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Influence of Aggressive Exposure Conditions on Performance of Repair Materials

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Abstract

Presently a wide range of materials are being used for repair of concrete structures. Their behaviour under aggressive conditions such as high temperature and acidic environment is not well understood. This paper presents the results of a study undertaken in CBRI to investigate the influence of aggressive environment on five different repair materials and to formulate optimised composition to resist different types of exposure conditions.

INTRODUCTION

Cement concrete is an integral part of modern structures constructed throughout the globe. However, the long term durability of concrete structures is always been of a great concern. These structures deteriorate due to various reasons such as moisture, temperature, load, chemical attack, fatigue and other factors. Consequently, they need frequent repairs. For this purpose, various types of repair materials are used (Fig.1). The requirement of the properties of the repair materials varies according to the properties of the base concrete and form of the repair i.e. structural or cosmetic (Plum, 1990). In most of the cases, the fresh plain cement mortar or concrete do not meet the desired properties. To achieve the desired properties in the repair materials, different types of polymers are often used (Plum, 1990; Mailvaganam, 1992). The addition of polymers in a cementitious matrix results in attaining the desirable properties like low shrinkage and good adhesion with the substrate. By varying type of polymers or additives and their dose in a cement/polymer mortar a wide range of properties can be achieved (Ohama, 1998). Polymers can be added in a cement-aggregate mix or can be used as a matrix itself. The composites made by using polymer along with cement and aggregates are called polymer modified mortars (PMM) or polymer modified concrete (PMC), while composites made with polymer and aggregates are called polymer mortar (PM) or polymer concrete (PC).

For making PMM, polymer particles are generally used in the form of a dispersible powder or as dispersion of particles in an aqueous medium, known as emulsion. Although the latter form is more common, redispersible powders are also gaining popularity. The choice of the polymer depends upon the intended use, and requirement of performances like strength, durability and chemical resistance. Further modifications of a polymer system can be achieved by using additives like surfactants, stabilisers, antifoaming and coupling agents and pigments (ACI, 2000; Ohama, 1998).

Nowadays polymer based repair materials are becoming popular due to various advantages over the plain cementitious mortar. However, their mechanical properties and chemical resistance at elevated temperature is poorly understood. Most of the properties are generally tested at room temperature (RT), while the field conditions are different. Moreover, when the PMM/PMCs are exposed to heat and consequent temperature changes, their properties may alter, which could lead to various stresses in the structures. Therefore, the repair materials are expected to be less sensitive to the varying ambient conditions like temperature, humidity and pollution.

CBRI has done a considerable work in developing repair materials (Aggarwal, 1996; Aggarwal et al. 2007a & b; Asthana et al. 1999; Karade and Agrawal, 2007; Karade et al., 2005 & 2006). In this effort various polymers such as styrene-butadiene rubber (SBR), acrylic, epoxy and their copolymers have been used. The mortars developed using epoxy emulsion have shown the best performance. The epoxy resin was further modified using CNSL based cardanol for better corrosion resistance. However, these properties were evaluated at room temperature only and there is no information available on how these repair material will behave at elevated temperature. Moreover, there is a lack of standard test methods for the evaluation of the repair materials. The reported properties of commercially available products are generally based on tests conducted at room temperature. With experience it has been realised that the outdoor conditions can aggravate or accelerate the degradation of the repairs, which often cause their premature failure and need '*repair of the repairs'*. Thus, the repair materials tested at room temperature in laboratory may not behave in field as expected. In view of this, it is important to understand how repair materials behave with increasing temperature and to formulate suitable compositions that have minimal effects of heat. In view of this one R&D project has been undertaken in CBRI to understand the influence of temperature and chemicals on the performance of polymer modified mortars and to formulate suitable compositions for high temperature exposure conditions. These conditions are prevalent in several industrial buildings and structures, such as coke handling plants, thermal power plants, prilling towers and chimneys. This paper reports some of the results of the ongoing study.

MATERIALS & METHODS

In this study five types of mortars are used. The 'Control' specimens were prepared using plain cement mortar (1:3 by wt.). For making PMM specimens three different latexes (acrylic, SBR and epoxy emulsion) were added individually (10% by weight of cement) to a cement-sand mix (1:3 by wt.) and thoroughly mixed with the required additional water. The water-cement ratio was 0.4 in all cases to provide a similar hydration of the cement matrix. Ordinary Portland Cement (43 grade) and quartz sand (grade No. 10) were used for making the specimens. One additional series of specimen were prepared using epoxy resin-sand (1:5 by weight) mortar.

The freshly moulded specimens were cured in the mould for the first 24 h by covering them with a wet cloth and a polyethylene sheet. Then the cement mortar specimens were cured in water, while PMM specimens were kept in the laboratory conditions, 20±2°C and 50±5 % relative humidity (RH) for the next 27 days. The epoxy mortar specimens were also used after 28 days curing at room temperature (RT).

For understanding the effects of thermal cycles, under which the cube specimens were exposed to a temperature of 85±2 °C for 8 hours a day and then allowed to cool at temperature in the oven, the specimens were tested for change in compressive strength after 30, 60, 90 and 120 cycles. These specimens were tested at RT. To understand the behaviour of these mortars at higher temperature a different set of specimens were tested in a thermostatic chamber maintained at 85±2 °C (Fig. 2).

To study the influence of exposure to acidic environment, the five types of specimens were submerged in a sulphuric acid solution (5%) and the changes in weight, shape, colour and compressive strength are recorded at various intervals of exposure time.

RESULTS & DISCUSSION

The results of the above mentioned tests are discussed below.

Effect of Thermal Cycles

The effect of thermal cycles on compressive strength of various repair mortars is shown is shown in Fig. 3. It can be observed that the compressive strength of plain cement mortar is decreasing with the increasing number of thermal cycles, while that of the epoxy mortar is increasing. However, there is no significant change in compressive strength of acrylic and SBR modified mortars. The main reason in loss of strength in the cement mortar is the fact that during cyclic heating and cooling the cement paste in the mortar is vulnerable to micro- cracking and consequently loose the bond with aggregate. In PMM the latex film possibly fills the micro-cracks and maintains the bond. The improvement in strength of epoxy mortar with increasing number of thermal cycle could be attributed to better curing of the resin.

Influence of High Temperature

The results of change in compressive strength of the repair mortar specimens tested at 85±2 °C in comparison to those tested at RT are shown in Fig. 4. The significant drop (82%) in compressive strength of epoxy mortar can be noted. There is a reduction in strength (17%) of cement mortar also, while slight improvement in the compressive strength of PMMs (3-7%) was noticed. This can be attributed to the crack bridging property of the latex films, which become flexible at high temperature.

Effect of Acidic Exposure

The changes in properties of different mortar specimens dipped in an acidic solution for 180 days is shown in Fig.5. It can be seen that the most affected specimens are those made of plain cement mortar, while the epoxy mortar is the least affected. The PMMs are also affected by exposure to acidic solution. The visual observations revealed that the edges of the control specimens were damaged and material was lost. The surfaces of the specimens were quite rusty. As a result there was a mass reduction of about 11%, while the strength reduction was upto 60%. Some rust was also observed on the surface of PMM specimens.

CONCLUSION & RECOMMENDATIONS

The results indicated that the plain cement mortar is greatly affected by heating & cooling cycles, high temperature and acidic environment. Epoxy mortar has the best resistance to acidic exposure and to the thermal cycles, but it has poor strength at higher temperature. Thus, on cooling epoxy mortar regains its strength. The latex modified mortars have moderate resistance to heating & cooling cycles, high temperature and acid. While selecting a suitable repair material for a given condition, these results will be helpful. Further study on the influence of these conditions on adhesion property of these mortars and their behaviour under fire is in progress. This will be followed by optimisation of the formulations of repair materials for different exposure conditions on the basis of their performance.

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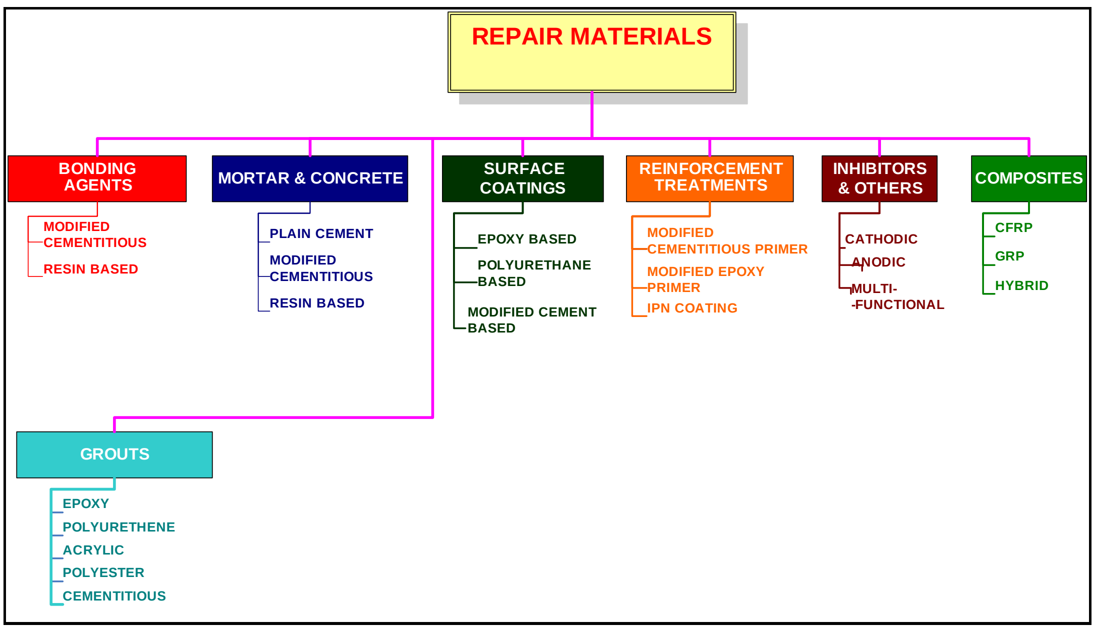
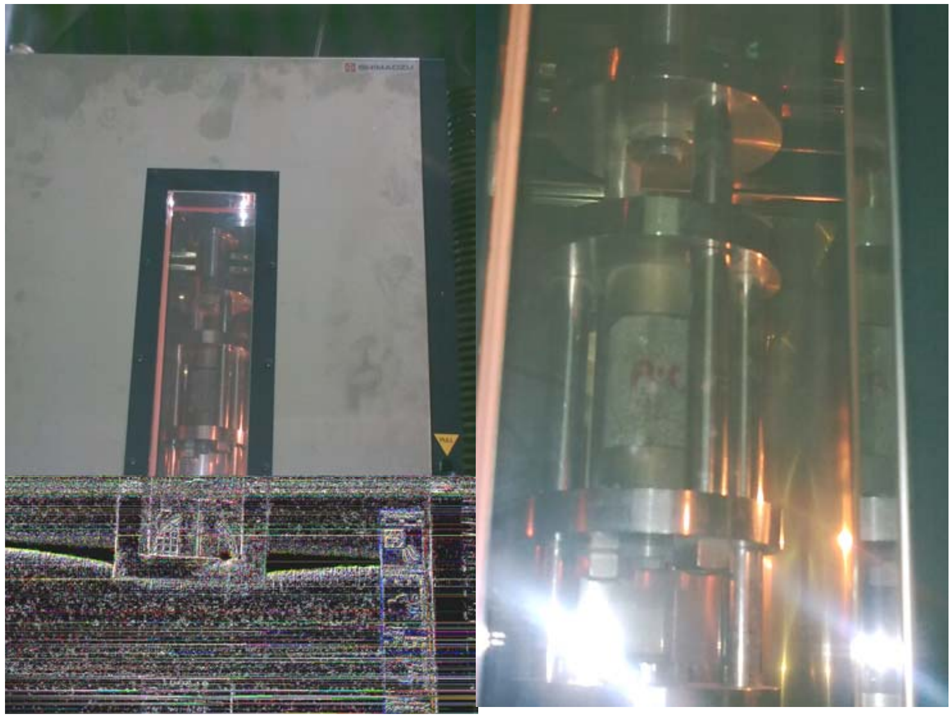


Figure 1 Various types of repair materials currently in use



(a) (b)

Figure 2 Testing of repair mortars at higher temperature (a) Thermostatic chamber (b) Compression test specimen inside the thermostatic chamber

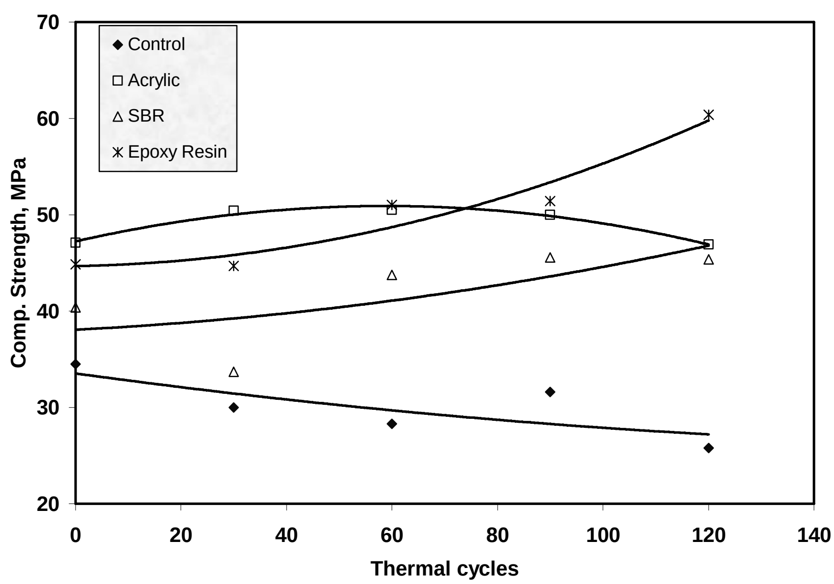


Figure 3 Effect of number of thermal cycles on compressive strength of repair mortars

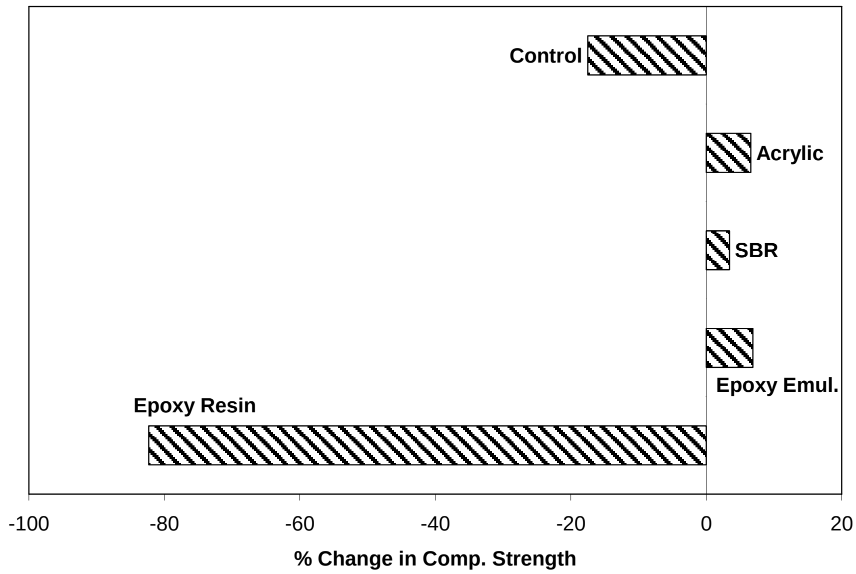


Figure 4 Change in compressive strength of repair mortars tested at higher temperature (85 °C) in comparison to those tested at RT

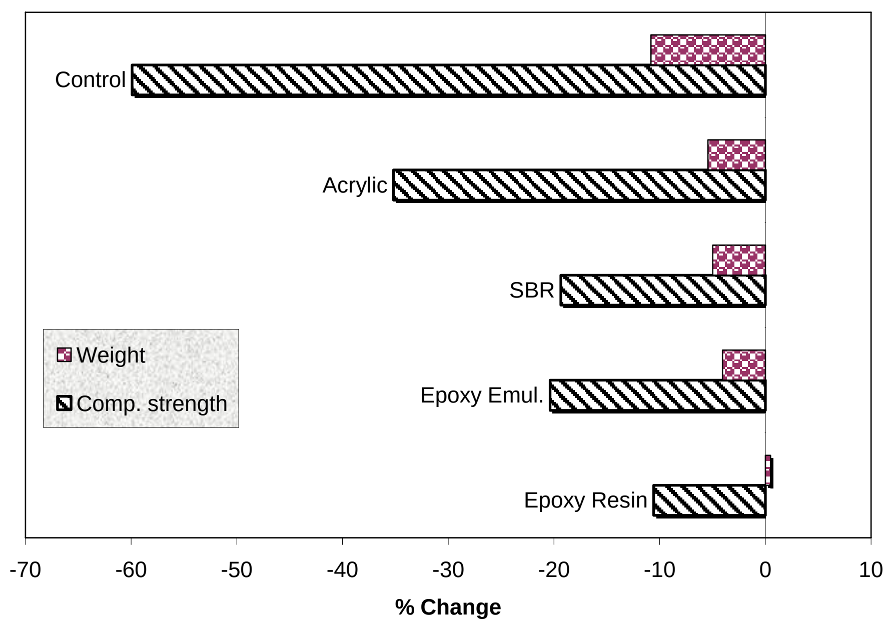


Figure 5 Change in compressive strength and weight of repair mortars after 180 days exposure to acidic solution