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Research Article

# FIRE RESISTANCE OF CEMENT MORTAR MADE WITH TREATED DOMESTIC WASTE WATER AND LIME

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A B S T R A C T

This article presents the fire resistance of cube compressive strength of cement mortar to ascertain the significance of the treated domestic water and lime concentration in the mixes. The specimens were exposed to different temperatures from 100 to 700$^0$C with an increment of 100$^0$C. The cube specimens were cast with various treated water dosages of 0,25,50,75 and 100% as replacement to potable water and for effective replacement the lime concentrations are varied from 0 to 30% by weight of water added to the mixes. From the results it came to know that 50% of Treated water and 25% of lime concentration provided remarkable results for OPC mix. Few models are generated for evaluation of experimental results.



## INTRODUCTION

Cement concrete industry using the potable water for casting of the structural and non structural elements and few research works has been carried out on usage of water, which is not fit for drinking (Waddell (1974)). Due to rapid urbanization, the natural resources in and around becoming scaring to meet the requirements, in this view the potable water is one among many requirements of human life. After utilizing the potable water from public it become waste water, if it is treated to desirable limits it can be used for other purposes. In this concern the treated domestic water using for plantation, to eradicate the dust problem (by spraying) on public roads etc. but in association of cement concrete works this water usage is at research stage and only few works has happened till today. Usually the used water or effluents may discharge to nearby sea or water bodies. Before discharging this water, a treatment is suggesting so as not to affect the water quality in concern with standard limits. Few countries are using the sea water for plain cement concrete works (Davis H.E et.a. (1982), Popovics S (1983)) and in the similar line few works has been occurred with industrial effluents (Bailey M.C (1980), Tay J.H and Yip W.K (1987)). In view of effluents and its usage for cement concrete works different design codes and hand books (enclosed in the references) on concrete suggesting certain limits (Neville A.M (1987), however still research works are continuing to change the limits specified by the codes.

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When concrete or cement mortar is subject to fire it is considerably affected and their physical and mechanical properties. Concrete with OPC has been examined for fire resistance, Ulrich Schneider (1988), Naus NJ (2006) and Phan LT (1996), in their articles have discussed in detail about the behavior of concrete in the view of strength degradation. For OPC fly ash was added as replacement to cement and for this cement paste, cement mortar and concretes temperature studies were carried out (Sulivan and Sharshar (1992), Sarshar and Khoury (1993), Dias et.al. (1990), Aydin and Baradan (2007) Papayianni and Valiasis (1991), Savva et.al.(2005), Xu et.al. (2001) and Jia et.al. (2011)) and found that, the compressive strength decrements was ranged from 12 to 46% by varying the temperature from 200 to 900$^0$C. From the above past review it is noticed that, less works has been happened on compressive strength of cement mortar produced with Domestic treated water and lime addition in the water. Hence in the present study an experimental work was planned to assess the behavior of cement mortar when exposed to different degree of temperature.

### *Experimental program*

To evaluate the cube compressive strength the work has planned in two stages. In the first stage the Treated domestic waste water is added to potable water as replacement in the proportion of 0,25,50,75 and 100%. From this the effective replacement is found in view of pre assumed strength of cement mortar (55MPa). In the second stage for effective replacement of treated water, lime is added in various proportion of 0 to 30% with an increment of 5%. In addition to those, a mix is prepared with potable water to know the variation of results and this is considered as reference mix. In the first stage total 60 cubes (70.06x70.06x70.06mm) were cast for OPC and PPC mixes and from these strength results, a selective mix (maximum strength) is to take to evaluate the performance of lime which exposed to various temperatures. All the mixes were cast with cement to artificial sand as 1:3 with water cement ratio of 0.45 and dosage of super plasticizer is0.2% by weight of cement.

## MATERIALS

OPC grade 55, PPC (fly ash based), Potable water, artificial sand or manufacture sand used for this experimental work and these properties were checked with IS code specifications and found that, those were satisfied the limits. The treated domestic waste water was collected from the treatment plant and the properties of treated water are presented in the Table 1, including the codes limits.

**Table 1** Properties of TDW and Portable water (PW)

| Description | TDWW | PW | Limits as per codes | | |
|---|---|---|---|---|---|
| | | | IS456-2000 | ASTM C1602 | BS EN 1008 |
| pH | 6.9 | 7.2 | ≮ 6 | ---- | > 4 |
| TS | 850 | 220 | ---- | 50000 | |
| TDS | 825 | 210 | | ---- | 2000 |
| TSS | 25 | 10 | 2000 | ---- | 2000 |
| Organic solids | 350 | 60 | 200 | ---- | ---- |
| Inorganic solids | 500 | 160 | 3000 | ---- | ---- |
| Alkalinity | 45 | 150 | 250 | ---- | 1000 |
| Acidity | 25 | 5 | 50 | ---- | ---- |
| Chlorides for RCC | 300 | 200 | 500 | 1000 | 1000 |
| Chlorides for PCC | 300 | 200 | 2000 | | 4500 |
| Sulphates | 202 | 85 | 400 | 3000 | 2000 |

*Note: Except pH, all are in mg/L*

## DISCUSSION OF TEST RESULTS

### *Compressive strength*

The cube compressive strengths for various mixes are presented in Table 2 and figure 1. From the results it is noticed that, for OPC and PPC mixes the strengths are increasing as the age of specimens increases. The mix with **0T** was taken as reference mix for comparison of other results. For (28 days), 25T, 50T, 75T and 100T mixes the compressive strength was decreased from 4.25 to 24.00%. In the similar line for 90 days observations the strength was varied from 4.12 to 22.90%. For PPC mixes the 28 days compressive strength was decreased and it ranges from 2.18 to 22.52%, in the similar way for 90 days it ranges from 3.04 to 21.22%. From the results and observation, the 28 days PPC mixes shows lesser strengths than the 28 days OPC mixes. Probably this may be due to presence of fly ash in the PPC; this may not react at early stage to attain the effective CSH gel. In PPC the fly ash used as replacement to cement but in OPC this was not appearing. Hence the variation in strengths apparently noticed. From 90 days compressive strengths it is observed that, the PPC mixes shows higher strengths than the OPC mixes. The trend is reverse to the 28 days strength discussions because in PPC the fly ash plays major role to attribute CSH gel but this is not so in the OPC mixes since the absence of fly ash. The cement mortar mix was designed to arrive at 55MPa and from the Table 2 it is observed that, the design strength was noticed for 50%TDW and for other mixes more than 50% TDW the strengths are less. Hence in this case the effective replacement was declared as 50% and this is considered as effective replacement for the cement mortar mixes.

From the cube compressive strength results it is observed that, the maximum strength is noticed for PPC 90 days mixes. Hence PPC T50 mix is taken to study the lime effect. The lime is varied from 0 to 30% to the effective mix (treated water); cube compressive strength results are presented in Table 3. From the results it is observed that, PPC L25 mix has shown the highest cube compressive strength 82.23MPa at 90 days. This highest strength may be due to presence of fly ash in the PPC and also extra addition of lime to the mix (es). This mix has been taken to further study to know the fire resistance.

**Table 2** Compressive strength (MPa)

| Sl.No. | Mix name | % TDW | OPC | | PPC | |
|---|---|---|---|---|---|---|
| | | | 28 days | 90 days | 28 days | 90 days |
| 1 | 0 T | 0 | 61.95 | 63.10 | 59.50 | 64.10 |
| 2 | 25 T | 25 | 59.32 | 60.50 | 58.20 | 62.15 |
| 3 | 50 T | 50 | 55.69 | 56.91 | 53.25 | 57.60 |
| 4 | 75 T | 75 | 51.10 | 52.16 | 50.20 | 54.15 |
| 5 | 100 T | 100 | 47.08 | 48.65 | 46.10 | 50.50 |

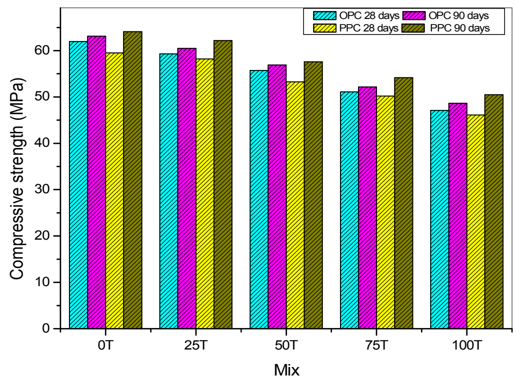


**Fig 1** Compressive strength vs Mix

**Table 3** Compressive strength (MPa)

| Sl.No | Nomenclature of the mix | Proportions | | OPC | | PPC | |
|---|---|---|---|---|---|---|---|
| | | %Lime | %TDW | 28 days | 90 days | 28 days | 90 days |
| 1 | R | 0 | 0 | 61.95 | 63.10 | 59.50 | 64.10 |
| 2 | L0 | 0 | 50 | 55.69 | 56.91 | 54.12 | 57.26 |
| 3 | L5 | 5 | 50 | 59.25 | 61.71 | 58.53 | 62.15 |
| 4 | L10 | 10 | 50 | 66.87 | 67.74 | 62.18 | 68.21 |
| 5 | L15 | 15 | 50 | 71.32 | 71.60 | 66.44 | 73.13 |
| 6 | L20 | 20 | 50 | 77.53 | 79.96 | 69.49 | 78.28 |
| 7 | L25 | 25 | 50 | 75.91 | 78.55 | 71.97 | **82.23** |
| 8 | L30 | 30 | 50 | 74.42 | 75.65 | 71.44 | 80.18 |

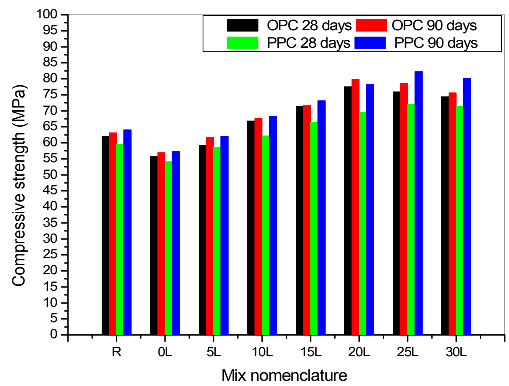


**Fig 2** Effect of lime in the cement mortar mixes

### *Temperature effect*

To study the behavior of temperature total three mixes were taken, they are 0%Lime +0%TDW (Reference mix), 0%Lime+50%TDW (L0) and 25%Lime+50%TDW (L25). Total 63 cubes were cast with the dimensions of 70.06x70.06x70.06mm and exposed for various temperatures for duration of 2.5 hours. The obtained results are presented in Table 4 and figure 3. From the results it is found that, as the temperatures increase the strength is decreasing. The percentage of loss of cube compressive strength is more for L25 mix followed by reference mix and L0 mix. For L25 mix it is shown a decrement of strength varies from 12.30 to 85.10% when compared with reference mix strength of 82.23MPa. In the similar line for L50 mix it showed the strength variation reduction of 8.90 to 79.21% with respect to reference mix strength of 57.26MPa. In the similar way for reference mix it showed the range from 10.25 to 82.60% when compared with 64.10MPa. The mix shows higher compressive strength led to more loss of compressive strength when it is exposed to higher temperature and it tried to expel the heat to outside but due to dense matrix it is unable and in turn the pressure develops inside the matrix. So in this aspect the order of strength loss for mixes is L25>Reference mix>L0. The experimental work was unable conduct more than $700^0$C due to limitation of the lab facility.

**Table 4** Compressive strength for 90 cured specimens

| Sl. No | Temperature ($^0$C) | 0%Lime+ 0%TDWW Reference mix | % of decrease with respect to RT | 0%Lime+ 50%TDWW | % of decrease with respect to RT | 20%Lime+ 50%TDWW | % of decrease with respect to RT |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 64.10 | --- | 57.26 | --- | **82.23** | --- |
| 2 | 100 | 57.53 | 10.25 | 52.16 | 8.90 | 72.12 | 12.30 |
| 3 | 200 | 50.96 | 20.50 | 47.24 | 17.50 | 62.37 | 24.15 |
| 4 | 300 | 42.85 | 33.15 | 39.94 | 30.25 | 52.42 | 36.25 |
| 5 | 400 | 34.61 | 46.00 | 31.49 | 45.00 | 42.35 | 48.50 |
| 6 | 500 | 24.29 | 62.10 | 22.82 | 60.15 | 29.36 | 64.30 |
| 7 | 600 | 14.61 | 77.20 | 14.17 | 75.25 | 18.09 | 78.00 |
| 8 | 700 | 11.15 | 82.60 | 11.90 | 79.21 | 12.25 | 85.10 |

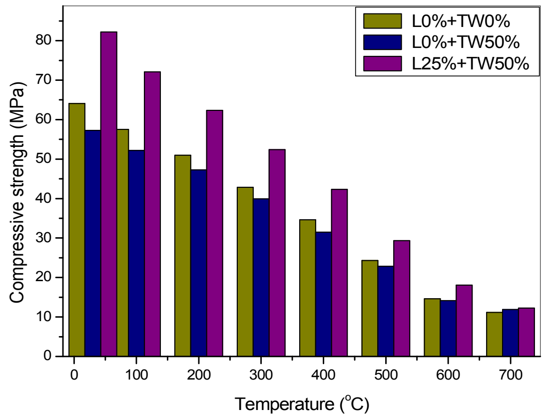


**Fig 3** 90 days cube compressive strength

### *Regression Modals for evaluation of compressive strength*

The ASCE provided a model for normal concrete to evaluate the residual compressive strength when exposed to higher temperatures. In the similar lines herein also would like to develop a model to arrive experimental results. In this section models were deduced to know experimental results for three mixes and same were presented below in Table 5, including regression coefficients. The models were generated with help of principle of least square (mathematics) and the performances of the models are tested and results are presented in Table 6 and figure 4. From the observation of the table it is known that, the models are varied with a maximum value of 15% and those were showed reliable results.

**Table 5** Regression Models

| Sl.No | 90 Days Cube Compressive Strength (MPa) | | |
|---|---|---|---|
| 1 | 0%Lime+ 0%TDWW | $f_c$=66.20-0.080(Temp) | $R^2$=0.9946 |
| 2 | 0%Lime+50%TDWW | $f_c$=60.01-0.071(Temp) | $R^2$=0.9948 |
| 3 | 20%Lime+ 0%TDWW | $f_c$=83.16-0.102(Temp) | $R^2$=0.9943 |

**Table 6** Model performance

| Sl. No | Temperature ($^0$C) | 0%Lime+ 0%TDWW (EXP) | Model | EXP/ Model | 0%Lime+ 50%TDWW (EXP) | Model | EXP/ Model | 20%Lime+ 50%TDWW (EXP) | Model | EXP/ Model |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 64.1 | 63.8 | 1.00 | 57.26 | 57.88 | 0.99 | 82.23 | 80.1 | 1.03 |
| 2 | 100 | 57.53 | 58.2 | 0.99 | 52.16 | 52.91 | 0.99 | 72.12 | 72.96 | 0.99 |
| 3 | 200 | 50.96 | 50.2 | 1.02 | 47.24 | 45.81 | 1.03 | 62.37 | 62.76 | 0.99 |
| 4 | 300 | 42.85 | 42.2 | 1.02 | 39.94 | 38.71 | 1.03 | 52.42 | 52.56 | 1.00 |
| 5 | 400 | 34.61 | 34.2 | 1.01 | 31.49 | 31.61 | 1.00 | 42.35 | 42.36 | 1.00 |
| 6 | 500 | 24.29 | 26.2 | 0.93 | 22.82 | 24.51 | 0.93 | 29.36 | 32.16 | 0.91 |
| 7 | 600 | 14.61 | 18.2 | 0.80 | 14.17 | 17.41 | 0.81 | 18.09 | 21.96 | 0.82 |
| 8 | 700 | 11.15 | 10.2 | 1.09 | 11.9 | 10.31 | 1.15 | 12.25 | 11.76 | 1.04 |

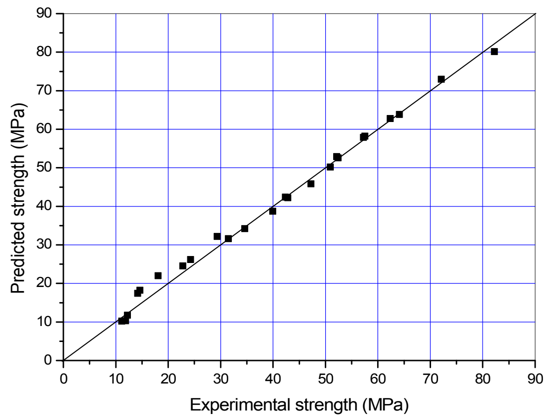


**Fig 4** Compressive Strength

## CONCLUSIONS

***The following conclusions are drawn from this study***

1. The effective replacement of treated domestic waste water for the OPC and PPC is noticed at 50%
2. The optimum dosage of lime is for OPC and PPC mixes 20 and 25%. The maximum compressive strength was observed for PPC mix for 90 days.
3. For cement mortar mixes as the temperature increases the compressive strength decreasing. More strength loss occurs for 25%Lime mix than other two mixes.
4. Models are generated to estimate the compressive strength for three mixes and results provided satisfactory.
5. The models shown a maximum variation of 15% and this can be accepted to consider for evaluation of results.

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