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Magnesium oxychloride cement concrete

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Abstract. The scope of magnesium oxychloride (MOC) cement in concrete works has been evaluated. MOC cement concrete compositions of varying strengths having good placing and finishing characteristics were prepared and investigated for their compressive and flexural strengths, *E*-values, abrasion resistance etc. The durability of MOC concrete compositions against extreme environmental conditions viz. heating–cooling, freezing–thawing, wetting–drying and penetration and deposition of salts etc were investigated. The results reveal that MOC concrete has high compressive strength associated with high flexural strength and the ratio of compressive to flexural strength varies between 6 and 8. The elastic moduli of the compositions studied are found to be 23–85 GPa and the abrasion losses between 0·11 and 0·20%. While alternate heating–cooling cycles have no adverse effect on MOC concrete, it can be made durable against freezing–thawing and the excessive exposure to water and salt attack by replacing 10% magnesium chloride solution by magnesium sulphate solution of the same concentration.

Keywords. Oxychloride cement concrete; magnesium sulphate; flexural strength; durability.

1. Introduction

Magnesium oxychloride cement (Sorell's cement) is one of the strongest cement possessing certain advantages over Portland cement. It is a high strength, high bonding and quick setting cement with high early strength. It does not require humid curing. It is a tough, stone like fire proof compound (Montle and Mahyan 1974; Thompson 1976) that can be used for light or heavy floorings (Hewlett 1998). Having tremendous load bearing capacity, it can withstand vibrations from heavy cast iron wheel movement without the least trace of cracks or fissures. It is relatively light in weight (sp.gr.2.4). It has low coefficient of thermal expansion and shows negligible volume change during setting. It is used in industrial floorings, ship decks, railway passenger coach floorings, hospital floors, ammunition factory floors, missile silos and underground armament factories and bunkers. Recently, concrete of high compressive and tensile strength prepared with magnesium oxychloride cement and recycled rubber has been reported (Timothy and Lee 1996). Several standards for the raw materials and codes of practice for installing the floors are available all over the world.

The cement is affected by excessive exposure to moisture, particularly at high temperatures. Use of various additives has been suggested to enhance the durability of this cement (Bludnov *et al* 1974; Paul 1975; Mingfen and Wei 1989; Misra and Mathur 1993; Chandrawat and Yadav 2000).

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Despite many merits associated with this cement, its poor resistance to excessive exposure to water has restricted its outdoor applications. There are only a few reports available worldwide on MOC cement concrete. No R&D work is found on MOC cement concrete for its application in roads and bridges etc. Therefore, there is exigent need to develop data through laboratory work for evolving the standards and codes of practice for MOC cement concrete so that the excellent bonding properties of this cement can be fully and effectively utilized in areas where such materials are urgently needed.

The present study was aimed at evaluating the potential of this cement in concrete works including its scope in paving concrete. Consistency and setting times of various MOC cement compositions prepared in the laboratory by mixing lightly calcined magnesite (magnesia) and magnesium chloride solution of different concentrations were determined. MOC cement mortars were prepared by mixing magnesia and inert filler in the ratio of 1 : 3, 1 : 4 and 1 : 5 and gauging the mix with magnesium chloride solution of different concentrations for the determination of compressive and transverse strengths. Concrete mixes were prepared by proportioning of magnesia and aggregates (fine and coarse) and gauging the dry mixes with magnesium chloride solution of varying concentrations to workable consistency.

Tests were performed on cement, mortars and MOC cement concrete compositions to determine their mechanical and durability characteristics. The results of these investigations have been presented and discussed in this paper. From the strength results, relationships were developed whereby dry mix compositions and concentration of magnesium chloride solution can be chosen tentatively for the desired compressive or flexural strength of MOC cement concrete.

2. Experimental

2.1 *Materials*

The raw materials used in the study were calcined magnesite (magnesia), magnesium chloride, magnesium sulphate and coarse and fine aggregates.

Calcined magnesite: Calcined magnesite, passing 97% (minimum) through 150 micron and 95% (minimum) through 75 micron IS sieves, having magnesium oxide (MgO), per cent by mass 87 (minimum), calcium oxide (CaO), per cent by mass 2·5 (maximum), carbon dioxide (CO_2), per cent by mass 2·5 (maximum), loss on ignition (CO_2 and H_2O), per cent by mass 8 (maximum), total contents of MgO, CaO, Al_2O_3, SiO_2 and loss on ignition, per cent by mass 99·5 (minimum).

Magnesium chloride: Magnesium chloride conforming to grade 3 of IS: 254–1973 having magnesium chloride (as $MgCl_2{\cdot}6H_2O$) per cent by mass 95, sulphate (as SO_4) per cent by mass 1·6, calcium (as Ca) per cent by mass 1·0 (maximum) and alkali chlorides (as NaCl) per cent by mass 2·0 (maximum).

Magnesium sulphate: Commercial grade magnesium sulphate, having magnesium sulphate (as $MgSO_4{\cdot}7H_2O$) per cent by mass 85.

Dolomite powder: The inert filler incorporated in the study was uncalcined dolomite ($MgCO_3{\cdot}CaCO_3$) powder passing 100% through 150 micron IS sieve and 50 per cent retained on 75 micron IS sieve.

Coarse aggregate: Locally available blue quartz crushed aggregate fractions passing through a 20 mm and retaining on a 4·75 mm IS sieves.

Fine aggregate: Locally available natural sand passing through a 4·75 mm IS sieve and retaining on a 75 micron IS sieve.

2.2 *Preparation of magnesium chloride/magnesium sulphate solutions*

Magnesium chloride/magnesium sulphate solutions were prepared in water. Flakes of magnesium chloride/magnesium sulphate were transferred into plastic containers to which potable water was added to prepare concentrated solution. This solution was allowed to stand overnight so that insoluble impurities settle at the bottom. The supernatant concentrated solution was taken out in other plastic containers and well stirred after each dilution before determining the specific gravity. Concentration of the solution is expressed in terms of specific gravity on Baume scale (°Be).

2.3 *Standard consistency and setting times of cement pastes*

Wet mixes were prepared by gauging magnesium oxide powder with magnesium chloride solution of known concentrations. The standard consistency, initial setting and final setting times were determined as per IS 10132-1982 using Vicat apparatus.

2.4 *Compressive and transverse strengths of cement mortar paste*

Cement mortars were prepared by gauging the dry mixes of magnesia and dolomite powders in the ratio of 1 : 3, 1 : 4 and 1 : 5 by mass with magnesium chloride solution of concentrations from 16°Be–36°Be as per standard consistency. The compressive and transverse strengths of cement mortars were ascertained from tests on cubes of size 70·6 mm and bars of 100 × 25 × 25 mm size, respectively. The specimens were prepared in metal moulds placed on non absorbent plates. The moulds were filled with the paste and were consolidated with light pressure only. The surface was made smooth with a blade of a trowel. These specimens were placed at 27 ± 2°C and in an atmosphere of 90% relative humidity for 24 h. After this, the specimens were removed from the moulds and were kept in desiccators at 60–70% relative humidity. The specimens were tested at the age of 7 days and 28 days as per IS 10132-1982.

2.5 *Mix proportions of MOC cement concrete*

For the preparation of magnesium oxychloride cement concrete, four concentrations viz. 24, 26, 28 and 30°Be of magnesium chloride solution were chosen corresponding to good workability and high strength of cement mortar pastes.

The dry mix proportions (MgO : aggregates) selected for the study were 1 : 4·5, 1 : 6·5, 1 : 8·5, 1 : 10·5 and 1 : 12·5. The volumes of magnesium chloride solution were so selected as to give workable concrete mixes.

The mix proportions selected for detailed investigations are given below.

Mix proportion (MgO : agg.)	Dry mix composition (MgO : sand : coarse agg.)	Concentration of $MgCl_2$ solution (°Be)
1 : 4·5	1 : 1·5 : 3	24, 26, 28, 30
1 : 6·5	1 : 2·275 : 4·225	24, 26, 28, 30
1 : 8·5	1 : 2·975 : 5·525	24, 26, 28, 30
1 : 10·5	1 : 3·675 : 6·825	24, 26, 28, 30
1 : 12·5	1 : 4·375 : 8·125	24, 26, 28, 30

Various mixes as given above were prepared in the laboratory for determination of the engineering characteristics viz. workability, compressive strength, flexural strength, E-value, abrasion resistance and for durability studies of concrete. Tests for compressive strength, flexural strength and elastic modulus of concrete were performed on cube (100 × 100 × 100 mm), beam (100 × 100 × 500 mm) and cylindrical (height, 300 mm; diameter, 150 mm) specimens, respectively. The test specimens were stored in a place free from vibration, in moist air of 90% relative humidity and at a temperature of 27 ± 2°C for about 24 h. After this period, the specimens were removed from the moulds and kept in an atmosphere of 60–70% relative humidity till their testing. However, no water curing of MOC cement concrete specimens was desired.

2.6 *Abrasion resistance of concrete*

Abrasion resistance of concrete under physical effects was determined as per IS: 9284-1979. The test was conducted on 28-day cured cube specimens from each set. Pneumatic sand blasting cabinet equipment was used and the abrasive charge used was standard sand driven by air pressure. The abrasion loss of specimen was taken as the percentage loss in mass for two separate impressions on the same face of the cube under test.

2.7 *Durability studies*

For outdoor applications, durability of concrete against extreme environmental conditions to which it is expected to be exposed during its service life was investigated. The changes in strength of concrete on exposure to 30 alternate cycles of heating–cooling, freezing–thawing, wetting–drying in water and in 5% sulphate solution were used as the judging index of durability. In the present work, the strength retention coefficient, SRC_{30}, defined as

$$SRC_{30} = S_{28}/RS_{30},$$

were determined, where SRC_{30} is the strength retention coefficient after the specimen was subjected to one of the 30 alternate cycles, S_{28} the strength of 28-day air cured concrete specimen and RS_{30} the retained strength of the specimen after 30 alternate cycles.

The heating–cooling cycle comprised of heating the specimen at 72 ± 2°C in an electric oven for 6 h and cooling in air at room temperature for 18 h.

One freezing–thawing cycle comprised of freezing the specimen at – 10 ± 2°C for 6 h in an environmental chamber and thawing in water at 27 ± 2°C for 18 h.

The wetting–drying and sulphate attack cycles comprised of immersion of the test specimen in water and 5% sodium sulphate solution, respectively at 27 ± 2°C for 6 h and drying at 72 ± 2°C for 18 h.

The effect of replacement of 10% magnesium chloride solution by magnesium sulphate solution on some selected concrete compositions (dry mixes, 1 : 6·5, 1 : 8·5, 1 : 10·5 and solution concentrations, 26 and 30 °Be) were investigated. 28-day strength and retained strength after 30 alternate freezing–thawing, wetting–drying and sulphate attack cycles were determined and the strength retention coefficients for each were worked out. Similarly strength retention coefficients for similar concrete compositions prepared with only magnesium chloride solution were calculated and presented here.

3. Results and discussion

In magnesium oxychloride cement system, depending upon the reactivity of magnesium oxide powder and concentration of magnesium chloride solution, different phases viz. $Mg(OH)_2$, $Mg_3(OH)_5Cl{\cdot}4H_2O$, $Mg_2(OH)_3Cl{\cdot}4H_2O$ etc have been identified (Metkovic and Young 1973; Soloeva *et al* 1974; Sorell and Armstrong 1976; Mathur *et al* 1984; Deng and Zhang 1999). In the present study, since same magnesium oxide was used, the observed variations in standard consistencies and setting times are related to the concentration of magnesium chloride solution. As the concentration of solution increases, the mixes tend to become highly viscous and their setting times were also found to increase (table 1) due to the formation of strength giving 3 and 5 form phases which require more time to set. The compressive and transverse strengths of the mortars increase with concentration of solution (tables 2 and 3).

Table 1. Effect of concentration of $MgCl_2$ solution on standard consistency and setting times of MOC cement.

Concentration of $MgCl_2$ solution (°Be)	Volume of gauging solution (ml)	Setting times (min)	
		Initial	Final
16	33·0	57	142
20	32·0	73	200
24	31·5	60	180
28	31·5	110	257
32	31·5	140	340
36	32·5	270	420

Table 2. Effect of concentration of $MgCl_2$ solution on the compressive strength of MOC cement mortar composition.

Conc. of $MgCl_2$ solution (°Be)	Compressive strength (MPa)					
	1 : 3 (dry mix)		1 : 4 (dry mix)		1 : 5 (dry mix)	
	Curing time (days)					
	7	28	7	28	7	28
20	30·0	40·0	22·8	30·0	10·0	12·8
24	46·0	58·2	30·0	36·0	14·0	17·6
28	61·2	67·0	50·0	56·0	36·8	42·0
32	69·8	72·0	56·0	60·0	39·0	43·0
36	68·6	85·6	64·0	70·0	42·0	44·0

Table 3. Effect of concentration of $MgCl_2$ solution on the transverse strength of MOC cement mortar compositions.

Conc. of $MgCl_2$ solution (°Be)	Transverse strength (MPa)					
	1 : 3 (dry mix)		1 : 4 (dry mix)		1 : 5 (dry mix)	
	Curing time (days)					
	7	28	7	28	7	28
20	10·8	11·1	10·6	11·0	8·6	9·0
24	12·5	12·0	11·8	12·5	9·0	9·8
28	13·0	14·8	13·2	13·7	10·0	12·1
32	15·4	16·1	14·0	14·5	11·3	12·5
36	15·8	18·0	15·5	15·8	13·0	13·0

Table 4. Compressive and flexural (within brackets) strengths, MPa of MOC concrete.

Dry mix (MgO : agg.)	Concentration of magnesium chloride solution											
	24°Be			26°Be			28°Be			30°Be		
	Curing time (days)											
	1	7	28	1	7	28	1	7	28	1	7	28
1 : 4·5	17·8	44·0	51·0	29·5	58·0	62·0	37·8	60·6	70·0	59·4	73·5	78·0
	(3·3)	(6·4)	(6·6)	(4·5)	(7·7)	(8·1)	(5·9)	(8·0)	(8·9)	(8·1)	(8·6)	(9·6)
1 : 6·5	17·2	26·9	40·0	28·6	40·6	50·9	34·5	50·4	58·0	42·7	58·0	68·4
	(3·2)	(4·2)	(5·3)	(4·6)	(6·1)	(7·0)	(5·4)	(6·9)	(8·0)	(6·3)	(8·0)	(8·2)
1 : 8·5	16·7	26·5	32·0	21·3	39·7	42·4	24·7	40·8	48·0	39·0	53·5	60·0
	(3·2)	(4·1)	(5·0)	(3·7)	(5·9)	(6·4)	(4·0)	(5·9)	(6·8)	(5·8)	(7·3)	(8·0)
1 : 10·5	12·2	21·5	30·0	20·9	34·4	39·0	23·3	36·7	42·1	24·0	42·0	50·0
	(2·7)	(3·8)	(4·5)	(3·8)	(5·4)	(6·0)	(3·8)	(5·6)	(6·3)	(3·8)	(6·2)	(6·8)
1 : 12·5	10·1	19·2	25·0	11·7	18·0	26·5	13·6	28·4	31·5	17·5	31·5	37·0
	(2·0)	(3·4)	(4·1)	(2·5)	(3·6)	(4·2)	(2·7)	(4·6)	(4·9)	(2·8)	(5·3)	(5·4)

Magnesium oxychloride cement concrete is basically a mixture of aggregates and paste. The usual method, as adopted for Portland cement concrete to determine the relationship between compressive strength and water-cement ratio is not applicable in MOC cement concrete. However, concrete compositions of wide strength range can be prepared from the same dry mix by minor adjustment in the concentration of magnesium chloride solution. Similarly, dry mixes having different proportions of aggregates viz. 1 : 4·5 to 1 : 12·5 and magnesium chloride solution of different concentrations can be used to prepare MOC cement concrete of varying strengths (table 4). As against Portland cement concrete which is weak in tension, the MOC cement concrete compositions have high compressive strength associated with high flexural strength, the ratio being 6–8 (table 5). Since the pavement design

Table 5. Effect of age on the ratio of compressive strength to flexural strength of MOC concrete.

Dry mix (MgO : agg.)	Concentration of magnesium chloride solution											
	24°Be			26°Be			28°Be			30°Be		
	Curing time (days)											
	1	7	28	1	7	28	1	7	28	1	7	28
1 : 4·5	5·40	6·87	7·73	6·55	7·48	7·65	6·37	7·49	7·86	7·30	8·47	8·08
1 : 6·5	5·39	6·40	7·55	6·22	6·60	7·27	6·52	7·28	7·25	6·76	7·20	8·34
1 : 8·5	5·23	6·46	6·34	5·75	6·73	6·59	6·17	6·91	7·05	6·66	7·28	7·45
1 : 10·5	4·53	5·58	6·66	5·51	6·37	6·53	6·13	6·52	6·71	6·36	6·79	7·28
1 : 12·5	5·05	5·56	6·02	4·60	5·01	6·30	4·96	6·17	6·63	6·32	5·88	6·85

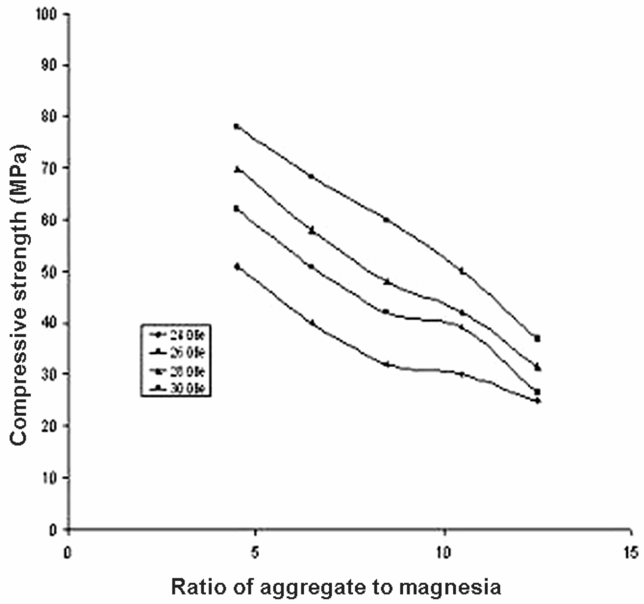

Figure 1. Compressive strength vs dry mix proportions.

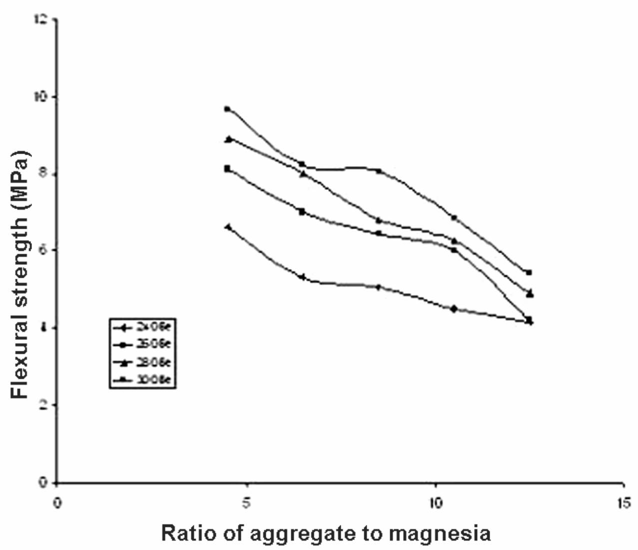

Figure 2. Flexural strength vs dry mix proportions.

Table 6. *E*-value of MOC concrete.

Dry mix (MgO : agg.)	*E*-value (GPa) Concentration of $MgCl_2$ solution (°Be)			
	24	26	28	30
1 : 4·5	53	64	78	85
1 : 6·5	42	55	73	80
1 : 8·5	34	37	56	50
1 : 10·5	28	34	40	45
1 : 12·5	23	27	32	37

Table 7. Abrasion loss (%) of MOC concrete.

Dry mix (MgO : agg.)	Concentration of solution (°Be)			
	24	26	28	30
1 : 4·5	0·11	0·10	0·10	0·10
1 : 6·5	0·15	0·11	0·10	0·10
1 : 8·5	0·16	0·12	0·12	0·11
1 : 10·5	0·17	0·13	0·12	0·11
1 : 12·5	0·20	0·14	0·13	0·12

of concrete roads is based on flexural strength, the required slab thickness of MOC concrete shall be less as compared to that of Portland cement concrete.

MOC cement concrete compositions (table 4) having 1 day compressive strength, ≥ 34 MPa and 28-day compressive strength, ≥ 69 MPa, correspond to the high early strength (HES) and very high strength (VHS) concrete (Zia *et al* 1994). Even the compositions prepared with very lean dry mix (1 : 12·5) and those prepared with dilute magnesium chloride solution (24°Be) have 1-day compressive strength (> 10 MPa) sufficient for the removal of form works etc and 28-day flexural strength (≥ 4 MPa) sufficient for paving application.

Concrete compositions of desired compressive and flexural strengths needed for varied applications can be tentatively chosen from the relationships developed under the study (figures 1 and 2).

Elastic modulus of concrete (table 6) increases with the concentration of magnesium chloride solution and for

Table 8. Effect of heating–cooling cycles on 28-day compressive strength, MPa of MOC concrete.

Dry mix (MgO : agg.)	28-day strength of concrete				Strength after 30 cycles of heating–cooling			
	Concentration of the solution (°Be)							
	24	26	28	30	24	26	28	30
1 : 4·5	51·0	62·0	700	78·0	55·0	66·0	75·0	83·0
1 : 6·5	40·0	50·9	58·0	68·0	45·0	59·0	62·5	72·0
1 : 8·5	33·2	42·4	48·0	60·0	35·0	43·0	53·0	65·0
1 : 10·5	30·0	39·0	42·0	50·0	31·5	40·0	42·5	55·0
1 : 12·5	25·0	26·5	31·5	32·0	25·5	30·0	32·5	37·0

Table 9. Effect of freezing–thawing cycles on 28-day compressive strength, MPa of MOC concrete.

Dry mix (MgO : agg.)	28-day strength of concrete				Strength after 30 cycles of freezing–thawing			
	Concentration of the solution (°Be)							
	24	26	28	30	24	26	28	30
1 : 4·5	51·0	62·0	70·0	78·0	40·0	48·5	53·0	60·0
1 : 6·5	40·0	50·9	58·0	68·0	31·0	40·0	44·0	55·0
1 : 8·5	33·2	42·4	48·0	60·0	25·7	32·0	37·8	46·0
1 : 10·5	30·0	39·0	42·0	50·0	22·4	28·4	32·0	38·0
1 : 12·5	25·0	26·5	31·5	32·0	17·5	20·4	24·0	24·5

Table 10. Effect of alternate wetting–drying cycles on 28-day compressive strength, MPa of MOC concrete.

Dry mix (MgO : agg.)	28-day strength of concrete				Strength after 30 cycles of wetting–drying			
	Concentration of the solution (°Be)							
	24	26	28	30	24	26	28	30
1 : 4·5	51·0	62·0	70·0	78·0	36·8	45·6	49·6	53·6
1 : 6·5	40·0	50·9	58·0	68·4	29·2	36·8	40·5	48·4
1 : 8·5	33·2	42·4	48·0	60·0	23·0	30·0	35·0	42·5
1 : 10·5	30·0	39·0	42·0	50·0	21·5	27·2	30·0	34·0
1 : 12·5	25·0	26·5	31·5	32·0	19·0	20·1	24·5	24·0

Table 11. Effect of sulphate attack on 28-day compressive strength, MPa of MOC concrete.

Dry mix (MgO : agg.)	28-day strength of concrete				Strength after 30 cycles of sulphate attack			
	Concentration of the solution (°Be)							
	24	26	28	30	24	26	28	30
1 : 4·5	51·0	62·0	70·0	78·0	36·0	43·5	48·0	54·7
1 : 6·5	40·0	50·9	58·0	68·4	28·8	35·0	40·0	47·0
1 : 8·5	33·2	42·4	480	60·0	24·5	31·5	36·0	40·0
1 : 10·5	30·0	39·0	42·0	50·0	21·0	29·0	31·0	32·0
1 : 12·5	25·0	26·5	31·5	32·0	19·0	20·0	23·0	22·5

strong compositions, its values are 70–85 GPa. The high strength of MOC cement concrete prepared with large proportions of aggregates is due to the high surface area (acicular structure) of MOC cement and its excellent bonding characteristics due to which it can migrate deep into the aggregate surface and forms interparticle and inter-surface friction (Timothy and Lee 1996). During compression, the aggregate–cement bond remains intact and aggregates themselves fail which was observed from the failure plains of concrete specimens. At higher concentra-

Table 12. Retained strength (MPa) and strength retention coefficient of MOC concrete after durability cycles.

		26°Be			30°Be		
Durability cycles	Dry mix (MgO : agg.)	28-day strength	Retained strength	Strength retention coefficient	28-day strength	Retained strength	Strength retention coefficient
Freezing/thawing	1 : 6·5	50·9	40·0	0·78	68·0	55·0	0·80
	1 : 8·5	42·4	32·0	0·75	60·0	46·0	0·77
	1 : 10·5	39·0	28·4	0·72	50·0	38·0	0·76
Wetting/drying	1 : 6·5	50·9	36·8	0·72	68·0	48·4	0·71
	1 : 8·5	42·4	30·0	0·71	60·0	42·5	0·71
	1 : 10·5	39·0	27·2	0·70	50·0	34·0	0·60
Sulphate attack	1 : 6·5	50·9	35·0	0·69	68·0	47·0	0·69
	1 : 8·5	42·4	31·5	0·74	60·0	40·0	0·66
	1 : 10·5	39·0	29·0	0·74	50·0	32·0	0·64

Table 13. Effect of magnesium sulphate solution on retained strength (MPa) and strength retention coefficient of MOC concrete after durability cycles.

		26°Be			30°Be		
Durability cycles	Dry mix (MgO : agg.)	28-day strength	Retained strength	Strength retention coefficient	28-day strength	Retained strength	Strength retention coefficient
Freezing/thawing	1 : 6·5	48·0	43·5	0·90	66·0	57·0	0·86
	1 : 8·5	40·0	36·4	0·91	55·2	48·0	0·86
	1 : 10·5	34·0	30·7	0·88	45·5	39·0	0·86
Wetting/drying	1 : 6·5	48·0	42·0	0·88	66·0	58·5	0·88
	1 : 8·5	40·0	35·0	0·87	55·2	48·0	0·87
	1 : 10·5	34·0	29·5	0·86	45·5	38·0	0·83
Sulphate attack	1 : 6·5	48·0	42·0	0·86	66·0	60·0	0·90
	1 : 8·5	40·0	35.7	0·89	55·2	48·0	0·87
	1 : 10·5	34·0	29·1	0·85	45·5	40·0	0·88

tions, a better match of elastic moduli of matrix and aggregate seems to be the reason of very high strength and elastic modulus of MOC cement concrete due to strong paste–aggregate interface (Nabil *et al* 2002).

MOC concrete compositions are highly resistant towards abrasion (table 7) and are suitable for all kinds of floorings and concrete pavements as per IS: 9284-1979.

Alternate heating–cooling results in increased strength of MOC concrete. However, the strength of concrete is affected by cycles of alternate freezing–thawing and wetting–drying in water and in sulphate solution (tables 8–11).

From tables 12 and 13 it can be seen that the values of strength retention coefficients of MOC concrete range between 0·6 and 0·7 while for compositions incorporating magnesium sulphate, strength retention coefficients are $\geq$ 0·8 (table 12) and hence suitable for all engineering applications.

4. Conclusions

(I) MOC cement is an early setting, high strength cement and can bind high proportions of aggregates and fillers.

(II) MOC cement concrete compositions have good rheological properties with excellent workability and placing characteristics. After setting, it does not require water curing.

(III) MOC cement concrete has high compressive strength associated with high flexural strength. This property can obviate the need of fibre reinforcement in MOC concrete, and permits reduction in slab thickness of concrete pavement.

(IV) MOC cement concrete has very high elastic modulus as compared to Portland cement concrete of same compressive strength.

(V) MOC cement concrete of desired strengths can be prepared by using various dry compositions and concentrations of gauging solution.

(VI) Replacement of 10% magnesium chloride solution by magnesium sulphate solution of same concentration makes the concrete resistant towards extreme weather conditions.

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