USE OF PREPACKAGED POLYMER-MODIFIED MORTARS AS AN EFFECTIVE EARTH QUAKE RESISTANT MATERIAL

M.U.K Afridi[1], Y. Ohama[2] and S. Mubin[3]

Civil Engineering and Architecture Department, Superior University, 17-Km Raiwind Road, Lahore, Pakistan

Nihon University, 14-10,402, Hiyoshi 2-Chome, Khoku-ku, Yokohama 223, Japan

Civil Engineering Department, University of Engineering and Technology, Lahore, Pakistan

Corresponding email address: sajjadmubin@yahoo.com, Phone No. +92 322 8880003

ABSTRACT: *Prepackaged Polymer – Modified Mortars (PPMM), using redispersible polymer powders, and polymer – modified mortars (PMM), using liquid polymer latexes or emulsions, are very effective repairs and rehabilitation materials for earthquake damaged structures and may be used for such remedial works with confidence and satisfaction. Such behavior of PPMM and PMM is due to their improved structures. In such PPMM and PMM the mortar constituents are compactly joined with each other. This is due to the presence of continuous, inter-weaving polymer films in PPMM and PMM. This forms a monolithic structure in which the inorganic Portland cement binder or matrix is improved or reinforced by an additional polymeric binder or co-matrix. This matrix has superior mechanical and durability characteristics as proved by scanning electron microscopic (SEM) studies in conjunction with other experimental data. Such PPMM was used to repair and rehabilitate a fire – damaged building in Karachi Pakistan in the year 2000. Soon after the repairs, Karachi was jolted with a high magnitude earthquake jolts up to 6.5 or more on Richter scale. Such PPMM proved highly successful in resisting these high magnitude earthquake jolts. This paper focuses on scanning electron microscopic (SEM) studies, which are important in explaining the structural-property relationships of the concerned materials. Such SEM studies should be used in the development of hi-tech construction materials along with other necessary experimental procedures. The paper also reviews the details of the PPMM, its application and performance.*

Key Words: Prepackaged Polymer – Modified Mortars (PPMM); Polymer – Modified Mortars (PMM); Scanning Electron Microscope (SEM); Unmodified Mortar (UMM); Earth Quake Resistant Materials.

1. INTRODUCTION

Polymer-Modified Concrete (PMC) is developed by mixing a polymer material to Portland-cement concrete with the interest of enhancing the concrete durability and bond strength. PMC, also known as Polymer Portland-Cement Concrete (PPCC) or latex-modified concrete (LMC), was originally developed during the 1950 and 1960s. The material quickly found its way to awaiting industry to make use of its unique properties and became a common material in bridge deck slab overlays, industrial floors and as repair material with enhanced tensile and bond strength. Extensive research and numerous publications on the behavior of PMC were produced from the late 1970s up to the early 1990s. These publications constitute most of our current knowledge on

PMC and polymer-modified mortars (PMM). While the development of PMC has significantly slowed down in the last decade, this document is designed to provide a major source of collective information for the public about PMC. The intent is to provide insight on most up-to-date standards, current practices, and the state of the art on research developments on PMC.

The International Congress on Polymers in Concrete (ICPIC) served during the last four decades as the international forum for research and development (R&D) on all types of polymer concrete including PMC. Proceedings of the ICPIC reflected the state of R&D on PMC and the issues of current interest for both academia and industry. The first ICPIC was held in London (UK) in 1975, and the most recent ICPIC was held in Chuncheon (South Korea) in 2007. For the last three decades, the ICPIC forum has served to connect interested specialists in PMC while providing insight on new technologies and future development trends. [1].

In the work on Cement – sand mixture with no additions or modification in motor by M.A. Islam, M.M. Rahman and M. Ahmed describe the importance of Prepackaged Polymer Modified Mortars in his work. [2].

Ordinary or Un-modified Mortar (UMM):

Afridi had also extensively studied polymer-modified cement systems (PMCS) including various PPMM and PMM [3]. In another study conducted by Afridi, Yol Komskiy and etal formed the basis for the formation of various industrial PMCS and PPMM, which got international recognition. PMCS, PPMM and PMM are high – tech construction materials which are popularly used as repair, rehabilitation and conservation materials. Usage of PMCS, PPMM and PMM has already proved successful in resisting seismic activity [4].

Prepackaged Polymer-Modified Mortars (PPMM):

PPMM are those materials in which inorganic Portland-cement binder or matrix is improved or modified by the inclusion of an organic, film-forming co-binder or co-matrix due to the addition of polymers and other related ingredients.

The PPMM used was a commercial prepackaged formulation developed in Pakistan on the basis of extensive Research and Development work explored by Afridi et al. [4].

Polymer-Modified Mortars (PMM):

PMM consist of cement sand mixture, organic film-forming polymer latex in emulsion (liquid) form, and other related ingredients in appropriate ratios.

Poor construction practices involve the usage of unmodified mortar (UMM) in repairs and rehabilitation jobs and in making constructions in earthquake prone areas, and doesn't guarantee performance. It is evident from research that the repairs and rehabilitation jobs carried out by such UMM are unsatisfactory, unsuitable, unsafe, non durable and cannot resist seismic forces. This is because UMM have many inherent limitations like low tensile, flexural and bond strengths, lesser elasticity and insufficient deformation resistance etc. Therefore, a special material like PPMM is required which with stand against forces generated in earthquake, which is different from normal loading. Based on the studies, the repairs and rehabilitation jobs carried out by using PPMM and other PMM are highly satisfactory, durable, and safe and can resist high intensity earthquake jolts. The improved behavior of PPMM and other PMM is due to their much improved tensile, flexural and bond strengths, highly improved deformation and other durability characteristics in addition to required compressive strength.

Scope of Research

a) This paper intends to compares the performance of PPMM and with that of UMM under special loading conditions.
b) The paper also focuses on scanning electron microscopic (SEM) studies, which are important in explaining the structural-property relationships of the concerned materials. Such SEM studies should be used in the development of hi-tech materials along with other necessary experimental procedures.
c) This paper also reviews the application of PPMM on a fire damaged building and its performance in resisting high magnitude earthquake jolts up to 6.5 or more on Richter scale.

2. MATERIAL AND METHOD

Materials, Mix Proportions and Experimental Procedures Used

ACI Standard method was used for the selection of material, its mix proportion, and for experiment / analysis. Details of materials, mix proportions and experimental procedures used have been explained elsewhere by Afridi,. **[3]**

Scanning Electron Microscopic (SEM) Studies

Details of SEM studies have been explained elsewhere by Afridi. [3,4,5].

Usage of PPMM on the Fire Damaged Building

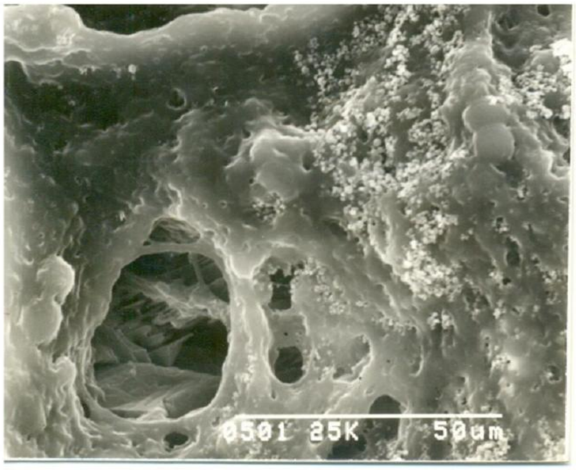
Details of application and procedure for using PPMM has been given elsewhere by Afridi et al. [6].

3. RESULTS AND DISCUSSION

Table 1 shows the comparison of properties of PPMM and UMM. Whereas Figs. 2 (a – e) are various scanning electron micrographs showing the morphological characteristics of UMM and various PMM. Since PPMM was developed on the basis of studies of above PMM. Hence, the above SEM micrographs represent the morphological characteristics of PPMM and support the data for PPMM, shown in Table 1.Fig. 1 shows the inorganic binder system or matrix of UMM. Various voids, cracks and discontinuities are clear. These shortcomings are responsible for various limitations of UMM as depicted in Table 1, where UMM is inferior in mechanical and durability characteristics than PPMM. Such inferior characteristics of UMM include low tensile, flexural and bond strengths, lesser elastic and deformation properties, low freeze-thaw durability and higher crack-coefficient as described by Afridi *et al*. [7,8,9]. The performance of UMM is also limited by its higher water absorption and permeation, higher uptake of corrosion leading factors like higher diffusion of CO_2 and higher chloride ion (Cl^-) intrusion given by Afridi .[3, 9]. As is clear from Fig. 1, such inferior characteristics of UMM are due to absence of polymer films in this system. This makes the mortar constituents of UMM loosely joined with each other thus having a structure with comparatively lower mechanical and durability characteristics.

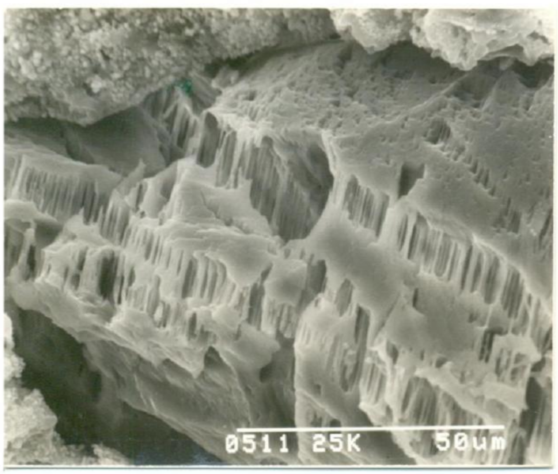
Fig. 1. Scanning electron micrograph of UMM. Cracks, flaws and continuous pores of larger sizes are apparent.

By contrast, as is clear from Figs 2 (a – e), mortar constituents in PMM are compactly joined with each other due to the presence of continuous, inter-weaving polymer films thereby forming a monolithic structure in which the inorganic Portland cement binder or matrix is improved or reinforced by an additional polymeric binder or co-matrix by Afridi *et al*.[3] Such structure of PMM and in turn that of PPMM shows improved mechanical and durability characteristics as is clear form Table 1 based on the analysis, compares the results of different properties of mortar. It is evident from the research that characteristics of PMM and PPMM are improved therefore due to an improvement in sand-matrix adhesion level or due to an overall improvement in calcium-silicate-hydrate-aggregate bond [4]. It is also obvious from Figs. 2 (a – e) that different polymers form different-shaped polymer films in PMM.

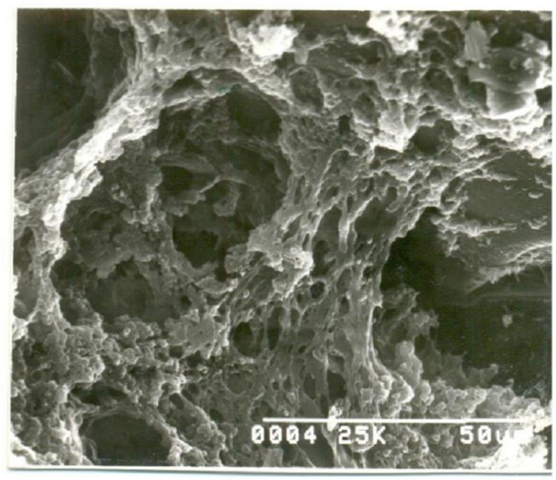


(a)

(b)



(c)



(d)

(e)

Fig. 2(a-e). Scanning electron micrograph representing PPMM. Cracks, flaws & larger pores are bridged by continuous inter weaving, inter connecting polymer films thereby improving the mechanical and durability characteristics of PPMM.

Such polymer films may appear mesh like, thread-like, rugged, dense and fibrous with fine or rough surfaces. It is also clear that different polymers induce different polymer-film distribution levels in the systems modified by them. This depends upon type of polymer used or polymer-cement ratio or both. It is also clear from the above micrographs that at a polymer-cement ratio of 10% or more, all PMM contain fully developed coherent polymer films.

Table 1. Comparison of properties of prepackaged polymer – modified mortar (PPMM) and un modified mortar (UMM)

a. Fresh Mortar Properties			
SNo.	**Property**	**PPMM**	**UMM**
1.	Unit Weight (kg/l)	1.9	2.0
2.	Air content (%)	8.2	6.1
3.	Water Retention (%)	96.6	70
b. Hardened Mortar Properties			
SNo.	**Property**	**PPMM**	**UMM**
1.	Total Pore Volume ($X10^{-2}$ cm^3/g)	10.3366	11.2531
2.	28 Day Compressive Strength (kgf/cm^2)	320	234
3.	28 Day Flexural Strength (kgf/cm^2)	130	74
4.	28 Day Tensile Strength (kgf/cm^2)	47	24
5.	Max. Deflection ($x10^{-1}$ mm)	1.0	0.42
6.	Max. Extreme Tensile Fiber Strain ($x10^{-6}$)	1231	385
7.	Max. Tensile Strain ($x10^{-6}$)	380	82
8.	Flexural Modulus Of Elasticity ($x10^4$ kgf/cm^2)	6.310	7.36
9.	Tensile Modulus Of Elasticity ($x10^5$ kgf/cm^2)	2.27	2.63
10.	Crack Coefficient ($x10^{-2}cm^2/kg$)	0.020	0.037
11.	Adhesion In Tension (kgf/cm^2)	22	5
12.	Water Absorption (%)	9.3	122
13.	Water Permeation (g)	6	66
14.	Freeze – Thaw Durability	72	10
15.	91 – Day Carbonation Depth (mm)	10	21
16.	Index Of Resistance To Rate Of Diffusion Of CO_2	2.43×10^{-4} $\sqrt{t}$+0.15(γ =.99)	5.57×10^{-4} $\sqrt{t}$+0.53(γ =.99)
17.	91 – Day Chloride Ion Penetration Depth (mm)	10.5	22.5
18.	Apparent Chloride Ion Diffusion Coefficient ($x10^{-9}$ cm^2/s)	0.2	13.2

PPMM in Resisting High Magnitude Earth Quake

Repairs and rehabilitation of the fire damaged building of the daily Business Recorder House, Karachi was carried out using PPMM as an admixture to concrete mix. The building suffered heavy damage due to fire in the year 2000. During the repairs, renovation and rehabilitation works, strengthening of cracked columns was done using PPMM modified concrete. Firstly PPMM was also applied as bond coat. Then cladding (jacketing) of the columns was done with 6 inches thick reinforced cement concrete using 10% PPMM as an admixture. The result of the cladding was excellent. The test cubes of concrete mix containing 10% PPMM as an admixture showed 25% increase in the compressive strength compared to unmodified concrete mix. Soon after the repairs and rehabilitation of the building, Karachi was jolted with a severe earthquake of the magnitude of 6.5 on Richter scale in the year 2001. However, the above repairs successfully withstood the seismic forces with no signs of any deterioration, showing excellent performance of PPMM. This performance of PPMM in resisting the earthquake jolts was in accordance with already published literature given by Afridi, Yol Konskiy and Shteyyert and sufficiently proves that such materials should be used with satisfaction and confidence in repairs and rehabilitation jobs of earthquake damaged concrete structures. [8, 9,10, 11, 12, 13,14, 15,[16].

4. FINDINGS AND CONCLUSION

PPMM are very effective repairs and rehabilitation materials for earthquake damaged structures and to resist horizontal loading. Their effectiveness in resisting earthquake jolts up to 6.5 or more on Richter scale have been proved through testing. These must be used for such remedial works with confidence and satisfaction. Such behavior of PPMM is due to their improved structures in which the mortar constituents are compactly joined with each other due to the presence of continuous, inter-weaving polymer films thereby forming a monolithic structure in which the inorganic Portland cement binder or matrix is improved or reinforced by an additional polymeric binder or co-matrix. SEM studies are important in explaining the structural-property relationships and should be used in materials development along with other necessary experimental procedures.

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