Effect of Chemical Exposure on Mechanical Strength of Polymer Mortar

Mohan Kantharia, Pankaj Kumar Mishra, Manoj Kumar Trivedi, Ripunjoy Gogoi

Abstract: ***Cement mortar is used as binding materials for bricks and stones and for plastering to get better finishing surface. This plaster not only for decorative purpose but also acts as protective surface for whole structure as it saves for sun, cold, rain and wind. These weathering forces affect the building, deteriorate the structure makes cracks, and propagation of cracks further deteriorate cement concrete, reinforcement etc. Various admixtures, nano materials, polymers, and some industrial waste fly ash, silica fume, rice husk ash etc are used for enhancement of engineering properties of cement concrete. Compressive and tensile strength are generally determined as these correlates the other properties also. In this experimental study polymer mortar is exposed for various aggressive conditions, saline water, acidic water, and alkaline water. Then change in compressive and split tensile strength is determined. Polyvinyl alcohol is used as water soluble polymer.***

Index Terms**: *polyvinyl alcohol, chemical exposure, compressive strength, durability.***

I. INTRODUCTION

Mortar is necessary material in saving the life of masonry structure. Normal cement mortar is generally used for all purpose in construction work. But for specific purpose or for enhanced properties polymers are used in cement mortar. Eminent historical structures are made by brick masonry and stone masonry. In old times lime was used in making those structures and now cement replaced lime, because it is the most economical building material. But the properties of this material cannot be predicted as it is heterogeneous and brittle in nature. With time it gets cracks and deterioration of masonry starts, Therefore, repair is inevitable in masonry structure. Repair material should be such that it must bond with the old surface of the structure and it should be durable and should have enough strength. Grouting is also done in case if the cracks are deep and broad. Some nano materials are also used in mortar materials like nano zinc oxide, nano alumina, and nano silica etc. mortar physical properties like compressive strength, tensile strength, permeability, freeze and thaw resistance, chemical resistance, are very important in deciding the life of the structure. Various polymers acrylic resin, epoxy resin, styrene butadiene rubber etc are tested many researchers and found that these polymers increases the compressive and tensile strength of mortar and enhances the durability also. Self-healing mortar are coming into market, which are mixed in the cement mortar and when cracks occur, due to carbonation of that mixed material the self-healing of cracks takes place up to some extent. Especially polymer mortar is good substitute for repair work as it has excellent physical and mechanical properties. The influence of polymer is to reduce porosity and increase flexibility by interactions on cement hydrates.

Manuscript received March 20, 2019.

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II. LITERATURE REVIEW

M. M. E. Hawary et al. (2004): In Kuwait temperature and humidity remains high so corrosion of steel become big factor for deterioration of concrete. Polymer cement reduces the corrosion in steel bars of RCC construction. In this work polymer concrete is used for assessment of corrosion resistance in marine environment. Prepared samples are kept in specially prepared accelerated marine durability system where cyclic exposure of sea water and dry is given. The samples prepared with cement replacement with polymer was used in proportion of 0, 20, 40, 60, 80, 100%. Cubes, cylinder and RCC specimen prepared. The testing is done after 90 and 150 cycles. Corrosion is measured by half-cell corrosion meter. After corrosion change in diameter and weight loss is also measured. The study revealed that by introduction of epoxy permeability reduces and corrosion resistance increases. The author concluded that 20 % replacement by polymer gives best results [1].

R. Skominas et al. (2013): Unequal settlement, impact loading, shrinking of cement, corrosion of reinforcement may cause the cracking of concrete structure. Crack is very common problem and reduces longevity of structure. Polymers and expansive additives are tired in this experimental work. Results showed that injection of polymer additives are more effective for reducing water permeability through cracks. The normal cement mortar (non-modified) compressive and tensile strength were found 20.94 and 4.4, while polymer mortar 29.10, 4.68 and expansive additive mortar 23.50 and 5.33 N/mm2. In slant shear test failure, the nature of the failure was cohesive, hence repair work was stronger.

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Research showed that polymer additive injection was more suitable for constructional work, while non-modified mortar for non-structural work. Environmental exposure classes also affect the results [2].

M. U. K. Afridi et al. (1995): Bond strength in hardened state is important for strength of materials, similarly in cement mortar water retention in fresh state shows how long water is available for internal hydration reaction. Polymers can be used in powder state and liquid state in cement mortar in both state its effect is almost same. It shows that adhesion in tension improves with increase of polymers in cement. For tension test 70x70x20mm plates are prepared (Japanies standards) and failure mode was observed. M cohesive mode of failure, An adhesive mode of failure, and S cohesive mode of failure in mortar substrate. However, these improvements depend on type of polymer added and mortar mix [3].

D.A. Silvaa et al. (2001): In this article porosity of polymer modified mortar is investigated. Two polymers Hydroxyethyl cellulose (HEC) and Vinyl acetate copolymer is chosen and mercury intrusion porosimetry method is adopted. HEC proportions were taken 0, 0.5, and 1.0 %, while EVA was taken 0, 10, 20 % of cement water cement ratio was kept 0.4 curing of 7 days and 27 days done. ANOVA variance analysis showed that curing method and EVA content is most affecting factor. When only EVA mixed in plain cement paste, porosity increases up to 40 % but in combination of HEC smaller changes in porosity, because HEC converts water into gel. Seven days sealed curing showed that pore size reduced the pore diameter for 50 nm to 1 nm. Dry polymer and cement mixed for 120 sec first at low speed and paste mixing for 120 sec is done, curing temperature was 23°C. polymers increase the porosity due to low degree of hydration [4].

M. Golestaneh et al. (2013): In this article investigation of polymer concrete against aggressive environment is done. Different types of resin and filler are used for assessment of chemical resistance of polymer resistance. Testing of samples is done against acidic and alkali environment and loss in compressive strength is determined. Three types of silica powder coarse, medium and fine 1100 µm, 600 µm.and 50 µm used as filler. Fly ash and different combination of silica is used to prepare the samples. F-flysh, s_b all silica, s_c two silica s_2 and s_3. Epoxy resin and hardner (polyamine) is taken to prepare sample. Ratio of resin and hardener was 2:1 whose sp gr. 1.18 at 25 °C and hardeners sp gr 1.07 [5]

S.R. Karade et al. (2009): The behaviour of mortar under aggressive conditions is discussed in this paper. Repair mortar undergo highly acidic, temperature, environment hence polymer mortar is tested for these conditions. Five different polymer mortar tested in this study. Epoxy, Acrylic, PMM, and SBR used. When plain cement mortar passes through the thermal cycles its compressive strength decreases. But using epoxy mortar compressive strength increases, however there is no significant change due to other two resins. Due to cyclic heating and cooling micro cracks develop and the bond between aggregate breaks then strength decreases. The strength of epoxy increases may be due to their crack bridging property. Similarly influence of high temperature at 85$\pm$ 2 °C is tested and found that reduction in strength of plain cement mortar is 17%, while PMM strength increases 3-7 %. But epoxy mortar has poor resistance to high temperature (strength reduced 82 %) but on cooling it recovers the strength. When samples are exposed to acidic exposure for 180 days their mass (up to 11 %) and compressive strength reduces(up to 60 %). But epoxy mortar is found least affected [6].

L. Zavrnik et al. (2014): Different exposure conditions affect the mortar strength and its durability. Pozzolanic cement is studied here for different aggressive exposure conditions like freeze and thaw, water with nitrate ion, ammonia, sulphate ion and sea water. And found that compressive strength decreased up to 50 % and flexural strength up to 90 % after freeze and thaw cycle. However, the mortar shoed better sulphate resistance. In accelerated carbonation test it was found that the pozzolanic cement have better carbonation resistance [7].

P. Lukowski et al. (2013): Self-repairing means ability of a material to the total or partial recovering of its properties, worsened because of damage, without any external intervention. The self-repair should proceed in the place and time expected by the designer, i.e. where and when it is desirable. However, achieving such ability is not easy. The carbonation is the process in which calcium hydroxide present in the hardened concrete reacts, in the presence of moisture, with the atmospheric carbon dioxide,

$CO_2+H_2O=H_2CO_3$

$H_2CO_3+Ca(OH)_2=CaCO_3+2H_2O$

$CaCO_3$ produced in this reaction has more volume than the reactants, and in comparison, to $(CaOH)_2$ produced $CaCO_3$ is less soluble which make the concrete less porous, and more durable as it is more water resistant and chemical resistant [8].

S.J. Lawrence et al. (2004): Large number of factors affects the durability of masonry mortar, environmental, factor, loading conditions, interactions between cement and bricks. It is very difficult to evaluate the durability of mortar by considering any one factor. In this paper author discussed the field and laboratory method for evaluation of durability of masonry mortar. Carbonation, wind, salt, cycles of wetting and drying considered as external factors, and curing, types of cement, mix proportion, types of sand etc are composition of internal factors. Mortar tablets are subjected to cycles of wetting and drying in 5% NaCl solution. After 8 hours of immersion dried under fan for 15 hours, after 5 such cycles the samples are oven dried 105 °C and weighed. The record of cycles and weight is kept. Max weight loss is 2 % considered for test and the no. of cycles for 2% weight loss is recorded. Second test performed with a scratching device. The depth of scratching after 5 nos. is considered as index of performance of durability [9].

M.M. A.Zahrani et al. (2003): The study contains the comparison of various properties of cement mortar contain various polymers. carbonation depth, elastic modulus, thermal expansion, shrinkage tensile and compressive strength are determined.

For durability chloride ion permeability, electrical resistance is determined. Elastic modulus reduced with polymer, electrical resistivity increased, and carbonation enhanced [10].

S.R. Karade et al. (2009): Plain cement mortar is greatly affected by sudden change of temperature and acidic environment. In this paper five repair mortar performance was investigated against high temperature and acidic exposure Epoxy content in mortar gives best performance against such acidic exposure but not against high temperature. Plain cement mortar loses its strength with rise in temperature [11].

T. M. A.Jabiri et al. (2013): In this paper epoxy polymer is investigated for higher temperature and found that all types of concrete lose its strength at high temperature, but the loss in polymer concrete was less, and at 7% content of polymer results are best [12].

K. Kikuchi1 et al. (2008): Some advance mortar and concrete are now used for seismic retrofit. Masonry walls having low shear and flexural strength To find the effect of polymer mortar on masonry, a comparative study is done in this paper. The Strength of masonry is determined by making four samples of masonry unit. One unreinforced and other three were modified with polymer mortar and reinforcement. The specimen made of size 100 thick. The specimen was tested for horizontal cyclic reversal load to understand seismic effect. The loads were applied with hydraulic jack and the failure pattern was observed. Three samples were retrofitted with steel bars in horizontal and vertical direction with Polymer cement mortar. The result shows that the polymer mortar application improves the lateral load carrying capacity. Flexural and shear strength increases compare to Unreinforced masonry wall [13].

III. MATERIALS AND METHODS

(a) ***Materials***: To understand the effect of polymer (polyvinyl alcohol) on cement mortar 1:3 mix by weight mortar is taken**.** Ordinary Portland cement 43 Grade is taken for this study. Natural river sand 1.18 size sieve passed is taken. The bulk density of sand is found 1.58 gm/cm^3 and specific gravity of sand was 2.85, the bulking of sand was 14.10 %. And fineness modulus of sand was 2.22. Polyvinyl alcohol is used as polymer admixture. HCl, NaCl, and NaOH 5 % solution were taken for chemical exposure and samples were kept for 28 days, after 28 days normal water curing.

(b) ***Water absorption Test:*** Water absorption of samples cubes shows porosity of the materials. It also increases water permeability which causes corrosion to steel bars of RCC. Hence for good concrete and mortar water absorption should be less. samples are own dried for 24 hours at 105°C and weighed W_1, then samples are dipped in fresh water for 24 hours and then weighed W_2. Percentage of water absorbed is calculated as

Water absorption % =[$(W_2-W_1)/W_1$]X100

(c) ***Chemical Exposure Test:*** Concrete structures made near sea shore have to face saline water continuously, therefore concrete should have good resistance against saline water, acid rain etc. Here mortar cubes are tested against aggressive exposure, hence tested in HCl, NaOH, and NaCl. After 28 days curing samples were placed 5 % solution of HCL, NaCl, and NaOH for 28 days. After removing from chemical solution compressive strength, split tensile strength and water absorption teste were conducted. Results are shown in table and graphs.

IV. RESULTS AND DISCUSSION

Results of water absorption indicate that increasing polymer content and after aggressive chemical exposure the water absorption decreases up to 4 % content of polymer then again increases, this trend is followed in all types of exposure. Reduction in water absorption is indication of less porosity and hence less permeability that will increase the durability of mortar. Comparing HCl, NaCl, and NaOH the porosity is least in HCl sample while NaCl moderate and NaOH is maximum, its mean NaOH affecting the most, this trend followed in every sample irrespective of polymer content. These results also indicate that this polymer mortar is good for acidic and saline water exposure. These results indicate that polymer concrete reduces the porosity because water absorption is less than the cement mortar without polymer. For reduction in water absorption maximum 4% polymer content is suitable. Compressive strength reduces after chemical exposure and strength reduces more in HCL exposure when polymer percentage increased. While this trend is reverse in case of NaOH, for NaCl it remains least affected.at 2% of polymer the resistance against is best in compressive strength. Tensile strength increases after chemical exposure when polymer percentage is 3% this increment is 12 % and polymer is also performing better against NaCl when its % is 2% and 4%. However, against NaOH at 4% its resistance is best but less than normal cement mortar. In general, the results show that polymer as an admixture is beneficial to polymer mortar against chemical exposure. Flow value of cement mortar with polymer shows that increasing polymer content the flow value increases. It means that the workability increases with use of this mortar. Flow value of 0% polymer is 20% and for 5% polymer it is 55%. Flow value increase is linearly proportional to the content of polymer. Therefore, for constant workability the water content can be reduced further.

Table 1: Polymer percentage and water absorption for different solution

Polymer %	Water absorption after 28 days chemical exposure		
	HCL	NaCl	NaOH
0%	0.6	0.55	0.7
1%	0.39	0.46	0.66
2%	0.3	0.41	0.67
3%	0.35	0.35	0.51
4%	0.1	0.34	0.36
5%	0.25	0.37	0.61

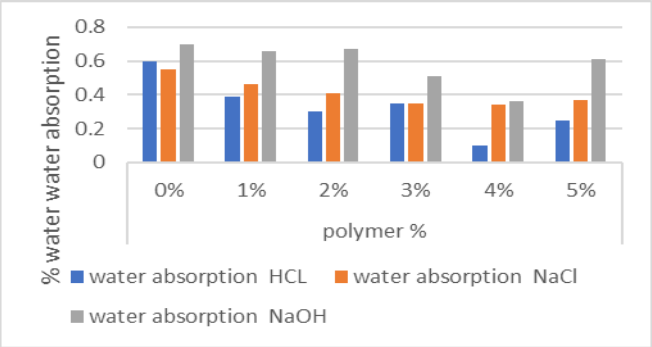

Figure 1. Water absorption after chemical exposure

Table 2: Compressive strength in N/mm2 after 28 days chemical exposure

Compressive Strength in N/mm^2 after 28 days chemical exposure			
Polymer %	HCL	NaCl	NaOH
0%	29.33	31.33	33.33
1%	25.33	25.33	23.33
2%	34.66	28	31.33
3%	21.33	24.66	24.66
4%	13.33	24.66	24
5%	16.66	20	22

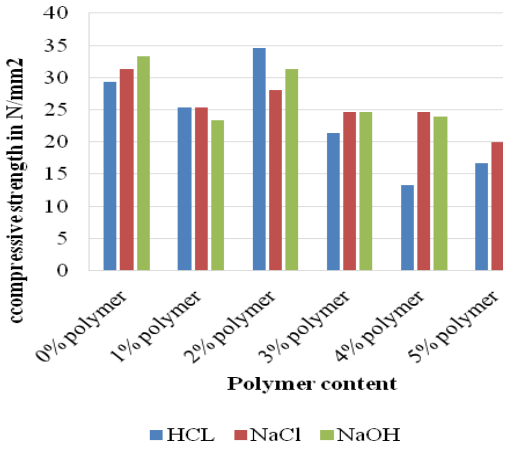

Figure 2. Compressive strength after chemical exposure

Table 3: Tensile strength in N/mm2 after 28 days chemical exposure

POLYMER %	HCL	NaCl	NaOH
0%	5.56	5.9	6.9
1%	5.56	5.23	5.23
2%	4.9	6.12	5.56
3%	6.23	5.23	5.9
4%	6.12	6.12	6.12
5%	4.9	5.56	5.56

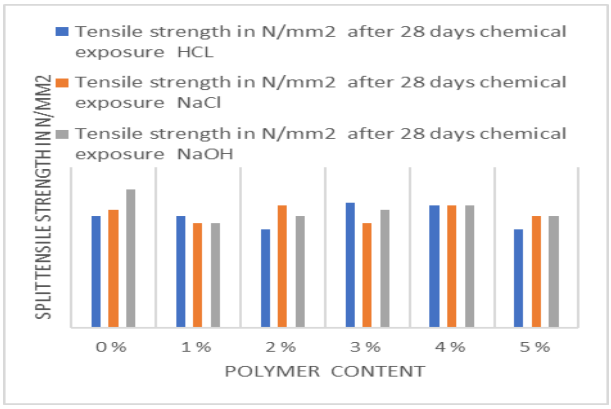

Figure 3. Tensile strength versus polymer percentage

Table 4: Polymer and flow values

Polymer %	Flow value %
0	20
1	36.6
2	26.6
3	36.6
4	45
5	55

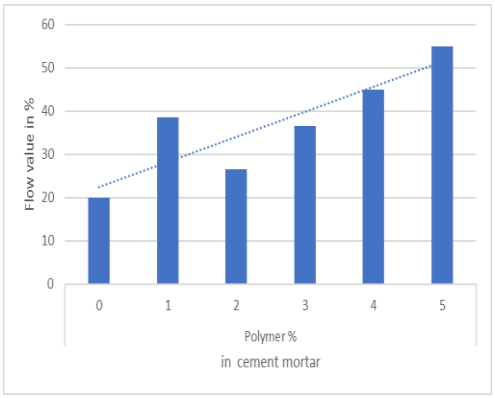

Figure 4. Flow value versus polymer percentage

FIG-5 Flow Value Test Apparatus

V. CONCLUSIONS

Polymer mortar and Concrete is now coming into regular practices because they enhance some of the mechanical properties. In this experiment it is found that used polymer Poly-vinyl alcohol can enhance workability of fresh mortar. The flow value results showed that workability increases with increase of polymer in the mortar. For keeping constant value of workability, the water content can be reduced with increase in polymer. Increase workability gives good quality of mortar. Inclusion of polymer does not increase its compressive strength but slightly increases the tensile strength. Water absorption results showed that increase in polymer content decreases the water absorption. Reduction in water absorption is good for durability of cement mortar and concrete. It can be concluded that polyvinyl alcohol is beneficial for cement mortar when it is added 2-4% of cement weight.

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