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Mechanical properties and durability characteristics of polymer- and cement-based repair materials

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Abstract

This study was conducted to evaluate the mechanical properties and durability characteristics of nine polymer- and cement-based repair mortars. Mechanical properties, such as compressive, tensile and flexural strength, elastic modulus, shrinkage and thermal expansion were studied. The durability characteristics of the repair materials were evaluated by measuring: (i) chloride permeability, (ii) electrical resistivity and (iii) carbonation depth. The mechanical properties of the selected repair mortars did not vary very significantly from each other. The elastic modulus of the polymer-based repair mortars was less than that of the cement-based repair mortars. This will lead to a reduced drying shrinkage cracking in the former repair mortars compared to the latter. The electrical resistivity of polymer-based repair mortars was more than that of cement-based repair mortars. Such a trend was not noted in the chloride permeability data. The chloride permeability in all the repair materials was very low according to ASTM C 1202 criteria. Enhanced carbonation was noted in some of the polymer-based repair mortars.

Keywords: Cement- and polymer-based repair materials; Durability characteristics; Mechanical properties

1. Introduction

Reduction in the useful service-life of reinforced concrete construction is a major problem confronting the construction industry worldwide. Concrete deterioration due to reinforcement corrosion is evident in the mild climatic conditions of the world while in the hot and arid regions this problem is caused due to a combination of environmental conditions, marginal aggregates and inappropriate construction methods. Considerable resources are expended to repair and rehabilitate the deteriorated concrete structures.

Repair and rehabilitation of deteriorated concrete structures are essential not only to utilize them for their intended service-life but also to assure the safety and serviceability of the associated components. A good repair improves the function and performance of the structure, restores and increases its strength and stiffness, enhances the appearance of the concrete surface, provides water tightness, prevents ingress of the aggressive species to the concrete/steel interface, and improves its durability.

Several repair materials are marketed for the repair of deteriorating concrete structures. These repair materials are classified into different types, such as cement, epoxy resins, polyester resins, polymer latex and polyvinyl acetate. Cement-based materials and polymer/epoxy resins are the most widely used among the repair materials [1–3]. These materials mostly consist of a conventional cement mortar often incorporating special waterproofing admixtures. These admixtures are commonly impregnated with one or more additives, such as polymer, silica fume, fly ash or other industrial by-products.

Polymer modified cement repair materials are used to overcome the problems associated with the cement-based repair materials, particularly the need for a longer curing period. Over the years, many different polymers have been used in a range of applications in the repair and maintenance of buildings and other structures. Such polymer mortars provide the same alkaline passivation protection to the reinforcing steel, as do the conventional cement materials [4,5]. Polymers are usually used as admixtures; they are supplied as milky white dispersions

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in water and in that state are used either as a whole or as a partial replacement of the mixing water. The polymer also serves as a water-reducing plasticizer that produces a mortar with a good workability and lower shrinkage at lower water-to-cement ratios. Polyvinyl acetates, styrene butadine rubber and polyvinyl dichlorides are some of the polymers commonly used in the cement mortars. A recent development in the field of polymers are redispersible spray-dried polymer powders, which may be factory blended with graded sand, cement, and other additives to produce mortars and bonding coats simply by adding water on site.

For the repair to be successful there should be compatibility between the repair material and the base concrete. Physical and chemical compatibility are some of the criteria considered in the selection of a repair material.

The study reported in this paper was conducted to evaluate the mechanical properties and durability characteristics of nine cement- and polymer-based repair materials.

2. Test procedures

2.1. Selection of repair materials

Seven proprietary repair materials were selected to represent the generic type of repair mortars that are presently utilized in the repair of deteriorated concrete. Three of the selected proprietary repair mortars were cement-based while the other four were polymer-based. In addition to proprietary repair mortars two cement-based repair mortars (CB1 and CB2) prepared in the laboratory were also evaluated. Table 1 summarizes the composition of the repair mortars evaluated in this study.

Table 1
Selected cement- and polymer-based repair mortars

Repair mortar	Description
CB1	Portland cement mortar (w/c: 0.38, sand/cement 2.5)
CB2	Portland cement silica fume mortar (w/c: 0.38, sand/cement 2.5, silica fume 5% of total cement)
CB3	Pre-packed blend of Portland cement, fine aggregate, fillers and additives
CB4	Pre-packed blend of Portland cement, fine aggregate and additives
CB5	One component cement-based repair mortar
PB1	Consists of Portland cement, sand and acrylic latex admixture
PB2	Consists of Portland cement, silica fume, fibers and polymer
PB3	Pre-packed blend of cement, silica fume and polymer
PB4	Single component polymer based-repair material. Based on Portland cement, graded aggregate, special fillers and chemical additives

2.2. Mechanical properties

The selected repair materials were tested to evaluate the following mechanical properties:

(a) flow, according to ASTM C 190;
(b) stiffening time, according to BS 4551;
(c) bleed, non-standard;
(d) compressive strength, according to ASTM C 109;
(e) tensile strength, according to BS 6319;
(f) flexural strength, according to BS 6319;
(g) elastic modulus, according to BS 6319;
(h) drying shrinkage, according to ASTM C 157;
(i) thermal expansion, according to ASTM C 531 and
(j) adhesion, according to BS 6319 Part 4.

2.3. Durability characteristics

The durability characteristics of the selected repair materials were evaluated by measuring chloride permeability, electrical resistivity, and depth of carbonation. For this purpose, specimens of varying sizes were prepared and tested. Details of the test procedures are discussed in the following sections.

2.3.1. Chloride permeability

Cylindrical specimens 75 mm in diameter and 50 mm high were prepared using the selected repair materials and the chloride ion permeability was determined as per the procedure described in ASTM C 1202.

2.3.2. Electrical resistivity

Cylindrical specimens 75 mm in diameter and 150 mm high were prepared using the selected repair materials. After sufficient curing they were utilized for measuring the electrical resistivity.

The electrical resistivity was measured using a SG ABEM Terrameter SAS 330 C precision digital electrical resistance meter. To measure the electrical resistivity, the specimen was fixed in a steel frame with end plates made of copper. The copper plates were covered with a cloth pad wetted with copper sulfate solution. The copper plate and wet cloth combination ensured a uniform distribution of current across the face of the test specimen. The current and potential binding posts, C1 and P1, were connected to one plate of the test frame, while the other current and the potential posts, C2 and P2, were connected to the other plate, as shown in Fig. 1. After fixing the specimen in the test frame, a current of known intensity was applied and the resulting resis-

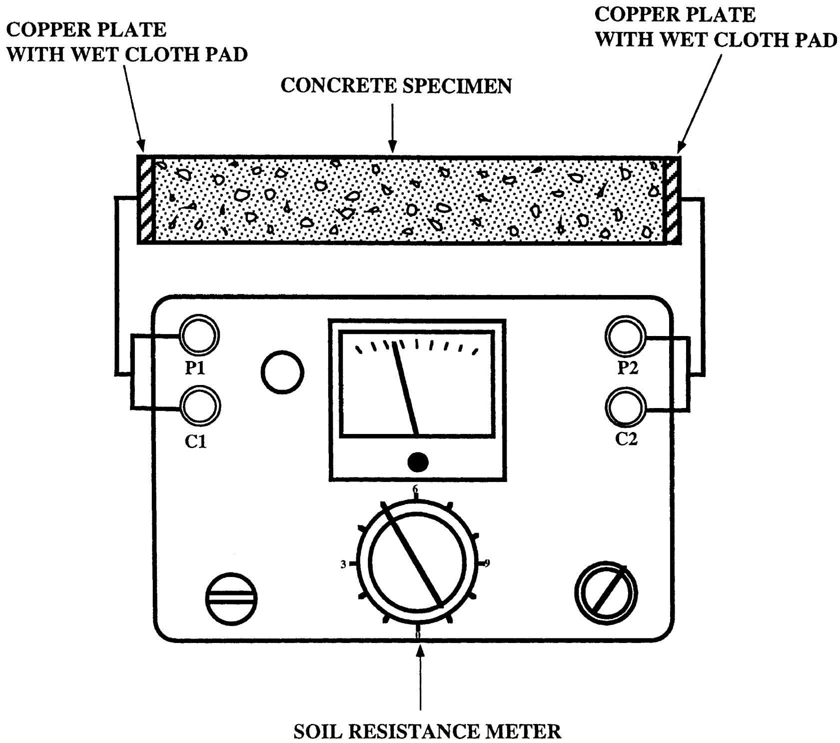

Fig. 1. Schematic representation of electrical resistivity measurements.

tance was read directly on the digital display of the equipment.

The electrical resistivity was obtained using the following expression:

resistivity $= RA/L \quad \Omega\,\text{cm}$,

where R is the resistance (Ω), A is the area of cross-section of the specimen (cm^2) and L is the length of the specimen (cm).

Since electrical resistivity is a function of the moisture content in concrete, resistance measurements were

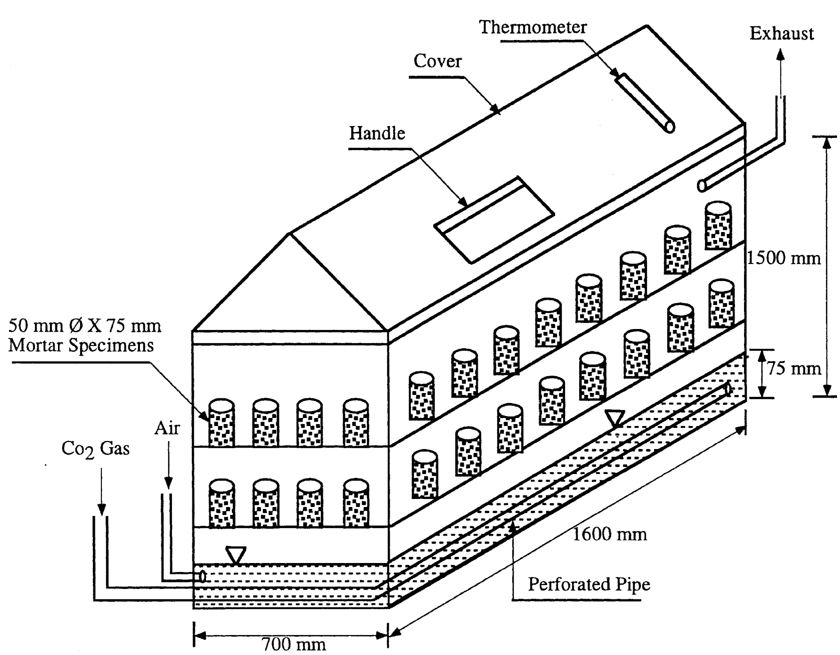

Fig. 2. Schematic representation of the accelerated carbonation chamber.

conducted after immersing the specimens in water for various time periods. When no further gain in weight was noted, the specimens were dried. These data were utilized to determine the relationship between moisture content and the electrical resistivity for each material.

2.3.3. Carbonation

The carbonation-resistance of the repair materials was determined using a non-standard test method. For this purpose, cylindrical specimens, 50 mm in diameter and 72 mm high, were prepared.

The prepared specimens were then exposed to an accelerated carbonation environment (6% CO_2, 55 °C temperature, and 70% RH) inside a chamber as shown in Fig. 2. The specimens were retrieved from the exposure chamber after, 2, 4, 6 and 12 months of exposure and cut at mid height to obtain two freshly broken surfaces. Phenolphthalein was sprayed on the freshly broken surfaces, and the depth of carbonation measured at 12 locations equally spaced on each surface. The average of 24 measurements was noted as the depth of carbonation.

3. Results

3.1. Mechanical properties

The flow characteristics of the selected polymer- and cement-based repair mortars are summarized in Table 2. While the flow of CB3 and CB4 was beyond the measuring range, as these materials were very fluid, no flow was measured in Portland cement (CB1) and silica fume cement (CB2) mortar specimens. The flow of other polymer- and cement-based repair mortars was in the range of 34–86%.

The stiffening time for the selected polymer- and cement-based repair mortars is summarized in Table 3. The stiffening time for all the proprietary products was of longer duration than that for Portland cement and silica fume cement mortars, except CB3 that was in a similar range.

Table 2
Flow characteristics of selected polymer- and cement-based repair mortars

Repair mortar	Flow (%)
CB1	None
CB2	None
CB3	Flowing
CB4	Flowing
CB5	86
PB1	78
PB2	48
PB3	36
PB4	34

Table 3
Stiffening rate of polymer- and cement-based repair materials

Repair mortar	Time (min) for a penetration resistance of		
	1 N/mm^2	1.5 N/mm^2	2 N/mm^2
CB1	114	145	167
CB2	139	182	212
CB3	159	180	197
CB4	305	345	375
CB5	305	339	364
PB1	NA[a]	NA[a]	NA[a]
PB2	278	342	387
PB3	278	342	387
PB4	295	366	443

[a] NA: Not available.

The bleeding characteristics of selected polymer- and cement-based repair mortars are summarized in Table 4. High bleeding was noted in CB3 repair mortar, while it was very low in the other repair mortars. Increased bleeding in CB3, CB4 and PB2 is expected, as these are supposed to be flowing mortar/concrete.

Table 5 shows the compressive strength development in the selected polymer- and cement-based repair mortars. As expected, the compressive strength of specimens prepared with the selected polymer- and cement-based repair mortars increased with the age of curing. After 28 days of curing, the highest compressive strength was

Table 4
Bleeding in selected polymer- and cement-based repair mortar specimens

Repair mortar	Bleeding	
	Rate (cm^3/cm^2 s)	Total (%)
CB1	No bleeding	No bleeding
CB2	No bleeding	No bleeding
CB3	0.000049	3.98
CB4	0.0000047	0.57
CB5	No bleeding	No bleeding
PB1	No bleeding	No bleeding
PB2	0.0000058	0.48
PB3	No bleeding	No bleeding
PB4	No bleeding	No bleeding

Table 5
Compressive strength of polymer- and cement-based repair mortar specimens

Repair mortar	Compressive strength (MPa)		
	3 days	7 days	28 days
CB1	39.3	45.4	45.8
CB2	39.4	40.3	44.2
CB3	36.5	44.4	71.9
CB4	34.9	42.9	50.1
CB5	28.5	36.3	44.7
PB1	7.0	9.5	19.3
PB2	26.8	34.7	45.8
PB3	14.4	16.6	24.1
PB4	42.9	43.2	60.4

measured in the specimens prepared with CB3. The compressive strength of CB3, CB4 and PB4 repair mortars was more than 50 MPa, while the compressive strength of the specimens prepared with PB3 and PB1 was in the range of 19–24 MPa. The compressive strength of specimens prepared with other proprietary repair mortars, Portland cement mortar and silica fume cement mortar, was around 45 MPa.

The tensile strength of the selected polymer- and cement-based repair mortars is summarized in Table 6. These values were in the range of 2.5–6.5 MPa, the maximum value being measured in the specimens prepared with PB4 and the lowest value being recorded in the specimens prepared with PB3.

Table 7 shows the flexural strength of the specimens prepared with the selected polymer- and cement-based repair mortars. These values were evaluated after 7 and 28 days of curing. As expected, the values at 28 days were more than those determined after 7 days of curing. After 28 days of curing, the flexural strength values were in the range of 4.3–7.8 MPa.

The data on modulus of elasticity of the selected polymer- and cement-based repair mortar specimens, measured according to BS 6319, are summarized in Table 8. These values were in the range of 25.8–32.6 GPa. An exception to this trend was noted in the specimens prepared with PB3, which exhibited a value of 11.3 GPa after 28 days of curing.

The slant shear strength of the selected polymer- and cement-based repair mortar specimens is summarized in Table 9. These values were in the range of 15.7–32.0 MPa. This table also describes the mode of failure noted during the slant shear test. While compression failure of the parent concrete was noted in the composite specimens prepared with PB2 and PB4, bond failure was noted in the composite specimens prepared with the other proprietary polymer- and cement-based repair mortars, ordinary Portland cement (CB1), and silica fume cement (CB2) mortar specimens.

The coefficient of thermal expansion of the selected polymer- and cement-based repair mortar specimens is summarized in Table 10. These values were in the range of 7.99–10.84 $\times 10^{-6}$ per °C.

The drying shrinkage of the cement-based repair mortars is depicted in Fig. 3. The drying shrinkage strain increased with time in all the cement-based repair mortars, increasing more rapidly at the earlier stages and slowly later. The drying shrinkage stain in the non-proprietary cement-based repair materials (CB1 and CB2) was less than that in the proprietary cement-based repair mortars, particularly CB3 and CB4. As shown in Fig. 4, the drying shrinkage strain in the polymer-based

Table 6
Tensile strength of polymer- and cement-based repair mortar specimens

Repair mortar	Tensile strength (MPa)		
	3 days	7 days	28 days
CB1	1.9	2.1	3.1
CB2	2.1	2.7	3.7
CB3	3.1	4.1	4.8
CB4	2.6	3.4	5.4
CB5	1.8	2.5	3.7
PB1	1.1	2.3	3.8
PB2	1.8	2.3	3.8
PB3	1.1	1.8	2.5
PB4	3.2	4.6	6.5

Table 7
Flexural strength of polymer- and cement-based repair mortar specimens

Repair mortar	Flexural strength (MPa)	
	7 days	28 days
CB1	4.2	6.5
CB2	4.8	7.6
CB3	4.9	7.5
CB4	5.7	6.5
CB5	4.3	6.2
PB1	3.6	7.8
PB2	2.9	4.3
PB3	3.3	4.3
PB4	4.4	6.1

Table 8
Elastic modulus in compression of cement- and polymer-based repair mortars

Repair mortar	Modulus of elasticity (GPa)	
	7 days	28 days
CB1	20.8	26.8
CB2	23.6	29.7
CB3	23.7	28.8
CB4	26.0	32.6
CB5	22.0	25.8
PB1	NA[a]	NA[a]
PB2	22.0	26.0
PB3	8.8	11.3
PB4	24.3	30.5

[a] NA: Not available.

Table 9
Slant shear strength of composite specimens prepared with polymer- and cement-based repair mortars

Repair mortar	Slant shear strength (MPa)	Mode of failure
CB1	27.8	Bond
CB2	32.0	Bond
CB3	28.8	Bond
CB4	NA[a]	NA[a]
CB5	19.5	Bond
PB1	NA[a]	NA[a]
PB2	27.4	Compression
PB3	15.7	Bond
PB4	24.7	Compression

[a] NA: Not available.

Table 10
Coefficient of thermal expansion of polymer- and cement-based repair mortar specimens

Repair material	Coefficient of thermal expansion ($\times 10^{-6}$ per °C)
CB1	8.99
CB2	7.99
CB3	10.33
CB4	8.92
CB5	8.03
PB1	10.84
PB2	NA[a]
PB3	NA[a]
PB4	9.31

[a] NA: Not available.

repair mortars also increased with time. Further, the ultimate drying shrinkage strain in the proprietary cement-based repair mortars, particularly CB3 and CB4, was more than that in most of the polymer-based repair mortars. The lower drying shrinkage in the polymer-based repair mortars compared to the cement-based repair mortars may be attributed to the addition of shrinkage compensating admixtures in the former.

The risk of cracking of a repair material, based on the assumption of a rigid concrete substrate, is defined as $\varepsilon_{sh}E/f_t$, where f_t is the tensile strength, E is the modulus of elasticity, and ε_{sh} is the drying shrinkage strain. In this relationship, the ratio E/f_t is extremely important with the lowest values being more preferable. Table 11 compares the E/f_t values of selected polymer- and cement-based repair mortar specimens after 7 and 28 days. The comparison between the proprietary polymer and cement-based repair materials indicates that PB3 has the lowest E/f_t, while this value is the highest in CB5 repair mortar. The low E/f_t noted in PB3 may be attributed to the presence of polymers in this repair material. It should be stated that most polymers increase the tensile strength whilst moderately influencing the ductility—thus the frequent use of polymer modified cement mortars. It is not surprising that the three materials with E/f_t on the lower scale are all polymer-modified mortars. Further, the two non-proprietary cement-based repair mortars (CB1 and CB2) exhibit higher risk of cracking compared to the other cement- and polymer-based proprietary repair materials.

Table 11 also shows the risk of cracking after 7 and 28 days. The risk of cracking varies from 1.5 to 4.1 after 7 days and 4.1 to 5.4 after 28 days. The higher risk of cracking after 28 days, compared to that at 7 days, indicates that unless there is a substantial relief of tensile strain, by creep mechanism, the risk of cracking increases with the age. This may well explain why drying shrinkage cracking is commonly noticed in structures after 7 days of exposure.

3.2. Durability characteristics

3.2.1. Chloride permeability

The chloride permeability of the selected polymer- and cement-based repair materials is summarized in Table 12. This table also provides the chloride permeability classification according to ASTM C 1202. Chloride permeability of the selected polymer- and cement-based

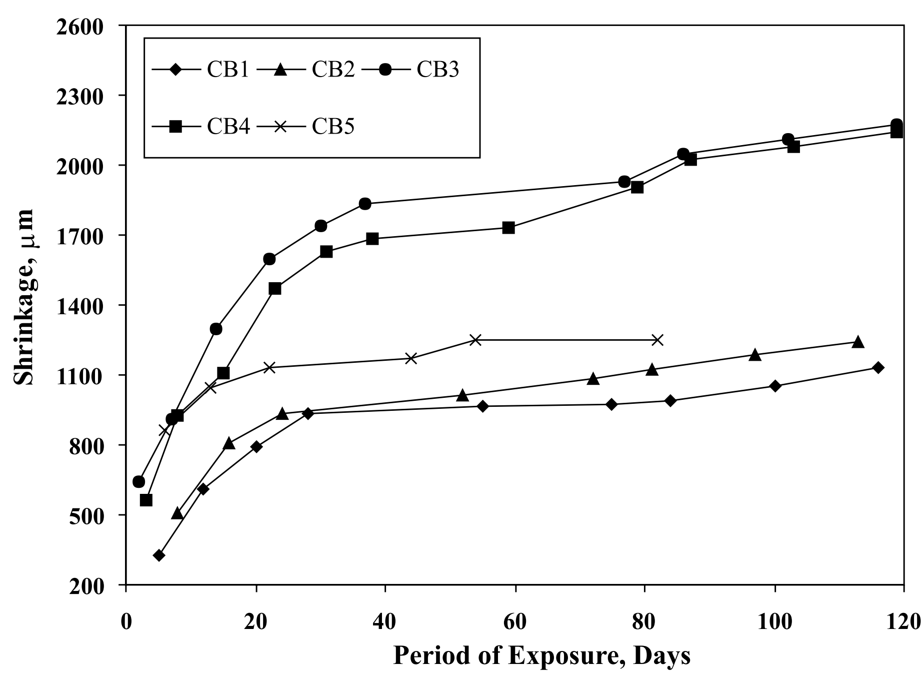

Fig. 3. Drying shrinkage in cement-based repair mortars.

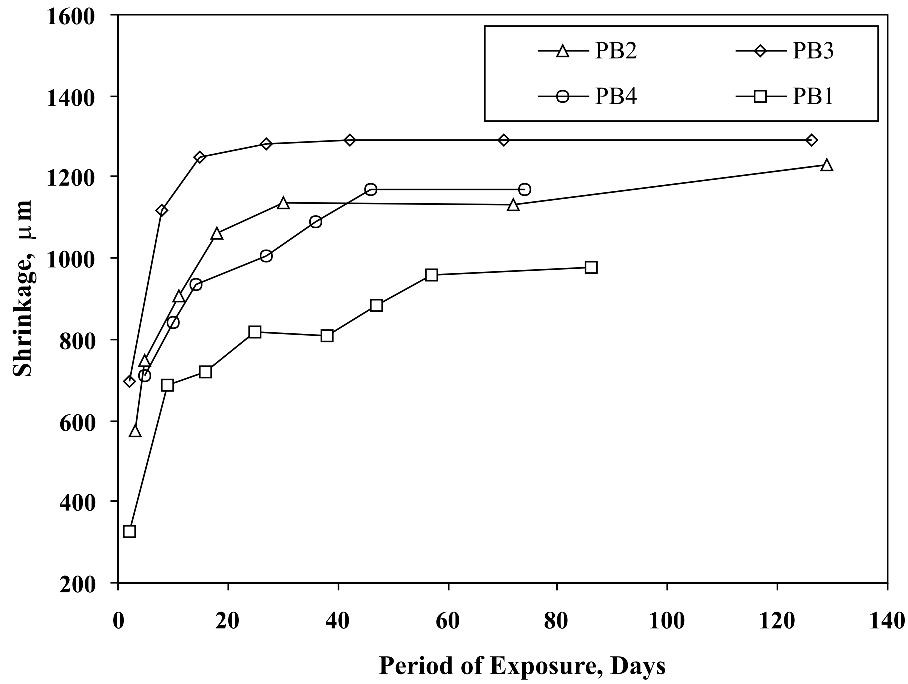

Fig. 4. Drying shrinkage in polymer-based repair mortars.

Table 11
Risk of cracking in polymer- and cement-based repair mortars

Repair material	$E/f_t \times 10^3$		Risk of cracking in the specimens exposed at 25 °C	
	7 days	28 days	After 7 days	After 28 days
CB1	9.72	8.49	3.8	NA[a]
CB2	8.88	8.07	3.6	5.4
CB3	5.78	6.05	3.9	NA[a]
CB4	7.69	6.06	3.1	4.1
CB5	8.73	6.94	2.9	4.4
PB1	NA[a]	NA[a]	NA[a]	NA[a]
PB2	8.4	6.81	4.1	NA[a]
PB3	4.78	4.54	1.5	4.1
PB4	5.28	4.70	3.2	4.2

[a] NA: Not available.

Table 12
Chloride permeability of cement- and polymer-based repair mortar specimens

Repair material	Chloride permeability (C)	ASTM C 1202 chloride classification
CB1	1043	Low
CB2	608	Very low
CB3	377	Very low
CB4	1368	Low
CB5	744	Very low
PB1	1002	Low
PB2	613	Very low
PB3	158	Very low
PB4	334	Very low

repair materials was in the range of 158–1368 C and is therefore classified as very low-to-low, as per ASTM C 1202 criterion. The results show that there is no clear difference between the cement- and polymer-based repair mortars with regard to the chloride permeability. Since the chloride permeability indirectly provides an indication of the electrical resistivity of concrete, these data indicate that both the cement- and polymer-based repair materials would be effective in reducing reinforcement corrosion.

3.2.2. Electrical resistivity

The electrical resistivity of concrete or mortar is a major factor affecting the corrosion process of embedded steel reinforcement. Further, the electrical resistivity depends on the moisture content in the concrete or mortar. To evaluate this effect the specimens prepared with polymer- and cement-based repair materials were immersed in a water bath and retrieved at varying time periods, and their weight and electrical resistivity were measured after surface drying them. This has resulted in the generation of data depicting the relationship between moisture content and electrical resistivity of the selected materials.

The variation of the electrical resistivity with the moisture content of the selected cement- and polymer-based repair mortars is depicted in Figs. 5 and 6, respectively. The electrical resistivity of the cement-based repair mortars decreased with an increase in the moisture

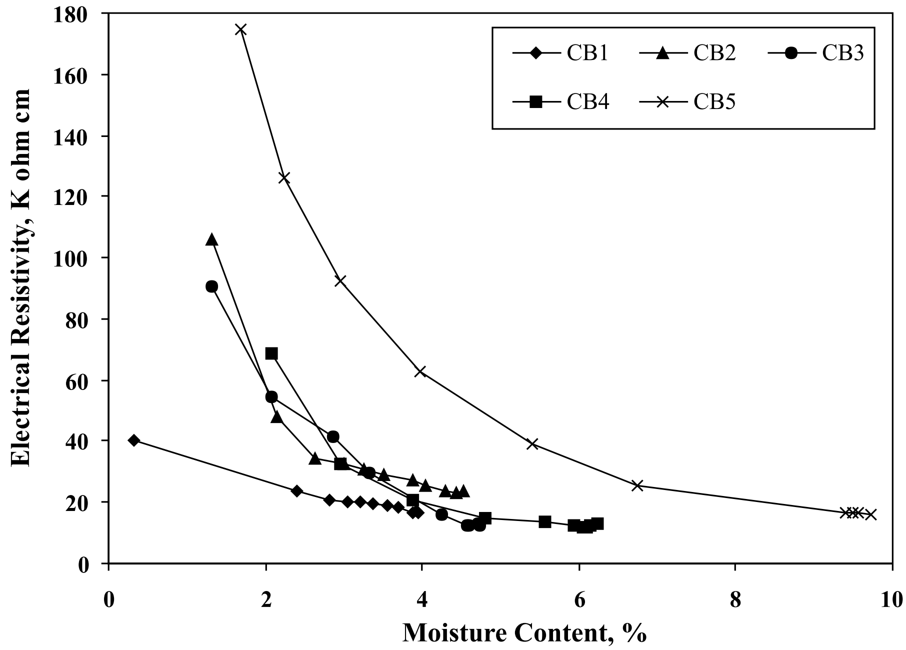

Fig. 5. Variation of electrical resistivity with moisture content of cement-based repair mortars.

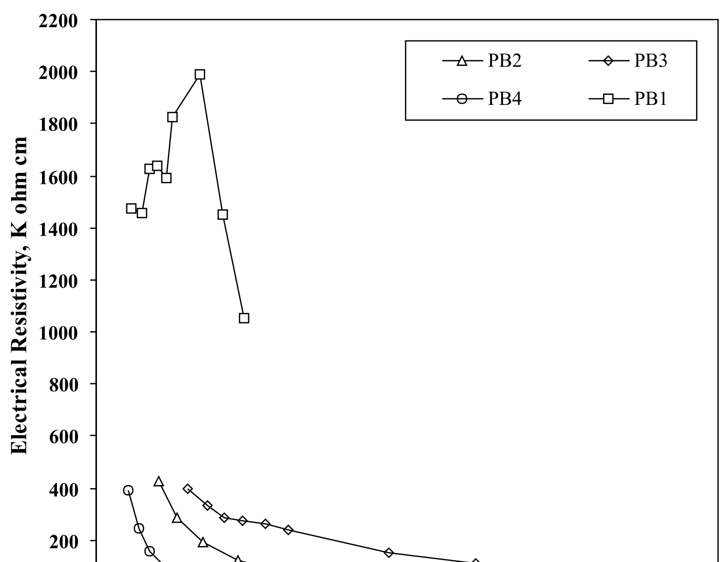

Fig. 6. Variation of electrical resistivity with moisture content of polymer-based repair mortars.

content, as shown in Fig. 5. With the exception of CB5, the electrical resistivity of the cement-based repair mortars was similar, particularly at higher moisture content. The higher electrical resistivity noted in CB5 compared to the other cement-based repair mortars, indicates the significance of the type and quantity of admixtures in the repair mortars. Most of the available cement-based repair mortars contain more than one type of additives, such as water reducing and shrinkage compensating admixtures. Another observation is the variation in the amount of moisture each material can take. Repair mortar CB5 absorbed more than 9% water compared to less than 6% absorbed by the other cement-based repair mortars.

The data in Fig. 6 show that the electrical resistivity values of the polymer-based repair mortars, with the exception of PB1, decreased with an increase in the water content. Further, the electrical resistivity of polymer-based repair materials is higher than that of cement-based repair materials. Also, a large variation in the electrical resistivity of polymer-based repair mortars was noted. The electrical resistivity of PB1 is more than five times that of the other three polymer-based repair materials. This may be attributed to the type and amount of polymer material used in the repair mortar. The amount of water each material can absorb also varies substantially. This was evidenced by the lowest and largest water absorption noted in PB1 and PB3 where the maximum water absorption values were 2.3% and 8.6%, respectively.

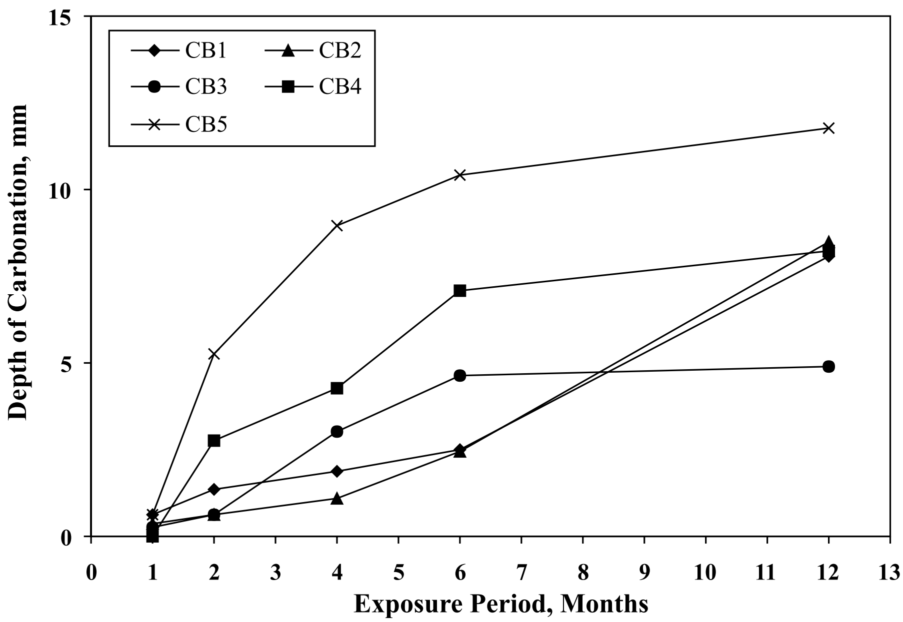

Fig. 7. Variation of carbonation depth with exposure period of cement-based repair mortars.

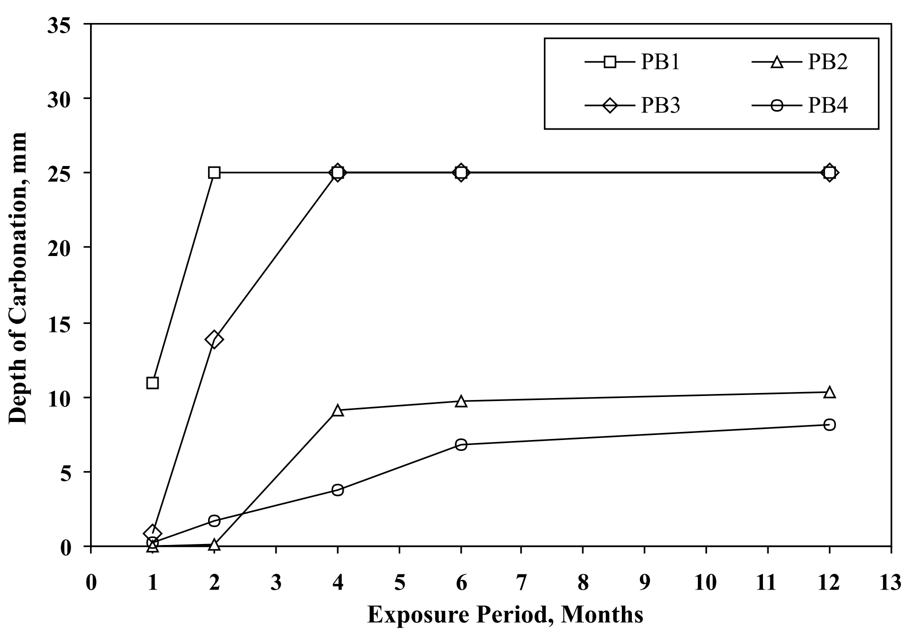

Fig. 8. Variation of carbonation depth with exposure period of polymer-based repair mortars.

3.2.3. Carbonation

The variation of carbonation depth in the selected cement- and polymer-based repair mortars with the period of exposure is depicted in Figs. 7 and 8, respectively. As expected the depth of carbonation increased with the exposure period in all the tested repair mortars. As shown in Fig. 7, the in-house prepared repair mortars (CB1 and CB2) showed almost constant rate of carbonation during the 6-month exposure period, and increased by almost three times afterwards. Also the in-house prepared repair mortars showed the smallest depth of carbonation in the first six months of exposure among the cement-based repair mortars. The rate of carbonation of the other three cement-based proprietary repair mortars CB3, CB4 and CB5 decreased substantially after 6 months of exposure. After 12 months of exposure, the best and worst performance in terms of carbonation was exhibited by CB3 and CB5, respectively.

Carbonation to full depth, i.e. 25 mm was noted in the specimens prepared with PB1 and PB3 after 2 and 4 months of exposure, respectively, as depicted in Fig. 8. PB2 and PB4 showed much better resistance to carbonation than PB1 and PB3. These results suggest the role of polymer type on the carbonation resistance of repair mortars. The generic types of the polymers used in the proprietary repair mortars tested in this study were not provided by the manufacturers, except PB1 where water dispersion of acrylic latex was used.

After 12 months of exposure to accelerated CO_2 environment, the depth of carbonation in the selected cement- and polymer-based repair materials, except PB1 and PB3, was in the range of 4.9–11.8 mm. The low carbonation depth noted in some of the tested repair materials may be attributed to the dense structure of these specimens, presumably due to the addition of silica fume, fibers and/or other additives.

4. Discussion

Over the years, several types of cement- and polymer-based repair mortars have been developed and used in repair and rehabilitation of different concrete structures. These repair mortars have wide variations in physical as well as durability properties. Although these repair materials have adequate and some times high strength, they may develop premature deterioration problems when used in hot or harsh environments. This is attributed to incompatibility in properties, such as drying shrinkage strain and thermal expansion, between the repair material and the concrete substrate. Such incompatibility may cause tensile cracking through the repair layer and/or delamination at the interface between the repair layer and the substrate.

The results of tests conducted to evaluate the mechanical properties and durability characteristics of the selected repair materials are discussed in the following sections.

4.1. Mechanical properties

The data developed in this study have shown a wide variation in the mechanical properties of the selected cement- and polymer-based repair materials. Further, the variation in the properties was noted within materials of similar generic type. However, it should be noted that the mechanical properties of the selected repair materials were within the acceptable range. The stiffening time for most of the proprietary repair mortars evaluated was more than that of the non-proprietary Portland cement and silica fume cement mortars. As expected, higher bleeding was noted in the proprietary micro concrete or repair mortar while no bleeding was noted in the other cement- and polymer-based repair materials.

No clear distinction could be established between the cement- and polymer-based repair mortars with regard to the compressive, tensile and flexural strength, drying shrinkage and coefficient of thermal expansion. The elastic modulus of the polymer-based repair mortars was, however, less than that of cement-based repair materials. This indicates that these materials tend to be more ductile than the cement-based repair materials. This could be attributed to the addition of polymers and/or fibers. The lower elastic modulus also results in a lower risk of cracking due to drying shrinkage.

4.2. Durability characteristics

The data generated in this study indicate the possibility of having large variation in some of the durability related properties of different pre-packed cement- and polymer-based repair mortars, due to the vast differences in their composition. This raises the important issue of the compatibility between the repair materials and the existing substrate concrete of repaired structure.

The chloride permeability of the selected repair materials was very low-to-low as per ASTM C 1202 classification. This indicates that to start with, the evaluated repair mortars may provide adequate resistance to chloride penetration required for protection against reinforcement corrosion if the repair materials are adequately mixed and placed.

A wide variation in the electrical resistivity was noted between the selected repair materials. More importantly, the tested repair materials showed different levels of water absorption that in turn influences the electrical resistivity. Therefore, a repair mortar with high electrical resistivity may isolate the repaired portion of the concrete structure from the undamaged areas, thereby providing an efficient protection to the steel in the repaired area.

Carbonation in some repair mortars, such as PB1 and PB3, was surprisingly very rapid compared to the other repair mortars. This indicates that when such materials are used as repair mortar the chances of carbonation related reinforcement corrosion are very high. The data developed in this study indicate the need to obtain information on the durability indices, such as those developed in this study, to ascertain the suitability of the repair materials for the expected exposure conditions.

5. Conclusions

The following are the main conclusions that can be drawn from the experimental program conducted to evaluate the durability characteristics of selected cement- and polymer-based repair mortars.

There was no clear difference between the cement- and polymer-based repair mortars with regard to the chloride permeability. The chloride permeability of the selected repair mortars can be classified as very low to low, as per ASTM C 1202 criterion.

The electrical resistivity of the polymer-based repair mortars, with the exception of PB4, was higher than that of the cement-based repair mortars. A large difference in the electrical resistivity values was noted between the polymer-based repair mortars and the cement-based repair mortars. The electrical resistivity of PB1 was more than five times that of the other two polymer-based repair mortars.

The specimens prepared using polymer-based repair mortars PB1 and PB3 were fully carbonated (25 mm) after only 2 and 4 months of exposure, respectively. After twelve months of exposure to accelerated CO_2 environment, the depth of carbonation in the selected cement- and polymer-based repair mortars, except PB1 and PB3, was in the range of 4.9–11.8 mm. The low carbonation in some of the tested repair mortars may be attributed to the dense structure of these specimens, presumably due to the addition of silica fume, fibers and/or other additives.

The risk of cracking, electrical resistivity and carbonation appear to be the criteria that differentiate between the performance of the selected repair materials. Therefore, it is necessary to request for information on tensile strength, drying shrinkage and elastic modulus from strength point of view and electrical resistivity and carbonation from the durability perspective.

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