Experimental Study on MOC Cement Based Micro Concrete for Repairing of Wide Cracks in Concrete Pavement Slabs

Avanish Singh, Rakesh Kumar, and Pankaj Goel

Abstract Cracks of variable width and types can develop due to various factors like overloading, thermal expansion and contraction, moisture and temperature stresses, poor construction quality, loss of support underneath the slab, and other similar causes. Often a combination of these factors contributes to the propagation and widening of cracks over time resulting in surface roughness if not repaired properly. Wide crack even requires reconstruction or a full-depth repair. Cracks should be repaired with a durable material lasting for longer life. To repair these cracks, several materials and procedures have been developed. The efficiency of these materials and procedures depends on weather conditions and application efficiency. This study aims to develop a cost-effective magnesium oxychloride cement-based micro concrete for a faster repair of wide cracks; 25 mm or more. To simulate the conditions in the laboratory beam specimens cast and tested for flexure strength failure were used. Then broken beams were repaired by laboratory-developed MOC cement-based micro concrete and again tested for flexure strength. It was found that up to about 80% flexure strength can be restored in one day.

Keywords Micro concrete · Flexure strength · Repair material · Compressive strength

1 Introduction

Concrete pavements often suffer cracking during their lifetime due to various reasons. Concrete cracks, when the tensile stress generated due to the physical and/or chemical processes exceeds its tensile strength. Some of the more typical causes in concrete pavement cracking include drying shrinkage, chemical reaction, thermal expansion, poor quality materials, lack of appropriate control joints and overload conditions, loss of underneath support, and the combinations of the causes that produce flexural,

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H. R. Pasindu et al. (eds.), *Road and Airfield Pavement Technology*, Lecture Notes in Civil Engineering 193, https://doi.org/10.1007/978-3-030-87379-0_10

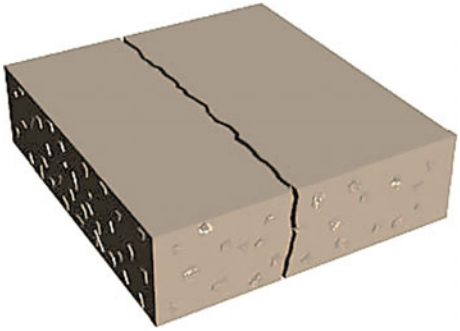

Fig. 1 Typical view of cracked concrete slab

tensile, or shear cracks in concrete. Cracks may not affect the appearance only but also causes the loss of structural integrity and functional characteristics of the pavement by making the surface rough. Repair of deteriorated concrete pavement is essential to restore structural capacity and assure serviceability and safety of road users (Fig. 1).

The concrete repair material industry shows a rapid development, the cases where the concrete repair materials that cannot meet their needs are quite common. It is estimated that almost half of the materials used for concrete repair fails in the application site conditions [1]. Repair materials are divided into 4 types: ordinary Portland cement (OPC)-based materials (cement paste, mortar, and self-compacting concrete), modified cement-based materials (cement mortars with high aluminum content, with phosphate, and concrete with fibers), polymer modifiers for OPC based products (styrene butadiene, acrylic, vinyl acrylic, or other copolymers modified cement-based materials), and pure polymers (epoxy resins, polyesters and some polyurethane-based systems) [2–4]. Park and Yang [5] reported that OPC mortars developed satisfactory performance to repair of reinforced concrete structures; however, polymer-modified mortars provided better mechanical properties of the repaired structural element [6]. The choice of repair materials with poor performance generates a significant spend of money and it is a big challenge in the civil construction industry [7]. Repair materials currently in use have serious problems due to generally early-age poor performance or incompatibility with the substrate or low endurance properties for a long time.

2 Scope of Study

The main objective of this study is to experiment with the use of magnesium oxychloride cement-based micro concrete to restore the integrity of a cracked slab (crack width >= 25 mm) under near gravity filling of the crack, emphasizing the physical characteristics of MOC cement. As a result, the objective of this laboratory work is to restore structural integrity and increase the flexure strength of cracked concrete beams by manual filling of MOC-based micro concrete.

3 Materials and Method

3.1 MOC Based Micro Concrete

To prepare the MOC-based micro concrete magnesium oxide of 85% purity, magnesium chloride solution, and locally available filler material was used. Two samples of MOC-based micro concrete were prepared. The detailed characteristics of MOC-based micro concrete are given in Table 1

Table 1 Properties of MOC based micro concrete

Characteristics	Sample 1	Sample 2
MgO:Sand	1:2	1:3
Concentration of $MgCl_2$ solution	26°Be	26°Be
Pot life		
20 °C	140 min	150 min
30 °C	100 min	110 min
40 °C	60 min	65 min
Flow (IS 5512)		
5 min	185 mm	190 mm
15 min	175 mm	185 mm
30 min	160 mm	160 mm
Compressive Strength (ASTM C 109)		
1 day	48 MPa	30 MPa
3 days	56 MPa	48 MPa
7 days	66 MPa	56 MPa
Flexure Strength (ASTM C 348)		
1 day	11 MPa	8 MPa
3 days	15 MPa	10 MPa
7 days	17 MPa	13 MPa
Bond Strength (MDOT)		
1 day	3.2 MPa	3.0 MPa
Drying shrinkage (ASTM 490)		
7 days	0.038%	0.036%
14 days	0.040%	0.041%
21 days	0.056%	0.054%
Abrasion Resistance (IS 9284)	0.26%	0.32%

Table 2 Mix details of substrate concrete

Description	M30	M40
Cement (kg)	375	400
20 mm Aggregate (kg)	613	575
10 mm Aggregate (kg)	695	705
Sand (kg)	629	658
Water (kg)	168	160
Super Plasticizer (%)	0.5	0.35

Table 3 Physical properties of substrate concrete

Test	M30 (MPa)	M40 (MPa)
Compressive strength (28 days)	34	45
Flexure strength (28 days)	3.8	5.2

3.2 Substrate Concrete

For the substrate concrete two grades of concrete M30 and M40 were prepared and cured for 28 days.

- Coarse aggregate: Crushed quartzite coarse aggregate of nominal maximum size of 20 mm ($\gamma = 1580$ kg/m^3 for the size range 10–20 mm, $\gamma = 1600$ kg/m^3 for the size range 4.75–10 mm) was used.
- Fine aggregates: fine aggregate used in the mix was river sand (4.75 mm) size, (γ = 1640 kg/ m^3).
- Cement: OPC 43 grade was used for both M30 and M40 grades.

The mix details and physical properties of the substrate concrete are given in Table 2 and Table 3, respectively.

3.3 Crack Repair by Micro Concrete Filling

If repair is required to restore structural integrity for cracks with surface widths of 25 mm and extending downward from nearly horizontal surfaces, they should be repaired by micro concrete filling incorporating a long pot-life material. First of all, the cracked surfaces should be cleaned. Contaminants such as oil, grease, dirt, or fine particles of concrete prevent bonding and diminish the effectiveness of repairs. Preferably, contamination should be removed by vacuuming or flushing with water (water blasting) or other especially effective cleaning solutions (air blasting). Then MOC based micro concrete should be filled in the crack and compacted by tamping rod and left in the atmosphere for curing for 24 h (Fig. 2).

Fig. 2 Repaired broken beams of substrate concrete

3.4 Compressive Strength of Concrete Cubes

Compressive strength cube specimens with dimensions 150 × 150 × 150 mm were cast from the concrete mix with and without fibers for the determination of compressive strength at various ages. The cubes were demolded after 24 h of casting and moist curing. Thereafter the molded specimens were marked for identifications and kept submerged in curing tanks at room temperature for 28 days.

3.5 Flexure Strength of Concrete Beams

The design of concrete pavement is based on the flexural strength of concrete. The flexural strength of concrete is determined by the use of beam specimen under 4-point loading standard test procedure. The beam specimen with the dimension 100 × 100 × 500 mm were cast from concrete mix. The beams were demolded after 24 h of casting and cured for 28 days.

4 Interpretation of Results

The compressive strength and flexure strength of substrate concrete after 28 days of curing are presented in Table 3. The broken beams tested for flexure strength were cut 1 in. from the longer portion to ensure a required gap between the two pieces of the tested beam. Repaired beams were air-cured for 1 day, 3 days, and 7 days, then tested for the flexure strength, and the results are presented in Table 4 (Figs. 3 and 4).

Table 4 Flexure strength of beams after repair

	Initial strength (MPa)	After repair (Sample1) (MPa)			After repair (Sample2) (MPa)		
		1 day	3 day	7 day	1 day	3 day	7 day
M30	3.8	3.0	3.1	3.1	2.5	2.5	2.6
M40	5.2	3.2	3.5	3.5	2.9	3.0	3.0

Fig. 3 Testing of compressive strength of substrate concrete

Fig. 4 Testing of flexure strength of substrate concrete under 4-point loading

5 Observations and Conclusions

Cracking of concrete is a casual process, highly variable, and influenced by numerous factors. However, the longer the crack, the higher the stress concentrations induced

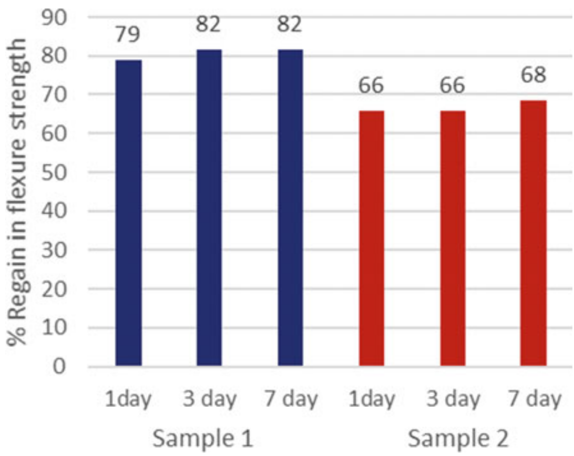

Fig. 5 Percentage regain in flexure strength of M30 grade repaired concrete beams

by it. Due to the presence of a crack in a structural element, the strength of the structure will decrease progressively with the increase of the size of the crack. As a result, the structure will be subject to failure when its strength becomes too low that fracture occurs under normal loading. This experimental study proved that completely fractured beams and concrete paving slabs can be repaired successfully to restore up to 80% of their original strength by using MgO-based repair material.

Beams repair by sample 1 (MOC based micro concrete having MgO: Sand is 1:2) shown an appreciable amount of regain in flexure strength. It is also evident from the results that the flexure strength of repaired beams is almost constant with the age. For M30 grade 82% and for M40 grade 67% flexure strength was regained by broken beams. Similarly, beams repair by sample 2 (MOC based micro concrete having MgO: Sand is 1:3) also shown a considerable amount of regain in flexure strength. For M30 grade 68% and for M40 grade 58% flexure strength was regained. Figures 5 and 6 shows the % regain in the flexure strength of M30 and M40 grade beams repaired by MOC-based micro concrete. Figure 7 shows the failure of repaired beams. It is clear that all the beams are failed in bond. That is why flexure strength is not increasing with the age.

Thus, the use of MOC-based micro concrete can be a cost-effective solution for the repair of wide cracks, as it can regain up to 80% flexure strength. It is an economical alternative for easily available repair materials in the market such as epoxy-based and polymer-based. It costs about 10 times cheaper than epoxy-based repair materials.

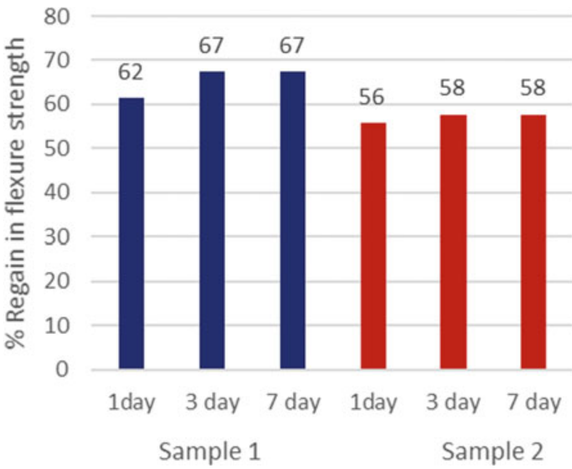

Fig. 6 Percentage regain in flexure strength of M40 grade repaired concrete beams

Fig. 7 Typical view of failure in repaired beams of substrate concrete

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