extreme in increasing degree of severity. Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing or severe condensation and those exposed to coastal environment, come under the category severe and structures exposed to aggressive solid chemicals come under extreme category. So in addition to strength properties it is also necessary to study the behavior of the concrete in aggressive environment to make the structure ready to face the factors faced in the aggressive environment and to make it durable.

To study the resistance of the structure against the deterioration many durability tests that stimulate the actual field deterioration mechanisms are available but all are time consuming [2]. Rapid Chloride Penetration Test described by ASTM C1202 [3], Water absorption test as mentioned in ASTM C1585-13 [4], Porosity test as explained in ASTM C642-13 [5], testing corrosion in reinforced concrete by ASTM C876-91 [6] are some of the accelerated durability tests which have been developed as a result of the need for estimating the durability characteristics of the concrete in a short period of time.

The production of blended cement had a significant increase since mid-nineties. Ternary cements consist of two supplementary cementitious materials in addition to Portland cement and if three such materials are added to cement it is termed as quaternary [7].

Several research works were performed using different types of blended cements using various combinations of mineral admixtures. Bagel [8] discussed the results of mortars containing blast furnace slag and silica fume forming a ternary blended concrete and reported that a denser pore structure and a satisfactory level of compressive strength can be achieved on using ternary blended cement. Olufemi et al [9] investigated the compressive strength development of binary and ternary cement concretes containing Portland cement, fly ash and metakaolin and suggested that metakaolin in the concrete contributed to the compressive strength in both early and later ages and fly ash contributed to later age strength development. The authors also recommended concrete made with blended cement for use in construction as they as less e-CO_2 levels than those made with ordinary Portland cement.

Haque et al [10] described the strength development of ternary blended concrete prepared using ordinary Portland cement, blast furnace slag and fly ash as mineral admixtures. Their results suggested the use of concrete with blended mixtures since they are least affected even under inadequate curing conditions compared with normal cement concrete. Lam et al [11] presented the results of investigations on using a ternary blended concrete with ordinary Portland cement, fly ash and a small amount of silica fume. The authors observed that addition of silica fume in concrete had large positive effects on cylinder compressive strength and tensile strength but had less impact on cube compressive strength.

Thomas et al [12] found that using small amount of silica fume say 3-6% and moderate levels of CaO Fly ash (20-30%) in ordinary Portland cement were very effective in reducing the alkali silica reactivity and sulfate attack. Also it is reported by the authors that concrete made using such proportions generally sow fresh and hardened properties since the combination of silica fume and fly ash is somewhat synergistic.

1.1 Significance of the present research work

This paper reports the experimental investigations done on ternary blended concrete with ceramic powder and silica fume as mineral admixtures in ordinary Portland cement. Ceramic powder obtained from waste ceramic tiles is added in 4%, 9% and 14% to ordinary Portland cement along with silica fume in 1% by weight of cement. Silica fume is added to initiate the early strength.

2. Experimental investigations

2.1 Material properties

2.1.1 Cement

Ordinary Portland cement of grade 53 was used for this research. Table 1 shows the chemical composition of cement used.

Table 1. Chemical composition of cement, micro silica and ceramic powder

Compounds	Cement Concentration (%)	Micro silica Concentration(%)	Ceramic Powder from waste ceramic tiles(%)
SiO_2	17-25	97.36	55.80
MgO	0.4-0.5	0.79	4.28
Al_2O_3	0.5-0.6	0.53	19.13
SO_3	2-3.5	0.51	0.54
K_2O	-	0.29	1.36
Fe_2O_3	3-8	0.15	7.88
CaO	60-67	0.14	7.85
P_2O_5	-	0.09	0.13
Na_2O	-	0.06	1.17
Cl	-	0.02	0.13
MnO	-	0.01	0.04
PbO	-	0.01	
TiO_2	-	0.01	1.31
Cr_2O_3	-	100 PPM	0.05
ZnO	-	70 PPM	0.10

CuO	-	51 PPM	0.04
Ru	-	47 PPM	90ppm

2.1.2 Ceramic powder

Ceramic powder was prepared by grinding waste ceramic tile in dry ball mill. Waste ceramic tiles are fed into the dry ball mill with 7 steel balls of diameter 30 mm weighing 400 gm each. The ceramic tiles were subjected to grinding for different grinding periods such us 30 minutes, 45 minutes and 60 minutes and then the powder obtained was sieved through a 75 micron sieve to collect particles finer than cement. Fig.1 shows the images of ceramic particles before grinding and after grinding. The samples of ceramic powder ground at different durations were subjected to Particle size analysis and sample which is finer was used for the research work.

Fig. 1 Ceramic material before and after grinding in Ball Mill

The chemical composition was found using X-Ray Fluorescent (XRF) and it is presented in Table 1. The particle size of the ceramic powder was checked by zeta analyzer to ensure that their size is less than the size of cement and it is shown in Table 2.

Table 2. Size of Micro silica and ceramic powder

Sl.No	Sample Type	Size
1	Micro silica	0.638μm
2	Ceramic powder	2481 nm

2.1.3 Micro silica

Micro-silica (SiO_2) a by-product obtained from Ferro silicon industries was chosen as the other mineral admixture and is obtained from Oriental Exporters, Navi Mumbai, Maharashtra. The particle size of micro-silica was analyzed using PSA and the chemical composition of the micro-silica was found using XRF. Both the results are shown in Table 1 and Table 2 respectively.

2.1.4 Aggregate

River sand was used as fine aggregate and the aggregate passing through 16 mm sieve and retained on 12.5 mm sieve was used as coarse aggregate in the concrete mix. The physical properties of the aggregates and mineral admixtures used for the present work are shown in Table 3.

Table 3. Physical properties of materials

Sl.No	Material	Specific Gravity
1.	Cement	3.16
2.	Fine aggregate	2.63
3.	Coarse aggregate	2.55
4.	Micro silica	2.2
5.	Ceramic powder	2.182

2.1.5 Super plasticizer

CONPLAST SP 430 a commonly available super plasticizer obtained from FOSROC Company was used fully in this research work to obtain the workable concrete mix.

2.1.6 Concrete mix proportions

A high strength concrete of M50 grade has been adopted for the present work and the mix design was arrived by ACI method. The obtained mix ratio is 1:1.04:2.13 (Cement: Fine aggregate: Coarse aggregate). A total of 4 combinations were prepared for the present research work namely CONTROL, C4%+MS1%, C9%+MS1%, C14%+MS1%. Except control specimens, all the combinations were made by partially replacing cement with ceramic powder in 4%, 9%, 14% percentages and micro-silica in 1% by weight of cement. Table 4 shows the mix proportion details.

Table 4. Mix Proportioning

Parameters	**Mix Reference**			
	Control	**C4-SF1**	**C9-SF1**	**C14-SF1**
Cement, kg/m^3	522.57	475.54	470.31	444.18
Ceramic Powder, kg/m^3	-	20.90	47.03	73.16
Microsilica, kg/m^3	-	5.23	5.23	5.22
Fine aggregate, kg/m^3	544.18	544.18	544.18	544.18
Coarse Aggregate, kg/m^3	1113.84	1113.84	1113.84	1113.84
Water, l/m^3	182.9	182.9	182.9	182.9
Super-plasticizer/ 100 kg of cement in l	1-3	1-3	1-3	1-3
w/c	0.29	0.29	0.29	0.29
Mix ratio	1:1.04:2.13			

2.1.7 Specimen details

Concrete cubes of size 100 mm x 100 mm x 100 mm and cylinders of size 100mm x 50 mm were cast to study the durability characteristics of the specimens. Cubes were used to check the rate of deterioration when exposed to aggressive environment and the cylinder specimens were used to study the water absorption capacity and resistance to permeability. BS 1881 codal provisions were used for casting specimens and automatic compression testing machine with a capacity 3000 kN was used to perform the strength tests of cube and cylinder specimens.

2.1.8 Curing environment

2.1.8.1 Acids

Sulphate attack on concrete may lead to severe damages such as cracking, expansion of concrete and disintegration of cement paste and is considered as one of the most common factors for deterioration in concrete. [13]. To know the behavior of concrete in aggressive industrial environment and also study the effect of sulphate attack on concrete the specimens were subjected to curing in H_2SO_4 acids, which the structures are encountered frequently in industries. The acids were diluted before using it and 1% H_2SO_4 was used in this work to observe the deterioration of concrete when cured in it.

2.1.8.2 Bases

Chloride attack is considered as one of the most severe durability problem for structures constructed in marine environment [14]. To simulate the effect of marine environment% sodium chloride was used in this study for curing the concrete specimens to study their behavior in aggressive marine environment.

3. Results and Discussion

3.1 Deterioration resistance of ceramic powder blended concrete cured in H_2SO_4

Fig.2 Sample Picture of specimen before curing in aggressive environment

Fig.3 Sample Picture of specimen after curing in H_2SO_4

Fig.2 shows the image of the specimen before subjecting to acid curing and Fig. 3 presents the deteriorated shape of the specimen after exposed to acidic environment for a period of 1 month. Fig 5 and Fig.6 illustrate the strength changes and rate of deterioration in the control concrete and ternary blended concrete after being exposed to aggressive acid environment. It can be observed that control concrete has reached strength of 40.45MPa but had deteriorated more by 33.14%. Among the blended concrete mixes it was observed that C9%+MS1% possessed acceptable strength values of 60.98MPa and 49.47MPa respectively when cured in water and aggressive environment and also the rate of deterioration was in the range of 18.88% which was found to be less. C14%+MS1% has deteriorated more by 29.85% and though the strength of C4%+MS1% is the least of all mixes when exposed to acidic environment the deterioration percentage is found to be less by 17.92%. But considering the overall strength behavior and rate of deterioration of blended concrete mixes in water and acidic environment C9%+MS1% performed well. The reason may be due to mixing of exact required percentage of ceramic powder which helped in proper filling of pores making the concrete denser and the addition of micro silica which helped in increasing the early age strength.

Fig.4 Sample Picture of specimen after curing in NaCl

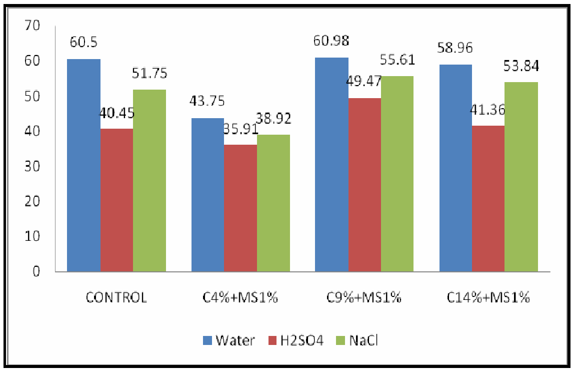

Fig.5 Compressive strength of specimen in different curing medium

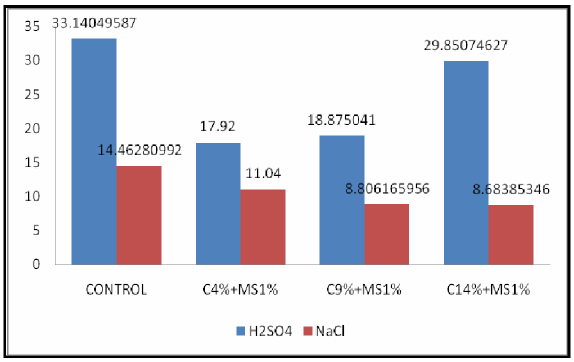

Fig.6 Percentage of deterioration in different curing medium

3.2 Deterioration resistance of ceramic powder blended concrete cured in H_2SO_4

The deteriorated shape of the concrete specimen after subjected to curing in marine environment is shown in Fig.4. The strength changes and rate of deterioration in the control concrete and ternary blended concrete exposed to aggressive marine environment are presented in Fig 5 and Fig.6. From the results it is clearly understood that the strength of control concrete in water and marine environment were 60.5MPa and 51.75 MPa respectively but the rate of deterioration was found to be more by 14.46 %. Among the blended the strength values of C9%+MS1% were in the acceptable range of 60.98MPa and 55.61MPa respectively when cured in water and aggressive environment and the rate of deterioration was also found to be less in the range of 8.81%. C14%+MS1% has deteriorated more by 29.85% and though the strength of C4%+MS1% is the least of all mixes when exposed to acidic environment the deterioration percentage is found to be less by 17.92%. But considering the overall strength behavior and rate of deterioration of blended concrete mixes in water and acidic environment C9%+MS1% performed well. The reason may be due to mixing of exact required percentage of ceramic powder which helped in proper filling of pores making the concrete denser and the addition of micro silica which helped in increasing the early age strength.

3.3 Resistance to water absorption

Table 5. Water absorption readings

Specimens Time	Control	C4%+MS1%	C9%+MS1%	C14%+MS1%
	Wt. (kg)	Wt. (kg)	Wt. (kg)	Wt. (kg)
Initial	1.118	0.986	1.006	1.106
1 min	1.122	1.004	1.006	1.108
5 min	1.124	1.010	1.012	1.110
10 min	1.126	1.012	1.012	1.110
20 min	1.126	1.014	1.012	1.110
30 min	1.126	1.014	1.012	1.110
60 min	1.126	1.014	1.014	1.110
2 hours	1.128	1.018	1.016	1.112

3 hours	1.130	1.018	1.016	1.112
4 hours	1.130	1.018	1.016	1.112
5 hours	1.130	1.018	1.016	1.114
6 hours	1.132	1.020	1.018	1.114

Table 6. Percentage of water absorption

Specimens	Control	C4%+MS1%	C9%+MS1%	C14%+MS1%
Percentage of water absorption	1.124	3.33	1.18	0.72

The values of water absorption for control concrete and blended concrete mixes are presented in Table 5 and the percentage of water absorbed by each mix are shown in Table 6. Control concrete has showed water absorption of 1.24%. All blended concrete mixes except C4%+MS1% exhibited water absorption less than 2%. C14%+MS1% showed a least water absorption by 0.72% and C9%+MS1% showed a moderate to water absorption with 1.18%. C4%+MS1% absorbed more water because the small amount of replaced filler materials are not sufficient to fill the pores. Khatib et al [15] reported that water absorption of 4.2% - 5.4% is advisable for concrete mixes with metakaolin as a mineral admixture and Pourkhorshidi et al [16] presented results of water absorption tests conducted for concrete mix with silica fume as mineral admixture in which a range of 2.9% - 4.5% is suggested.

Fig.7 Water absorption test being performed

Since the results of water absorption for the present research is well within the above discussed ranges it is under stood that the blended concrete mixes perform well in resisting water penetration. Fig.7 shows the specimens being tested for water absorption.

4. Conclusions:

Following conclusions were arrived from the experiments conducted:

1. The size of ceramic powder obtained after grinding for 1 hour in dry ball mill was in the range of 2412 nm.
2. Control concrete has reached strength of 60.5MPa after curing in water but had deteriorated more by 33.14% in acid environment and 14.46 % in marine environment.
3. Among the ternary blended concrete mixes C9%+MS1% possessed acceptable strength values when cured in water and acid environment and less deterioration of 18.88%.
4. In NaCl curing (marine environment) also C9%+MS1% deteriorated less by 8.81%.
5. Considering the overall strength behavior and rate of deterioration of blended concrete mixes in water and aggressive environment C9%+MS1% performed well.
6. C14%+MS1% showed a least water absorption by 0.72% and C9%+MS1% showed a moderate to water absorption with 1.18%. But all the results are well within the discussed ranges and it is under stood that blended concrete mixes can perform well in resisting water penetration.

Abbrevations:

XRF: X-Ray Fluroscent
C4%+MS1%: Concrete with Ceramic 4% and Microsilica 1%
C9%+ MS 1%: Concrete with Ceramic 9% and Microsilica 1%
C14%+ MS 1%: Concrete with Ceramic 14% and Microsilica 1%
H_2SO_4: Sulphuric Acid
NaCl : Sodium Chloride

References

1. IS 456-2000, Plain and reinforced concrete – code of practice, New Delhi: Bureau of Indian Standards]
2. Santhosh G. Cheriyan, Dhanya, B.S., and Manu Santhanam,'Durability indices for concretes with different dosages of mineral admixtures', The Indian Concrete Journal, Vol.88, No.3, pp-60-68, 2014.
3. Standard test methods for electrical indication of concrete's ability to resist chloride penetration, ASTM C1202, Annual book of ASTM standards, West Conshohockers, United States.
4. Standard Test method for Measurement of Rate of Absorption of water by Hydraulic Cement Concrete, ASTM C1585-13, Annual book of ASTM standards, West Conshohockers, United States.
5. Standard Test method for Density, Absorption and voids in Hardened Concrete, ASTM C 642-13, Annual book of ASTM standards, West Conshohockers, United States.
6. Standard Test method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete, ASTM C 876-91, Annual book of ASTM standards, West Conshohockers, United States.
7. Antiohos, S.K., Papadakis, U.G., Chaniotakis, E., Tsimas, S., 'Improving the performance of ternary blended cements by mixing different types of fly ashes', Cement *and Concrete Research*, Vol. 37, No.36, pp. 877-885, 2007.
8. Bagel, L.,'Strength and pore structure of ternary blended cement mortars containing blast furnace slag and silica fume', *Cement and Concrete Research*, Vol.28. No.7, pp.1011-1022, 1998.
9. Folagbade S. Olufemi and Moray Newlands, 'Compressive strength development of blended cement concretes containing Portland cement, fly ash and Metakaolin', *The Indian Concrete Journal*, Vol.88, No.9, pp.20-29, 2014.
10. Haque, M.N., and Chulilung, 'Strength development of slag and Ternary blend Concrete', *Cement and Concrete Research*, Vol. 20, No.1, pp. 120-130, 1990.
11. Lam, L., Wong, Y.L., and Poon, C.S.,' Effect of fly ash and silica fume on compressive and fracture behavior of concrete', *Cement and Concrete Research*, Vol.28, No.2, pp.271-283, 1998.
12. Thomas, M.D.A., Shehata, M.H., Shashi prakash, S.S., Hopkins, D.S., Cail, K.,'Use of ternary cementitious system containing silica fume and fly ash in concrete', Cement and Concrete Research, Vol.29, pp.1207-1214, 1999.
13. Erhan Guneyisi, Mehmet Gesoglu & Kasim Mermerdas. (2010). Strength Deterioration of Plain and Metakaolin Concretes in Aggressive Sulfate Environments. *Journal of Materials in Civil Engineering*, Vol.22, No.4, 403-407.
14. Bulu Pradhan, 'Corrosion behavior of steel reinforcement in concrete exposed to composite chloride-sulfate environment', *Construction and Building Materials*, 22, 398-410, 2014.
15. Khatib, J.M., Roger, M. and Clay, R.M., 'Absorption characteristics of metakaolin concrete', Cement and Concrete Research, Vol.34, No.1, pp. 19-29, 2004.
16. Pourkhorshidi, A.R., Najimi, M., Parhizkar, T., Hillemeier, B. and Herr, R., 'A comparative study of the evaluation methods for pozzolans, Advances in cement Research, Vol.22, No.2, pp.157-164, 2000.

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