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Preferred test methods to select suitable surface repair materials in severe climates

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HIGHLIGHTS

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ABSTRACT

In severe climates, the surfaces of concrete sidewalks, parking decks, bridges, canals, dams and other structures deteriorate progressively due to variety of causes. For their repair and maintenance, countless surface repair mortars are abundantly available on the market and are constantly used without prior testing in the laboratory. For this reason, 40 different mortars, comprising of cement-based mortars, polymer-modified cement-based mortars containing styrene–butadiene rubber and acrylics, epoxy mortars and emulsified epoxy mortars from different manufacturers were subjected to a battery of mechanical and durability tests. These tests included: bond strength, abrasion–erosion resistance, shrinkage–expansion, compressive strength, thermal compatibility with base concrete, etc. (−50 °C to +40 °C), etc. All these tests are considered important and essential but different views and opinions exist in the literature regarding their order of preference or importance. This paper presents the test data obtained from these tests. The test data revealed that over 65% (dry cure) and 89% (wet cure) of the mortars had a bond-strength better than the reference cement mortar, while over 90% performed better in the abrasion–erosion resistance test. Similarly, over 80% of the mortars exhibited higher compressive strength (84% in dry curing and 81% in wet curing) than the reference mortar. In the shrinkage–expansion test, 53% and 66% of the surface repair mortars showed lower than 0.15% net change and 0.2% total change, respectively, as specified in ASTM C928. However, in the thermal compatibility with base concrete test, only 36% of the mortars performed better indicating its importance and preference in severe climates. The latter test was therefore conclusive to select suitable surface repair mortars prior to a major maintenance and rehabilitation concrete work and should be performed as representing the most important selection criteria for mortars and concretes, especially those exposed to severe climatic conditions.

1. Introduction

In severe climates, the surfaces of concrete sidewalks, parking decks, bridges, canals, dams and other structures deteriorate progressively due to variety of causes. For their repair and maintenance, countless surface repair mortars are abundantly available on the market but are constantly used before they have been tested in the laboratory. In the last few years, many materials and methods have been developed to repair concrete. Sales representatives selling repair materials, all promise wondrous results with their products [25]. Information on these products has always been scarce and manufacturers have been unable to supply specific data on these mortars' resistance to the harsh conditions found in many parts of the globe. Even if data is available, it is normally for room-temperature conditions and is therefore of very little value for structures exposed to severe hot and cold climatic conditions. Some experts also estimate that up to half of all concrete repairs fail. Many of the "wonderful" materials do not work, and concrete repairs are tricky. There are few engineers who have adequate knowledge of concrete repair, and contractors with experience in concrete repair are scarce too.

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In cases where laboratory tests are conducted prior to the repair job, tests such as bond strength, abrasion–erosion resistance, shrinkage–expansion, compressive strength, and thermal compatibility with base concrete are usually carried out to evaluate and compare the performance of various types of repair materials. The other tests carried out are freezing–thawing cycles, permeability, etc. All these tests are considered important and essential but different views and opinions exist in the literature regarding their order of importance. A research study was carried out to prioritize laboratory tests and evaluate the performance of various mortars, both existing and under development, for repairing the surfaces of concrete hydraulic structures [14]. This paper presents the results of bond strength, abrasion–erosion, shrinkage–expansion, compressive strength and thermal compatibility with base concrete tests which were subsequently used to determine their order of priority.

2. Experimental

2.1. Materials

In order to respect the confidentiality of the manufacturers and the generic names of the repair mortars, these are referred to by codes. The following 40 mortars, taken from different manufacturers, were studied and their availability in the market is given in Table 1:

- 15 cement-based mortars (CM), symbolized as C1 to C15.
- 11 polymer-modified cement-based mortars (PMCM):
  - 7 containing styrene butadiene rubber (SBR) labelled as R16 to R22 and
  - 4 containing acrylics, A23 to A26.
- 12 sand–epoxy mortars (E), E27 to E38.
- 2 emulsified epoxy mortars (EE), EE39 and EE40.

2.2. Preparation of mortars

In preparing these mortars, Ottawa (Illinois) sand was used as per ASTM C109; otherwise, the sand provided by the manufacturers was used. Mortar C1 was a standard cement mortar used as a reference (water-to-cement ration (W/C) = 0.46) throughout the study. Mortar C2 had the same mixture ratio of ingredients as C1 except that it had a W/C = 0.31and used the superplasticizer. Mortars C3–C6 contained 6%, 9%, 12% and 15% silica fume as a replacement of cement with low water:-binder ratio (W/B) and a napthaline based superplasticizer. All other mortars were prepared as per recommendations of the manufacturers.

2.3. Tests

Tests performed on the 40 mortars included bond strength, abrasion–erosion resistance, shrinkage–expansion/expansion, compressive strength and thermal compatibility with base concrete. Various sizes and shapes of specimens were prepared from the same mixture, depending on the standard used. Moreover, for abrasion–erosion resistance test, in-house developed equipment was used. In case of thermal compatibility with base concrete test, temperatures and durations were modified according to the climatic conditions generally found in the northern parts of North America.

Table 1
Shrinkage–expansion and compressive strength tests data of surface repair mortars.

Mortars	Availability of mortars	Shrinkage–expansion after 28 days (%)		Compressive strength after 28 days (MPa)	
		Net change	Total change	Dry curing	Wet curing
C1	In-house mortar, W/C = 0.46	−0.097	0.123	31.9	29.0
C2	In-house mortar, W/C = 0.31 + SP[a]	−0.140	0.238	33.5	43.4
C3	6% SF[b] mortar	−0.116	0.180	37.3	51.1
C4	9% SF mortar	−0.166	0.226	52.0	53.8
C5	12% SF mortar	−0.171	0.221	50.3	61.0
C6	15% SF mortar	−0.160	0.229	49.4	61.1
C7	Yes	0.031	0.165	72.8	73.3
C8	Yes	−0.076	0.163	79.6	73.5
C9	Yes	−0.078	0.118	41.9	44.0
C10	Yes	−0.123	0.174	52.1	70.9
C11	Yes	−0.154	0.174	59.0	77.3
C12	Yes	−0.106	0.118	58.6	65.3
C13	?[c]	−0.089	0.125	48.8	52.1
C14	Yes	−0.020	0.050	82.1	95.1
C15	Yes	0.013	0.089	85.3	115.2
R16	Yes	−0.005	0.091	57.8	54.8
R17	?	0.023	0.433	48.1	46.5
R18	?	0.019	0.433	45.1	46.0
R19	?	−0.001	0.109	62.6	61.5
R20	Yes	−0.143	0.171	80.5	80.5
R21	Yes	−0.179	0.201	55.3	53.2
R22	Yes	−0.063	0.087	23.2	24.4
A23	Yes	−0.096	0.180	35.6	27.3
A24	Yes	−0.091	0.163	52.3	50.2
A25	?	0.051	0.253	55.0	44.2
A26	Yes	−0.015	0.193	44.8	27.7
E27	Yes	0.521	0.619	55.6	–
E28	Yes	0.081	0.131	27.5	–
E29	?	0.064	0.128	55.6	–
E30	?	0.165	0.295	36.9	–
E31	Yes	0.135	0.279	30.2	–
E32	?	1.064	1.152	36.7	–
E33	?	0.315	0.337	37.7	–
E34	Yes	0.030	0.030	16.1	–
E35	Yes	−0.071	0.071	68.8	–
E36	Yes	0.032	0.116	40.0	–
E37	Yes	0.010	0.026	73.8	–
EE39	Yes	−0.086	0.098	20.1	21.8
EE40	Yes			27.9	14.4

[a] SP = superplasticizer.
[b] SF = silica fume.
[c] ? = Either no more available or the manufacturers bought by others so they eliminated or modified the products.