STUDY ON MMA-BASED REPAIR MATERIAL FOR REPAIRING THE CRACKING CAUSED BY AAR IN CONCRETE

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Abstract

Concrete often suffers from the deterioration of alkali-aggregate reaction (AAR) when reactive aggregate has been used. Cracking would be observed on the surface of concrete due to the expansion. The cracking should be repaired as soon as possible to stop further deterioration. MMA-base repair material with low viscosity enters the crack easily and can polymerize to form a film on the surface of concrete. The results indicate that the bonding strength between MMA-based repair material and concrete is high enough. The tensile strength and flexure strength are 25.2MPa and 40.4MPa respectively, the elongation under tensile is 26%. The durability of MMA-based material, such as thermal shocking (heating cycles and cooling cycles) and ultraviolet radiation has been investigated. The outdoor repairing effect has been evaluated.

Keywords: MMA, repair, cracking, AAR, concrete

1 INTRODUCTION

Concrete would be deteriorated by physical effect and chemical attack, in which alkali-aggregate reaction (AAR) is a common problem. The cracking caused by AAR would be the pathway of water or the corrosive solution entering into the concrete. In order to ensure the safety in service the concrete should be maintained and repaired in time with good quality. There are various types of materials for concrete repair, classified to inorganic type, organic type and composite type. Inorganic materials are mainly mortar and concrete made from ordinary cement or special cement, which are widely used because they are got easily and cheap, whereas they are also easily deteriorated by the same reason as the old concrete. Organic ones are considered effective in the local repair, which are mainly epoxy-based materials. The other organic repair material for concrete is methyl methacrylate (MMA)-based material, the outstanding characteristics of low viscosity would enable it flows into crack easily, and has been used to repair the crack caused by ASR at McClellan airport [1,2]. In this paper, the preparing process and properties of MMA-based repair material (called RMPMA herein) are investigated.

2 PREPARATION OF RMPMA

RMPMA was prepared from MMA monomer by bulk polymerization. The polymerization includes three stages, chain starting (reaction (1) and (2)), chain growth (reaction (3) and (4)) and chain stopping (reaction (5) and (6)).

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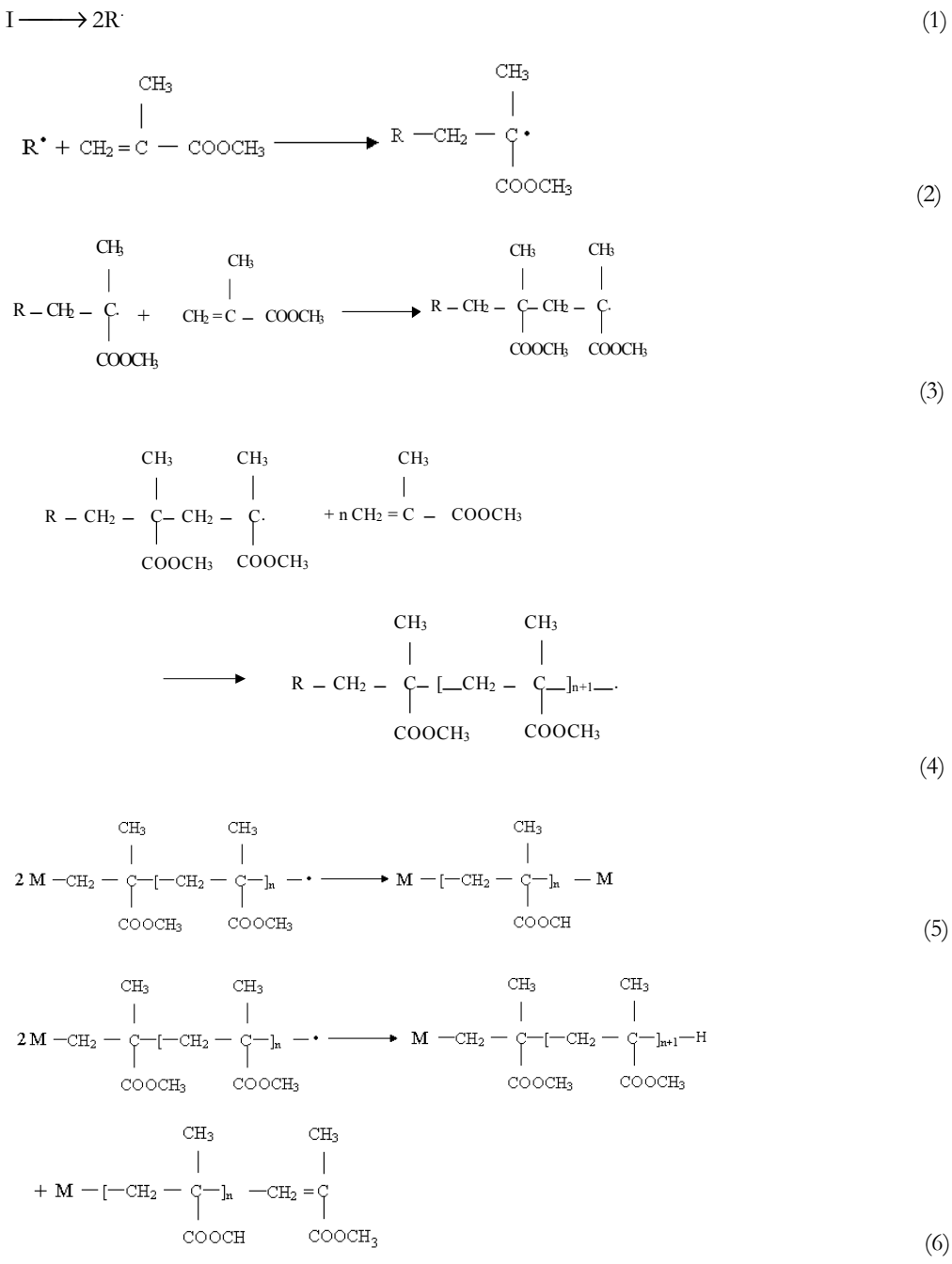


(1)

(2)

(3)

(4)

(5)

(6)

According to reaction (1) to (6), the initiator was chosen to accelerate the polymerization of MMA monomer. To improve the flexure property, plasticizer was also used during the preparation. For crack repair the flowability is the important property to ensure the RMPMA to enter into the crack. So the viscosity of RMPMA should be controlled during preparation. Fig 1 shows that the viscosity increases with the preparation time. From repairing experiment, the suitable viscosity is proposed about 150mPa·s tested using rotary viscosimeter. In common case, the repairing work should be finished as soon as possible and not disturb the traffic. Sometimes additive D was suggested to be used to adjust the solidification time.

3 PROPERTIES OF RMPMA

3.1 Tensile strength and bending strength

Tension strength and bending strength of RMPMA were tested referring to the standard GB1040-79 testing methods of plastic. The testing samples were shown in Fig 2 and Fig 3. The relationship between displacement and bending load showed in Fig 4 indicates that RMPMA can resist the bending load till the displacement gets about 40mm, the maximum flexure movement is about 8mm, and the flexure strength is 40.4MPa. The similar situation is with the tension testing (see Fig 5), the elongation is about 24mm, the tensile strength 25.2MPa. The fracture characteristics has been considered to be very favourable for repairing, especially for crack repairing, that is, RMPMA has the capability of withstanding the load stress to open the crack.

3.2 Thermal properties

RMPMA has good thermal resistance, the Tg temperature is about 172.5°C as shown in Fig 6 indicates the RMPMA can be used under 170°C. To clear whether RMPMA can stand the cycles of heating and cooling, the following experimental was designed. One is heating cycle, the RMPMA samples was heated at 105°C for 10min, then put into the water instantly at 15°C for 10min, then heated at 105°C for 10min again, the other part is cooling cycle, the RMPMA samples was kept in room at about 15°C for 30min, then put into the refrigerator instantly at -20°C for 30min, then kept at 15°C for 30min again, it is found that the tensile strength and bending strength can keep up 60% after 170 heating cycles and 100 cooling cycles respectively.

Concrete cubes (150mm×150mm×150mm) with cracks of width 0.25 ~ 1mm were covered by RMPMA, then suffered from 150 heating cycles and 100 cooling cycles. The appearance observation makes sure that there are no cracking and no damage at corner and side of cubes.

3.3 Bonding strength

The strength of bonding mortar with RMPMA is a valuating index of repairing materials. In experimental the mortar bar with 40mm×40mm×160mm was prepared using cement P.O 52.5, cured in room for 28 days, then broken. The flexure sections were cleaned, fixed up and 3~5mm space was kept between the two broken mortar bars. After sealed, the RMPMA was injected into the space. The bonded mortars were cured in room for 7d, broken again, the fracture situation was recorded. The photos in Fig 7 show that the damage takes place in cement mortar, not at the bonding zone, the RMPMA has good bonding strength.

3.4 Ultraviolet irradiation

The ultraviolet radiation durability of RMPMA has been notable because it is a kind of organic material. The deleterious wave for RMPMA is 290~315nm of which the fluorescence violet lamps (three lamps) with 10W were chosen in simulation test as shown in Fig 8. The results show that the tension strength and bending strength of RMPMA after radiating 250d can keep up 85%. If referring to the radiation data from a northwest of China, RMPMA can stand about 45 years in ambient site.

3.5 Repair practice

Fig 9 shows concrete prepared outside has many cracks with width of 0.10~0.60mm. The

concrete were covered by RMPMA and the appearance was as shown in Fig 10 where no cracks were observed (see Fig 10(a)), even after 4 years (see Fig 10(b)).

4 CONCLUSION

From the investigation described, it is obvious that the repair material RMPMA developed has good bonding strength, good thermal resistance and can stand heating and cooling cycles and resistant to the ultraviolet radiation. The high tensile and flexure strength, 25.2MPa and 40.4MPa respectively, can enable RMPMA to resist the load stress and keep the crack bonded well.

5 REFERENCES

[1] Nishibayashi, S (1986): Situation of damage of construction caused by alkali aggregate reaction. Concrete Technology (24/11): 57.

[2] Nishibayashi, S (1985): Alkali aggregate reaction in America and Canada. Concrete Technology (23/10): 65.

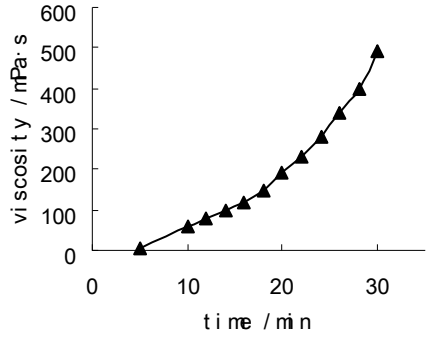


Figure 1: Relation of viscosity with preparation time.

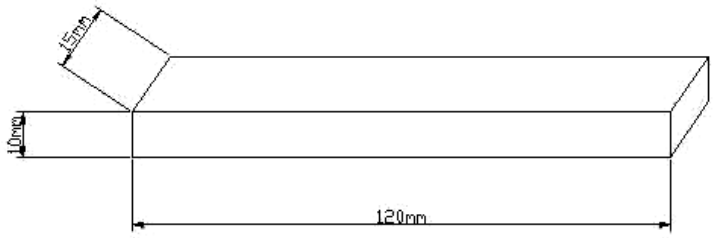


Figure 2: Dimensions of sample for bending strength testing.

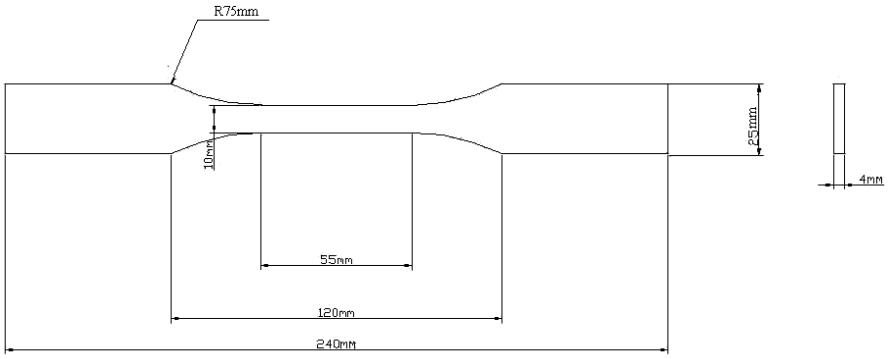


Figure 3: Dimensions of sample for tension strength testing.

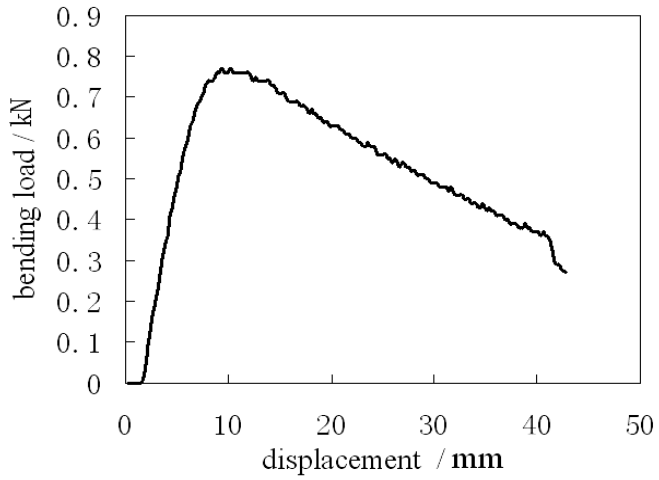


Figure 4: Relationship between bending load and displacement.

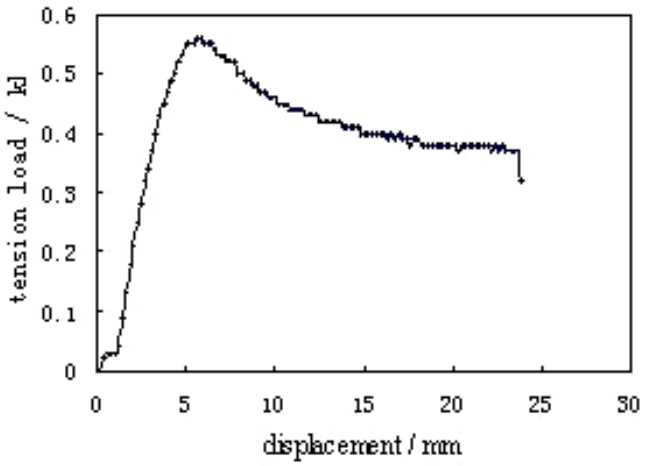


Figure 5: Relationship between tension load and displacement.

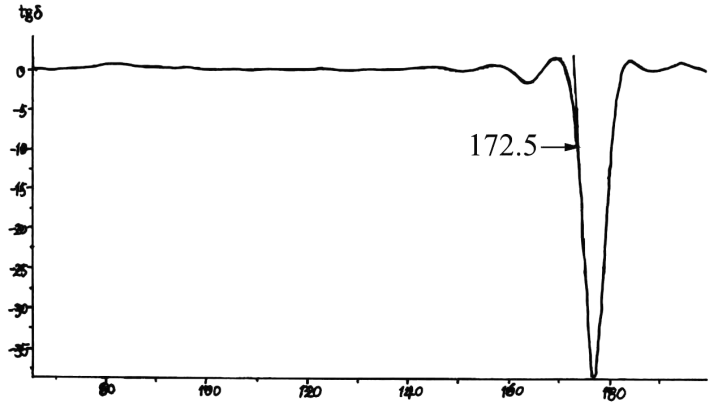


Figure 6: The Tg testing curve of RMPMA.

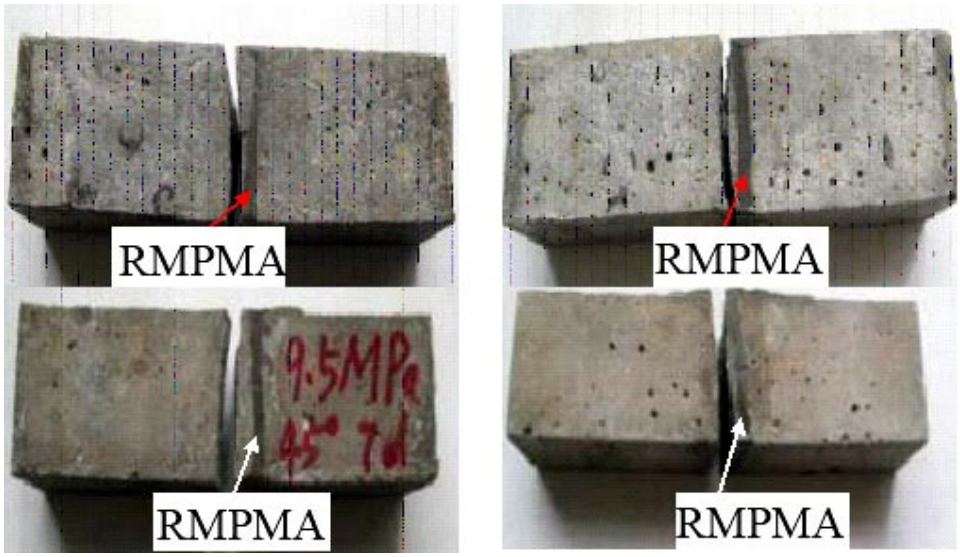


Figure 7: Photos of broken bonded mortar bars.

Figure 8: Experiment with ultraviolet radiation.

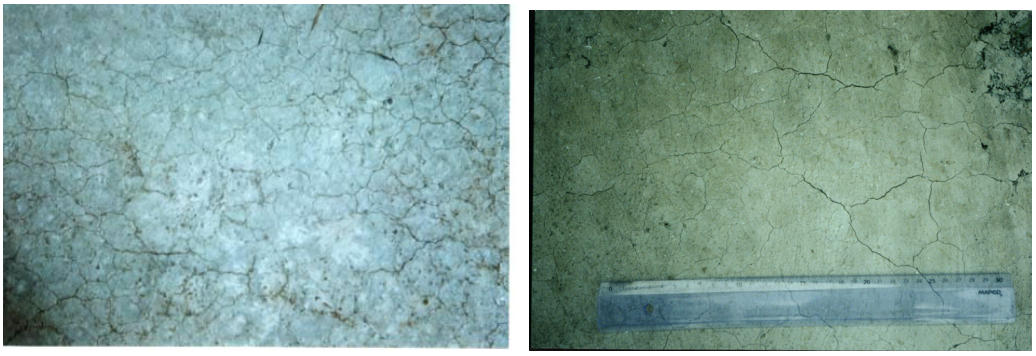
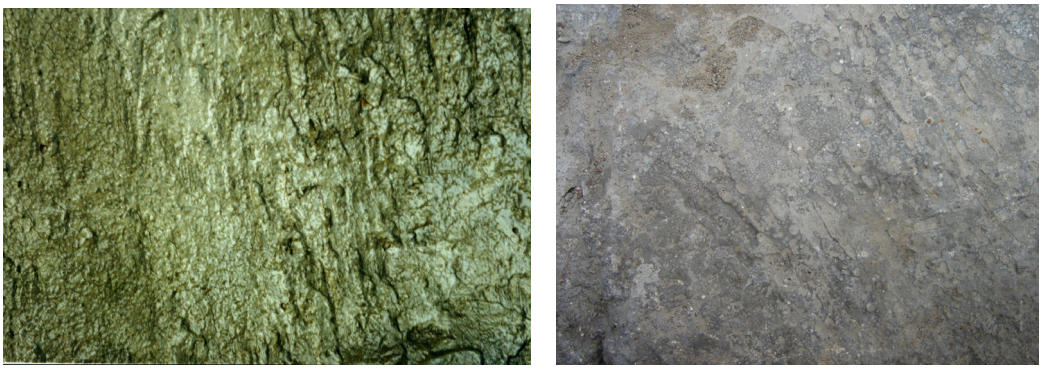


Figure 9: Cracking concrete prepared outside the lab.



(a) just finished (b) after 4 years

Figure 10: The cove concrete with RMPMA.