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# Effect of sulphuric acid on plasticized concrete

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This paper presents the results of an experimental investigation on the influence of plasticizer on the behaviour of cement and concrete subjected to sulphuric acid attack. Cement mortar and concrete specimens were prepared in different proportions with and without plasticizer. These specimens were cured in one day in air and immersed in 1 N solution of sulphuric acid up to a maximum period of 28 days. The change in weight with time for each specimen was determined at regular intervals. The effect of plasticizer addition on the workability and compressive strength of concrete was also investigated. The study shows that the addition of plasticizer enhances the resistance of concrete to sulphuric acid. The deterioration of concrete subjected to sulphuric acid attack increased with increase in cement content. Concrete with plasticizer showed better workability and compressive strength.

Sulphuric acid attack on concrete can occur in many ways. Concrete can be subjected to attacks by mineral acids which include sulphuric, nitric, hydrochloric and phospheric acid. When concrete is in contact with such acids, the calcium hydroxide reacts with the acid to form gypsum, which can readily be washed away[1]. Random spillage and unscheduled washing down of sulphuric acid can also occur in industrial environments resulting in localised deterioration of concrete. Acid rain, in which sulphuric acid is an important component, can affect long term durability of concrete structures exposed to the atmosphere. Another source of severe sulphuric acid attack encountered is sewage systems.

Useful information regarding the effect of sulphuric acid on concrete and recommendations to improve the durability of concrete structures to such attacks is found in literature[2-9].

The experimental results given by Raju & Dayarathnam[4] on the reduction of strength and weight of concrete when exposed to sulphuric acid at different concentration has enabled to develop expressions to estimate the reduction factors. The expression developed to estimate the depth of prediction of acid has enabled the designers to provide an appropriate cover to the reinforcement. According to Gutt & Harrison[5], it is observed that low permeability concrete achieved by careful attention to its design and manufacture has a high chemical resistance. Fattuhi & Hughes[8] used different admixtures and coatings in an attempt to improve the chemical resistance of concrete mix. It has been observed that considerable improvements in workability and acid attack resistance can be achieved when admixtures were added to a concrete mix. However, the influence of plasticizer on the behaviour of concrete subjected to sulphuric acid attack has not been thoroughly established.

This paper presents the results of an experimental investigation carried out to assess the influence of plasticizer on the behaviour of concrete subjected to sulphuric acid attack.

## Experimental Investigation

### Materials Used

The materials used were ordinary Portland cement of 43 grade, land quarried fine aggregate from a source near Bangalore confirming to grade zone II, 20 mm maximum size crushed granite coarse aggregate, plasticizer and potable water. The plasticizer was based on hydroxylated carboxylic acid derivatives and the dosage of plasticizer was kept constant at 450 mL per 100 kg of cement through out the experimental work.

**Mix Proportion**

The following mixes were used:

| | |
|---|---|
| Concrete | Mix A - 1:2:4:0.52 |
| | Mix B - 1:1.5:3:0.46 |
| | Mix C - 1:1:2:0.40 |
| | by weight of cement: fine aggregate: coarse aggregate: water |
| Mortar | Mix D - 1:3:0.41 |
| | Mix E - 1:4:0.40 |
| | by weight of cement:fine aggregate: water |

**Specimen Preparation**

The specimens were 15 cm concrete and 7.07 cm mortar cubes. From each mix five cubes were cast. Concrete cubes were cast with a steel rod in central position for handling the cubes in acid. The specimens were demoulded after 24 h of casting and tested.

**Testing Procedure**

Compaction factor method was used to determine the workability of concrete with and without plasticizer. Five cubes from each concrete mix were tested statically at 28 days to estimate the compressive strength of concrete and the average compressive strength of the different mixes were obtained.

To determine the loss of weight of cubes due to sulphuric acid attack, the cubes were immersed in acid after one-day air curing. The concentration of acid was checked regularly and the depleted acid was replenished to maintain the concentration as close as possible to that required by doing volumetric analysis. The cubes were removed from acid containers and weighed at regular intervals. Before weighing, the cubes were lightly brushed to remove debris from the surface. The percentage loss in weight after any period of acid exposure was calculated as:

Weight loss (%) = (Loss in Specimen Weight / Initial Specimen Weight) × 100

## Results and Discussions

**Workability of Concrete Mixes**

The values of workability of different concrete mixes are compared in Table 1. It is seen from this table that the workability of concrete increases with the addition of plasticizer.

**Compressive Strength of Concrete and Mortar**

The compressive strengths of the different mixes are plotted in Figs 1 and 2. The addition of plasticizer enhanced the compressive strength of concrete. It is seen from Fig. 1, that the maximum increase in the compressive strength was 35 % for mix A. The increase in the compressive strength with the addition of plasticizer may be due to the greater degree of hydration caused by the plasticizer.

Table 1—Compaction Factor (C.F.) Test Results

| Mix | Dosage of admixture (per 100 kg of Cement) | C.F. |
|---|---|---|
| A | Nil | 0.80 |
| A | 450 | 0.85 |
| B | Nil | 0.83 |
| B | 450 | 0.90 |
| C | Nil | 0.93 |
| C | 450 | 0.95 |

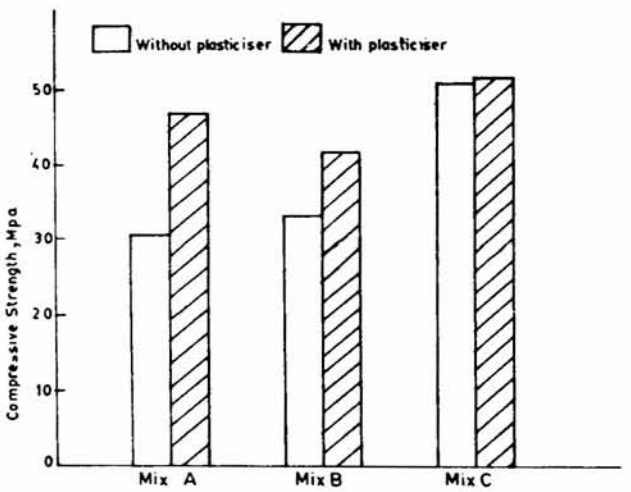


Fig. 1—Compressive Strength of Different Concrete Mixes

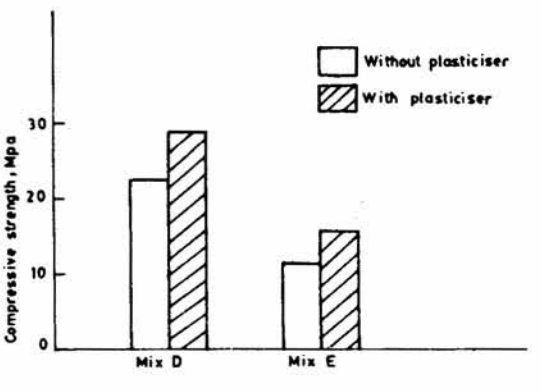


Fig. 2—Compressive Strength of Different Mortar Mixes

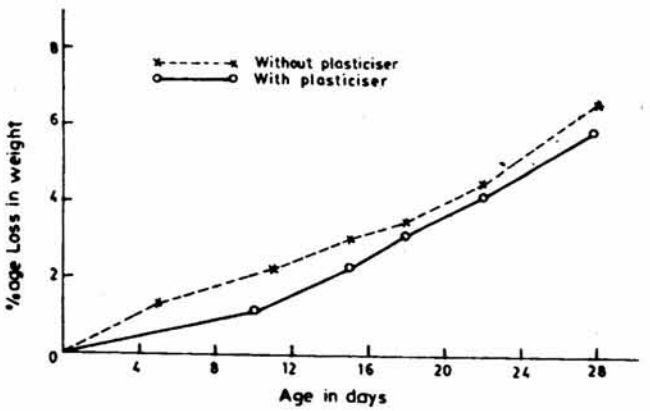


Fig. 3—Loss in Cube Weight with Time for Mix A

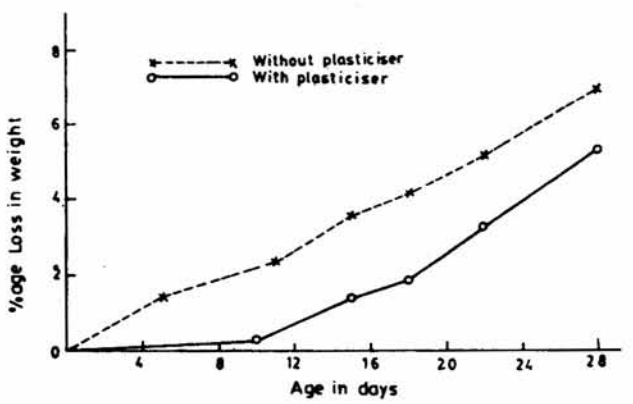


Fig. 4—Loss in Cube Weight with Time for Mix B

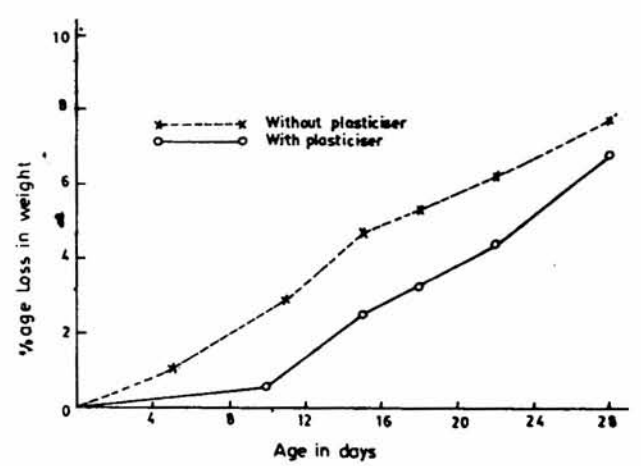


Fig. 5—Loss in Cube Weight with Time for Mix C

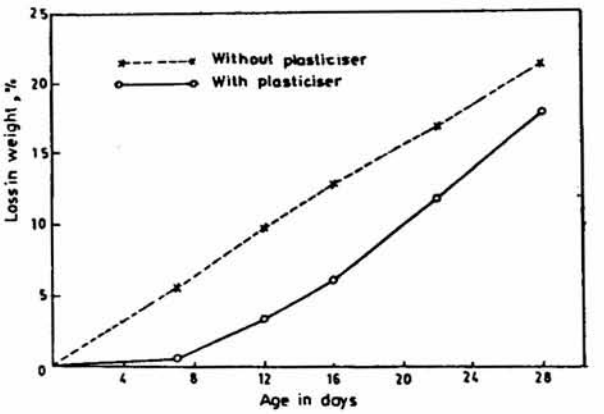


Fig. 6—Loss in Cube Weight with Time for Mix D

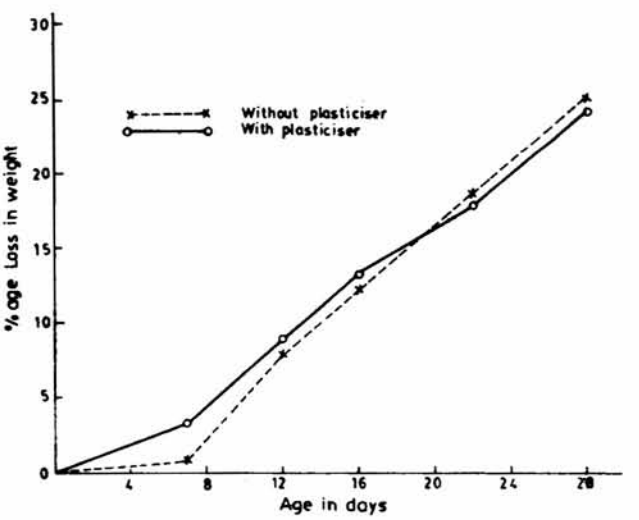


Fig. 7—Loss in Cube Weight with Time for Mix E

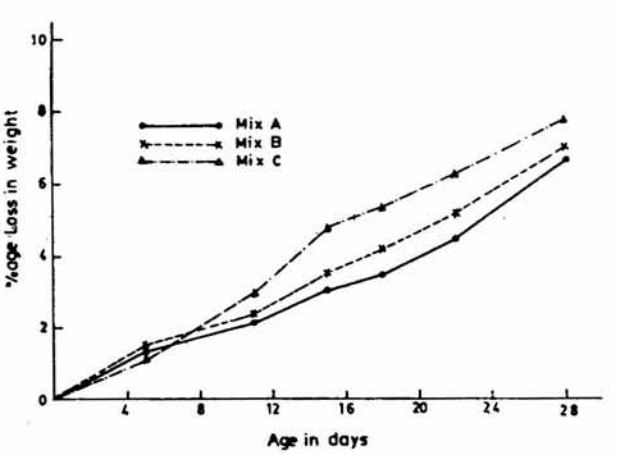


Fig. 8—Loss in Cube Weight with Time for Different Concrete Mixes without Plasticizer

**Loss in weight of cubes immersed in acid**

The loss in weight of concrete for mixes A, B and C are plotted in Figs 3 to 5. It is seen from these figures that there is an improvement in the resistance to the acid attack with the incorporation of plasticizer. These improvements were 12 %, 28 % and 14 % for mixes A, B and C respectively. Figs 6 and 7 show the loss in weight of mortar for mixes D and E. The addition of plasticiser also enhanced the resistance of mortar to sulphuric acid attack. However, the improvements in the resistance to acid attack for mortar mixes were not significant compared to concrete mixes.

The loss in weight of concrete when immersed in sulphuric acid is mainly due to the action of sulphuric acid on concrete. Sulphuric acid attacks the calcium hydroxide in concrete and convert it to calcium sulphate which can be leached out of concrete. The calcium silicate hydrate reacts with sulphuric acid to form fragile silica gel, which is easily destroyed by external physical forces. The calcium sulphate formed by initial reaction can proceeds to react with calcium aluminate phase in cement to form voluminous calcium sulpho-aluminate (ettringite), which can cause expansion, cracking, loss in strength and disintegration of concrete. The chemical reaction involved in sulphuric acid attack on ordinary Portland cement can be given as:

$$Ca(OH)_2+H_2SO_4=Ca\ SO_4.2H_2O$$

$$3CaO.2SiO_2.3H_2O+H_2SO_4=CaSO_4.2H_2O+Si(OH)_4$$

$$3CaSO_4+3CaO.Al_2O_3.6H_2O+25H_2O=3CaO.Al_2O_3\ 3CaSO_4+31H_2O$$

Fig. 8 shows the weight loss of concrete with time for different mixes. It is seen from this figure that the rate of deterioration of concrete due to acid attack is more for mix C, which has higher cement content than the other mixes.

## Conclusions

Based on the results of this investigation, the following conclusions are made:

1 The addition of plasticizer increases the workability and compressive strength of concrete.

2 Plasticized mortar and concrete resists the acid attack in a better way than the normal concrete.

3 Mortar has less resistance to acid attack than concrete.

4 Increase in the cement content increases the rate of deterioration due to acid attack.

## References

1 Harrison W H, *Concrete (London)*, 2 (1987) 18.
2 Henry T Thorton, Jr., *ACI J*, 11 (1978) 578.
3 Grube H & Rechenberg W, *Cement & Concrete Res*, 5 (1989) 783.
4 Raju P S N & Dayarathnam P, *Build & Environ*, 2 (1984) 5.
5 Gutt W H & Harrison W H, *Concrete*, 5 (1977) 35.
6 Guest G E & Huger B P, *Mag Concrete Res*, 102 (1978) 11.
7 Fattuhi N I & Hughes B P, *ACI Mat J*, 6 (1988) 512.
8 Fattuhi N I & Hughes B P, *Cement & Concrete Res*, 5 (1983) 656.
9 Fattuhi N I & Hughes B P, *Mag Concrete Res*, 144 (1988) 159.