Volume : 2 | Issue : 12 | Dec 2013 • ISSN No 2277 - 8160

Research Paper | Engineering

Effects of Magnesium Sulphate in Mixing and Curing Water on Strength of High-Performance Metakaolin Concrete

E. Arunakanthi Civil Engineering Dept., JNTUACEA, Ananthapuramu, Andhra Pradesh, India

H. Sudarsana Rao Civil Engineering Dept., JNTUACEA, Ananthapuramu, Andhra Pradesh, India

I. V. Ramanareddy Civil Engineering Dept., SVUCEA, Tirupati, Andhrapradesh, India

ABSTRACT

This paper presents the results of an experimental investigation carried out to study the effect of aggressive chemical environment on High performance concrete with metakaolin in which Ordinary Portland cement is partially replaced by 20% of metakaolin by weight and aggressive chemical environment is simulated by subjecting the concrete to different concentrations of Magnesium sulphate (MgSO4) in deionised water during mixing and curing. Compressive strengths and split tensile strengths were determined at 7, 28 and 90 days. The results indicate that the compressive strength and split tensile strength decrease with the decrease in concentration of Magnesium sulphate when compared with concrete without Magnesium sulphate in mixing and curing water.

KEYWORDS : Ordinary Portland cement, High-Performance concrete, Metakaolin, Compressive strength, Split tensile strength, Magnesium sulphate.

Introduction

Any concrete which satisfies certain criteria proposed to overcome limitations of conventional concretes may be called High-Performance concrete (HPC). It may include concrete which provides either substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability.

The primary application for HPC have been structures requiring long service lives such as oil drilling platform, long span bridges and parking structures. HPC still requires good construction practice and good curing to deliver high performance. The Federal Highway Administration (FHWA) has proposed criteria for four different performance grades of HPC [1]. Metakaolin is a high quality Pozzolanic material, which is blended with Portland cement in order to improve the durability of concrete and mortars; it removes chemically reactive calcium hydroxide from the hardened cement paste. Khatib and Wild studied the improved sulphate resistance of metakaolin mortar [6]. Curcio et al. presented the utility of metakaolin as micro filler in the production of high performance mortars [2]. Palomo et al. studied the chemical stability of metakaolin based cement composites [7]. Frias and Cabrera investigated the relationship between the pore size distribution and degree of hydration of metakaolin based cement pastes [3]. Roy et al. studied about the effect of Metakaolin, silica fume and fly ash on chemical resistance of concrete [9]. Poon et al. studied about the rate of Pozzolanic reaction of metakaolin in high performance cement mortars [8]. Hydration progress in metakaolin blended high performance cement paste with age was studied from the compressive strength, porosity and pore size distribution properties.

Arunakanthi et.al., studied the effect of Hydrochloric acid in mixing and curing water on strength of High-Performance Metakaolin concrete [1]. The present investigation presents the effect of $MgSO_4$ on strength properties of HPC with and without metakaolin for various concentrations of $MgSO_4$.

Experimental program

Materials

Cement

Ordinary Portland (53 grade) cement of Ultratech brand was used. It was tested as per Indian Standards Specifications IS: 8112-1989. Its properties are specificgravity 3.1, normalconsistency of 33%, fineness of 5%, initial setting time is 105 minutes and final setting time is 350 minutes.

Fine aggregate

The locally available natural river sand was used as fine aggregate. It was tested as per Indian Standard Specification IS: 383-1970. Its fineness modulous is 2.69 and specific gravity is 2.7.

Metakaolin

Metakaolin obtained from KOAT manufacturing company, Vadodara, Gujarat, India is used in this investigation. The properties are Bulk Density (Gms / Ltr) 300 to 340, Average Particle Size 1.5 – 2.5 micron, Residue (> 45 micron) (max. %) 0.5 – 2%, Moisture content ≤ 1%, Specific Surface Area BET (m2/gm) 12 – 18.

Super-plasticizer

GLENIUM B233 is the super-plasticizer of BASF company. The properties are Aspect: Light brown liquid, Relative Density: 1.08 ± 0.01 at 25°C, PH: >6, Chloride ion content: < 0.2%

Variables studied:

- Concrete mix: The mix ratio of cement: sand: corse aggregate is 1:0.76:1.8 with water/ binder ratio as 0.3. The dosage of superplasticizer is 1% by weight of cement. 20 % of Cement was replaced with of Metakaolin.
- Mixing and curing environment: Four different concentrations of MGSO4 (50 g/L, 100 g/L, 400 g/L and 800 g/L) were adopted during the mixing in the deionised water and cured in same condition.
- Exposure period: Specimens were tested periodically after the specified curing periods of 7, 28 and 90 days.
- Size of specimens: 150mm x150mm x150mm size of cubes for compressive strength test and 150mm dia- 300mm height of cylinders for split tensile strength test.
- Samples for XRD and SEM testing: The cubes with maximum concentration of MGSO4 after 90 days testing are collected and grinded and sieved under 40 micron sieve. This powder sample is sent for XRD testing and the broken pieces of cube samples are sent for SEM testing. A total of 135 cubes and 135 cylinders were cast in the laboratory. After 72 hours, all the specimens were demoulded and cured in water in a curing tank at room temperature. After specific exposure period, specimens were tested for compressive strength, split tensile strength in accordance with test procedure IS 516: 1959 [5].

Results and discussion

Effect of $MgSO_4$ on compressive strength

The effect of $MgSO_4$ concentration on the compressive strength and split tensile strength of HPC with and without metakaolin is presented in table: 1, 2, 3 and 4 and figures 1, 2, 3 and 4. Continuous decrease in compressive strength and splittensile strength is observed with the increase in concentration of $MgSO_4$ for both HPCs. If the difference is less than 10% the change is considered to be negligible and if the difference is more than 10% the change is considered to be significant. It is observed that there is significant decrease in both compressive

strength and split tensile strength of both HPC's from 1.5 g/L concentration of $MgSO_4$. The percentage change in compressive strength and splittensile strength of HPC with and without metakaolin increased with the increase in concentration of $MgSO_4$. The XRD and SEM results show the formation of Calcium silicate hydrate (C-S-H gel) and Portlandite ($Ca(OH)_2$) in both samples without $MgSO_4$. But the intensities of C-S-H gel and Portlandite differ in two samples. The XRD patterns corresponding to HPC without metakaolin and HPC with metakaolin are shown in figures 3 and 5. By analyzing the XRD patterns of samples of two HPC's, the formation of C-S-H gel and Portlandite are formed at angles as shown in table 5 and 6. The intensity of C-S-H gel is more and the intensity of Portlandite is less for HPC with metakaolin when compared with HPC without metakaolin. This may be the cause for the strengths of HPC with metakaolin to be high under aggressive environment. The XRD tests are conducted for the two samples after 90 days with 1.5 g/L concentration (maximum) of $MgSO_4$. It is observed that inaddition to the compounds formed above, a compound named Sepiolite **($Mg_4SiO_5(OH)_2.6H_2O$)** is formed in both HPC's with $MgSO_4$. So the decrease in strengths may be due to the formation of Sepiolite. The angles at which the compounds are formed as shown in the table 4. The XRD patterns are shown in figures 5 and 6 respectively. The compound Sepiolite is orthorhombic and dipyramidal in structure. This is fibrous and looks like crystals made up of fibers. Under the microscope the mineral consists of bundles of fibers.

The probable chemical reaction upon the hydration of cement with mixing water containing $MgSO_4$ concentration is

$$4MgSO_4 + SiO_2 + 7H_2O \qquad Mg_4SiO_5(OH)_2.6H_2O + 4SO_3$$

In tables and graphs CHPC is HPC without metakaolin and MHPC is HPC with metakaolin

Table 1: Compressive strength in N/mm² for different concentrations of $MgSO_4$

S No	Dosage of $MgSO_4$ g/L	Compressive strength (N/mm²)					
		7 days		28days		90 days	
		CHPC	MHPC	CHPC	MHPC	CHPC	MHPC
1	0	39.5	60.0	58.0	78.0	63. 5	80.0
2	0.2	39.0	59.9	57.5	77.6	61.9	79.2
3	0.5	37.9	59.3	55.3	76.0	57.96	74.8
4	1	37.5	58.2	52.6	74.3	57.43	74.2
5	1.5	36.4	57.4	50.8	69.6	54.1	71.4

Table 2:%age change in compressive strength for different concentrations of $MgSO_4$

S No	Dosage of $MgSO_4$ g/L	Percentage change in Compressive strength					
		7 days		28days		90 days	
		CHPC	MHPC	CHPC	MHPC	CHPC	MHPC
1	0	0.00	0	0.00	0	0.00	0
2	0.2	-1.27	-0.15	-0.92	-0.46	-2.42	-0.95
3	0.5	-4.05	-1.25	-4.62	-2.56	-8.64	-6.54
4	1	-5.06	-2.98	-9.36	-4.76	-9.48	-7.24
5	1.5	-7.85	-4.29	-12.45	-10.75	-14.68	-11.06

Table 3: Split tensile strength in N/mm² for different concentrations of $MgSO_4$

S No	Dosage of $MgSO_4$ g/L	Split tensile strength (N/mm²)					
		7 days		28days		90 days	
		CHPC	MHPC	CHPC	MHPC	CHPC	MHPC
1	0	4.19	5.3	5.35	6.05	5.67	6.15
2	0.2	4.17	5.29	5.29	6.02	5.52	6.08
3	0.5	4.06	5.23	5.08	5.89	5.17	5.74
4	1	4.01	5.13	4.83	5.76	5.13	5.69
5	1.5	3.89	5.04	4.67	5.39	4.84	5.45

Table 4:%age change in split tensile strength for different concentrations of $MgSO_4$

S No	Dosage of $MgSO_4$ g/L	Percentage change in Split tensile strength					
		7 days		28days		90 days	
		CHPC	MHPC	CHPC	MHPC	CHPC	MHPC
1	0	0.00	0	0.00	0	0	0
2	0.2	-0.51	-0.17	-0.98	-0.48	-2.53	-1.01
3	0.5	-3.03	-1.31	-5.01	-2.59	-8.71	-6.58
4	1	-4.35	-3.21	-9.75	-4.79	-9.52	-7.36
5	1.5	-7.05	-4.85	-12.62	-10.83	-14.69	-11.23

Table 5: Compounds and their intensities for samples of HPC's without $MgSO_4$

S NO	Angle in degrees	Compound	Intensity	
			CHPC	MHPC
1	12.58	C-S-H Gel	76	132
2	17.94	Portlandite	266	66
3	21.18	C-S-H Gel	32	86
4	24	Portlandite	110	72
5	34.34	C-S-H Gel	124	154
6	37.3	C-S-H Gel	34	72
7	42.24	Portlandite	64	38
8	50.76	C-S-H gel	90	120

Table 6: Compounds and their intensities for samples of HPC's with $MgSO_4$

S NO	Angle in degrees	Compound	Intensity	
			CHPC	MHPC
1	10.2	C-S-H gel	58	84
2	11.66	Sepiolite	662	78
3	12.34	C-S-H gel	58	84
4	15.9	Sepiolite	126	52
5	16.2	C-S-H gel	32	56
6	21.12	Portlandite	68	54
7	24.34	C-S-H gel	56	130
8	28.22	C-S-H gel	130	162
9	32.22	Sepiolite	194	160
10	35.94	C-S-H gel	46	62
11	41.24	Portlandite	116	86
12	45.84	C-S-H gel	70	108

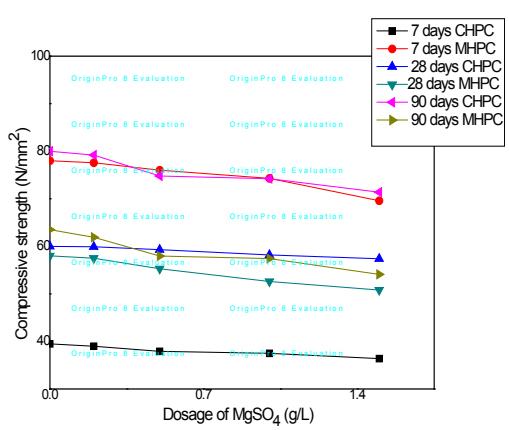


Fig 1: compressive strengths

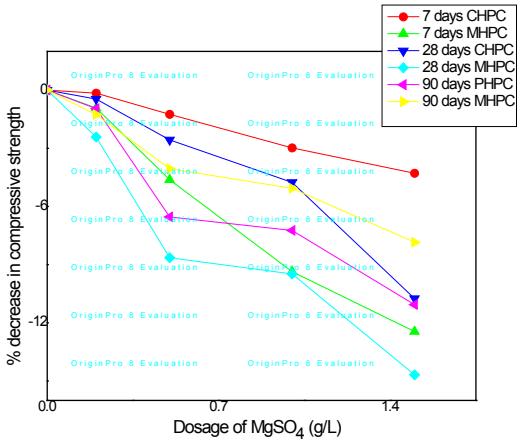


Fig 2: percentage decrease of compressive strengths

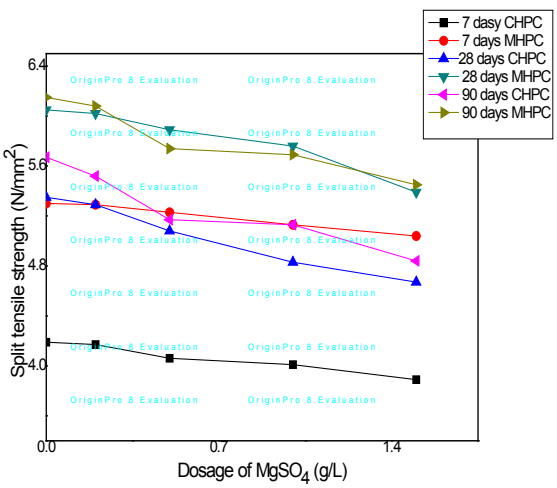


Fig 3: splittensile strengths

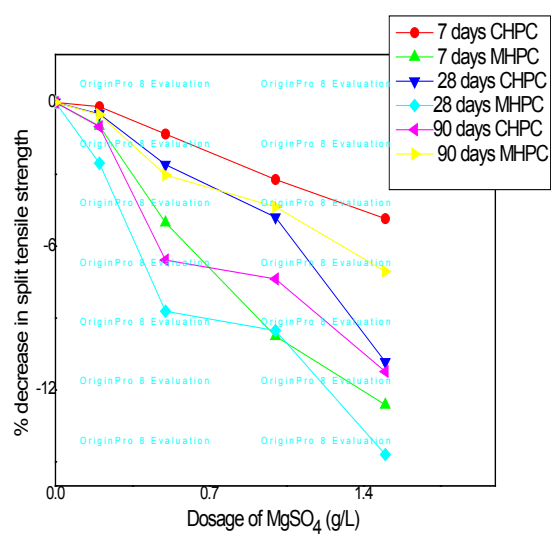


Fig 4: percentage decrease of splittensile strengths

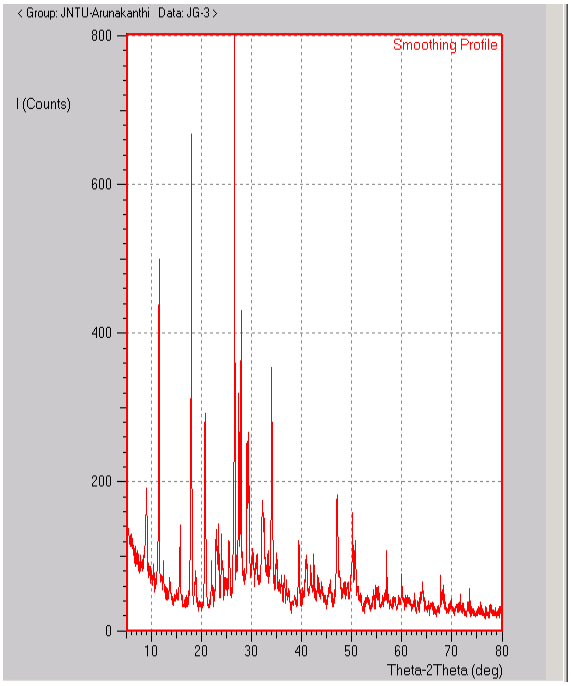


Figure 5: XRD pattern of HPC i) without Metakaolin

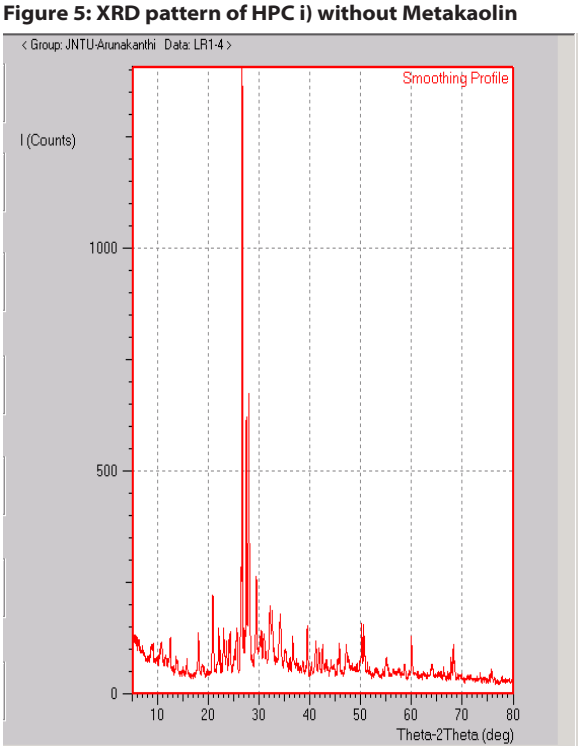


Figure 5: XRD pattern of HPC ii) with Metakaolin

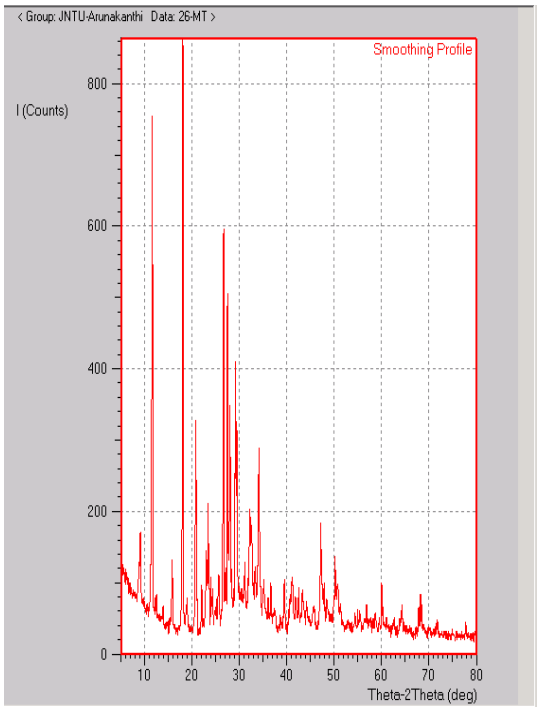


Figure 6: XRD pattern of HPC i) without Metakaolin + $MgSO_4$

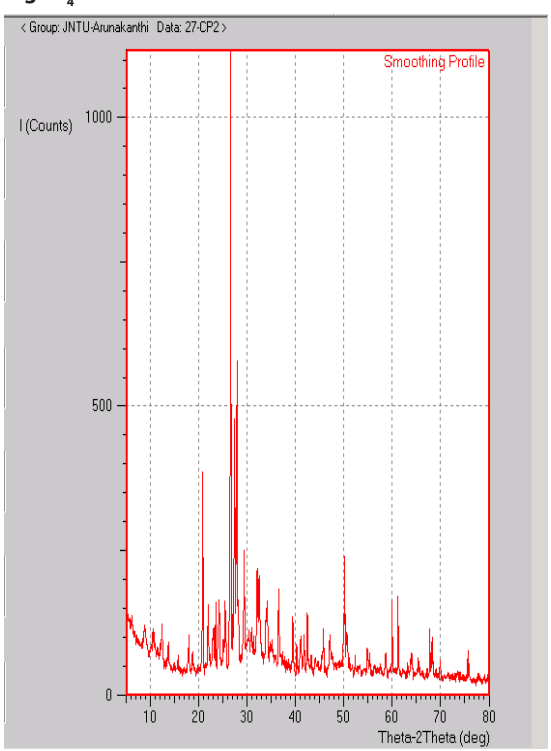


Figure 6: XRD pattern of HPC ii) with Metakaolin + $MgSO_4$

Conclusions

Based on the above results of the investigation conducted on High-performance concrete with partial replacement of cement by 20% metakaolin and subjected to various concentrations of $MgSO_4$, the following conclusions can be drawn:

1. Compressive strength and split tensile strength of HPC increased with the replacement of cement by 20% metakaolin. And the stengths decreased with the increase in concentration of $MgSO_4$ in mixing and curing water.
2. Compressive strength and split tensile strength decrease as the curing period increases for later ages of curing i.e., 7 days, 28 days and 90 days for 20% metakaolin and for all concentrations of $MgSO_4$.
3. From XRD studies it is concluded that the formation of C-S-H gel with more intensity and Portlandite with less intensity may be responsible for more strengths of HPC with metakaolin.
4. From XRD studies it is concluded that the formation of compound Sepiolite may be responsible for decrease in strengths with the increase in concentration of $MgSO_4$.

REFERENCES

1. Arunakanthi. E., Sudarsanarao,H., and Ramanareddy,I.V, (2012), Effects of hydrochloric acid in mixing and curing water on strength of high-performance metakaolin concrete. International journal of applied engineering and technology, Vol.2, No.2 pp.68-76. | 2. Curcio, F., DeAngelis, B. A. and Pagliolico, S. (1998). Metakaolin as a Pozzolanic Micrifiller for High-Performance Mortars. Cement and Concrete Research, Vol. 28, No. 6, pp. 803-809. | 3. Frias, Moises and Cabrera, Joshep. (2000). Pore Size Distribution and Degree of Hydration of Metakaolin-Cement Pastes. Cement and Concrete Research, Vol. 30, No. 4, pp. 561-569. | 4. Goodspeed, C.H., Vanikar, S. and Cook, R.A. (1996). High-Performance Concrete Defined for Highway Structures. Concrete International, Vol. 18, No. 2, pp. 62-67. | 5. IS 516: 1959, Standard Method of test for strength of concrete. | 6. Khatib, J. M. and Wild, S. (1998). Sulphate Resistance of Metakaolin Mortar. Cement and Concrete Research, Vol. 28, No. 1, pp. 83-92. | 7. Palomo, A., Blanco-Varela, M. T., Granizo, M. L., Vazquez, T. and Grutzeck, M. W. (1999). Chemical Stability of Cementitious Materials based on Metakaolin. Cement and Concrete Research, Vol. 20, No. 7, pp. 997-1004. | 8. Poon C.S., L.Lam, S.C.Kou, Y.L.Wong, Ron Wong. (2001). Rate of Pozzolanic reaction of metakaolin in high performance cement pastes. Cement and Concrete Research, Vol.31, pp.1301-1306. | 9. Roy.D.M, P.Arjunan, M.R.Silsbee. (2001). The effect of Silica Fume, Metakaolin and low calcium Fly Ash on Chemical resistance of Concrete. Cement and Concrete Research, Vol.31, pp.1809-1813. |