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ORIGINAL ARTICLE

The participation ratios of cement matrix and latex network in latex cement co-matrix strength

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Abstract This investigation aims to determine the participation ratio of cement matrix and latex network in latex cement co-matrix strength. The first stage of this study was carried out to investigate the effect of styrene butadiene rubber (SBR) on cement matrix participation ratio by measuring degree of hydration and compressive strength. The second stage in this study shows an attempt to evaluate the latex participation ratio in mortar and concrete strength with different latex chemical bases. Effect of latex particle size on latex network strength was studied. The test results indicated that the latex participation ratio in co-matrix strength is influenced by type of cement matrix, type of curing, latex type, latex solid/water ratio, strength type and age. For modified concrete, when the SBR solid/water ratio increases the latex participation ratio in flexural and pull out bond strength increases. The latex participation ratio in co-matrix strength decreases as latex particle size increases.

1. Introduction

Polymers are being increasingly used in civil engineering applications modifiers, especially for the purpose of improving service performance of both concrete and mortar [1,2]. In fact, among the different presentations of polymeric substances, polymer latexes are the most widely used [3]. However, inclusion of polymers particularly elastomeric latexes toward improving physical, mechanical and durability properties of normal concrete and mortar may cause undue loss of integrity [4].

The microstructure of mortar and concrete is of considerable importance since it governs their mechanical properties, cement hydration and durability [1–3]. In addition, chloride permeability is recognized as a critical intrinsic property affecting the durability of reinforced concrete [5,6]. The use of polymer as a modifier in new structures seems to be a promising strategy in improving microstructure and enhancing the durability of cement mortar and concrete [7–9]. As one of the popular polymers suitable for admixing into fresh mortar and concrete, styrene butadiene rubber (SBR) latex has been widely used for a long time [10,11]. The molecular structure of SBR comprises both the flexible butadiene chains and the rigid styrene chains. The combination of those chains offers the SBR-modified mortar and concrete many desirable

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characteristics ices such as good mechanical properties, water tightness and abrasion resistance [12].

On the traditional (unmodified) mortar or concrete, the cement beside other constitutes have the full responsibility on mechanical properties of mortar and concrete. On the other hand, in modified mortar and concrete, latex shares cement and other constitutes on the responsibility of mechanical properties. In the presence of latex, cement does not share on the mechanical properties of modified mortar and concrete by its full capacity.

Many conclusions can be explained by the traditional phenomena such as, the effect of water cement ratio and cement content on the mechanical properties of mortar and concrete. On the contrary, some of test results in this research work cannot be explained easily by the traditional theories such as irregularly of latex modified mortar and concrete compressive strength relation with water cement ratio and cement content. In addition, the effect of polymer solid content and solid chemical base show an irregular trend with the co-matrix mechanical properties.

To interpret these previous phenomena, another expression can be used. This expression is called ''Participation Ratio'' of cement mixture and latex network in the latex cement co-matrix strength. This is due to the deposition of latex particles on the surfaces of unhydrated cement particles causing a decrease on each of cement matrix hydration degree (polymeric effect) [1–3]. The share of cement on strength of latex cement co-matrix is called cement participation ratio. This phenomenon is described as; during the withdrawal of water in the latex cement co-matrix by hydration process, the latex particles started to deposit on the cement particles surfaces preventing the increase in cement hydration degree [2,3,6]. This deposition leads to decrease cement hydration degree as latex solid content increases. This polymeric effect was confirmed by many previous researches [13–17]. These researches showed that degradation of cement hydration degree due to latex addition resulted a decrease in cement matrix strength [18–21]. Also, there is a linear relationship between strength of modified cement paste and degree of hydration. Based on the previous phenomenon, one can conclude that the increase in latex cement co-matrix is the sum of cement and latex participation in strength. This study focuses on the participation ratios of cement mixture and latex network in the strength of latex cement co-matrix.

2. Experimental program

The experimental program of this research divides into two phases: hydration degree and compressive strength of cement paste. The second phase is the mechanical properties of mortar and concrete.

2.1. Materials

Three types of latex chemical base were used: styrene butadiene (SBR), acrylic ester (ACR), and polyvinyl acetate (PVA). Different five particle sizes of styrene butadiene as a chemical base from different commercial companies were considered. The SBR particle size ranges from 18.2 to 255.8 μm. Table 1 and Fig. 1 presents the physical properties and grading of used latex. Type I cement according to ASTM C150 was used in this study. Chemical compositions, physical and mechanical properties of cement are given in Table 2. Natural sand with 2.8 fineness modulus and pink lime stone with nominal maximum size of 9.5 mm were used.

2.2. Mix proportions and test procedure

For first phase, the latex with styrene butadiene rubber (SBR-1) as a chemical base was used in cement paste mixtures (P). The effect of latex addition on cement hydration degree was studied in cement paste. The water cement ratio was kept constant as 0.35. Different concentrations of latex ranged from 0.0% to 50.0% by weight of water content were used. All cement paste specimens were subjected to dry and wet curing methods. In wet curing, the specimens were put in water after 48 h of casting until testing date while the dried specimens were left in air until testing date. The degree of hydration of cement-modified paste was calculated using the thermo-gravimetric analysis test results (TGA). The determination of degree of hydration depends on the magnitude of the drop in the TGA curve between two distinct data points. The degree of hydration (α) can be calculated from TGA curves using Eq. (1) [22] as follows:

$$\alpha = W_{n(t)}/M_c * W_{n(\infty)} \quad (1)$$

where $W_{n(t)}$ is defined as mass loss between 145 and 1000 °C, $W_{n(\infty)}$ is the ratio of non-evaporable water corresponding to full hydration, M_c is the initial unhydrous cement mass of sample in gram.

Mixture proportions, hydration degree and compressive strength of cement paste with SBR-1 latex are presented in Table 3.

For all mortar mixtures (M) in the second phase, the ratio between cement and sand was kept constant of 1.0:2.7 by weight. The water cement ratio was kept constant as 0.28. The used concentration of latex solids ranged from 0.0% to 36.0% by weight of water content was used. Three types of

Table 1 Physical properties of different types of latex.

Type	Commercial name	Production company	Chemical base	Color	Specific gravity	Solids%	Solids particle N.M.S (μm)
SBR-1	Adebond 65	CMB	Styrene butadiene rubber	Milky white	1.01	45.5	29.7
SBR-2	Sika latex	Sika	Styrene butadiene rubber	Milky white	1.02	35.0	18.2
SBR-3	Techbond SBR	MCC	Styrene butadiene rubber	Milky white	1.03	50.5	72.7
SBR-4	Sikabond latex	Sika	Styrene butadiene rubber	Milky white	1.01	17.0	255.8
SBR-5	Kim latex	Prokim	Styrene butadiene rubber	Milky white	1.02	38.0	153.2
ACR	Sika top 77	Sika	Acrylic	Milky white	1.01	37.0	125.8
PVA	Techbond PVA	MCC	Polyvinyl acetate	Milky white	1.01	38.0	79.7