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Studies on Paper Mill Effluent as a Workability Aid for Cement Mortars

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An attempt to use paper mill effluent, which is a source of pollution, as a workability aid for cement mortars is presented. Various percentages of effluent from a medium scale unit have been studied in cement mortar as a workability aid. The effects of dosages on setting time of cement, flows, compressive strength and reduction in water content have been determined.

INTRODUCTION

DURING the last four decades, there has been tremendous growth in the pulp and paper industry in India. In 1989 there were 305 paper and paper board mills in India [1] with an installed capacity of 3.0 million tonnes. A number of small industries having 10–30 tonnes per day capacity make use of agriculture residue and waste paper. These industries consume around 250 m^3 water per tonne of paper and discharge about 200 m^3 of waste water per tonne of paper produced. In the case of large industries the water consumed is about 360–425 m^3 per tonne of paper and discharge is about 250–360 m^3 per tonne of paper.

The paper industries have become a pertinent source of a widespread and intriguing industrial waste disposal problem due to the brown colour and intense bad odour carried by the effluent [2–6] on long standing. The brown colour on long standing is imparted mainly by the presence of lignin [7] and its derivatives. Lignin, a polymeric compound of high molecular weight and unspecified composition, is one of the major components of wood and other natural fibrous materials like jute, rice straw, hemp, etc. Lignin derivatives account for about 20% of the composition of wood. In pulp and paper mills, wood and other raw fibrous materials are pulped by chemical and mechanical means. Pulping brings lignin into aqueous phase from the fibres, which gets into the liquid effluent. The colour-causing materials are carmelized sugars and lignin degradation products. The waste lignin is responsible for the brown colour and the loss of a potentially valuable raw material, and causes a serious water pollution problem.

The paper mill effluent contains lignin and its derivatives, especially lignosulphonates. These lignosulphonates are known to act as water reducing admixtures [8]. In view of the huge cost of a waste treatment plant, and to avoid pollution, it becomes of prime importance to find a simple method by which the effluent can be utilized as such whenever it is discharged. After a preliminary investigation of the liquid effluent from the paper industry, it was thought worthwhile to use it as a water reducing admixture for cement mortars.

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EXPERIMENT

Materials:
Ordinary Portland Cement conforming to IS 269/1989 was used for experimental work.
Sand:
Standard ennore sand conforming to IS 650/1966 was used for preparing mortars, etc.
Effluent:
Paper mill effluent was collected from a factory located in Muzaffarnagar (UP).

Experimental details

The physical characteristics of the effluent, such as pH, Cl^- content, sugar content, colour, Biochemical Oxygen Demand (5 day 20°C value) (BOD), Chemical Oxygen Demand (COD) and total solids were determined in accordance with the standard methods and are given in Table 1.

Table 1. Characteristics of the paper mill effluent

Sl. No.	Parameters	Observation
1	Colour	Dark brown
2	Temperature (°C)	20
3	pH	8.5
4	Total solids (mg/l)	8600
5	Chlorides (Cl) (mg/l)	390
6	Sulphates (SO_4) (mg/l)	730
7	COD (mg/l)	4800
8	BOD (mg/l)	1545
9	Sugar content (mg/l)	8

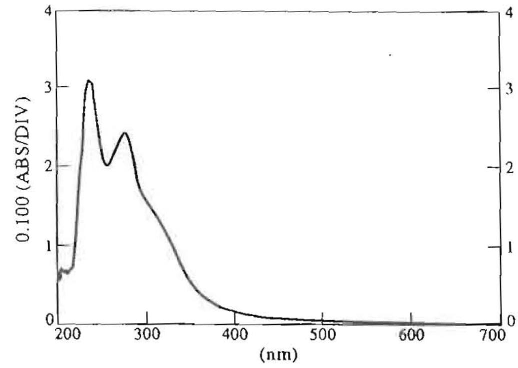

Fig. 1. Determination of lignin by UV visual spectrophotometer.

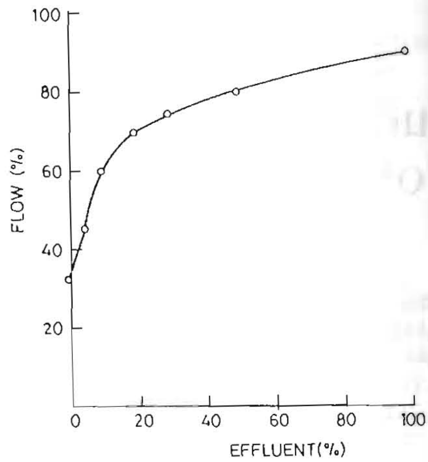

Fig. 2. Effect of effluent dosage (%) on the flow of 1 : 3 cement : sand mortar.

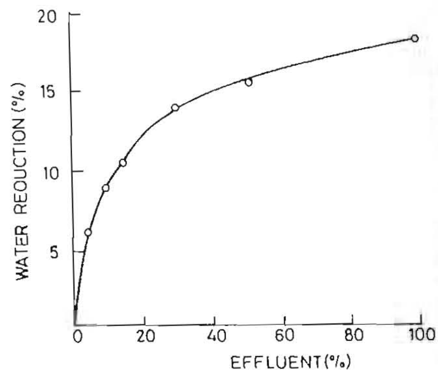

Fig. 3. Effect of effluent dosage (%) on the water reduction of 1 : 3 cement : sand mortar.

Table 2. Effect of addition of effluent on setting time

*Dose (%)	Initial setting time (min)	Final setting time (min)
0	78	130
5	82	135
10	85	139
20	85	135
50	90	140
100	93	150

* As based on water requirement.

Table 3. Flow values (%) of 1 : 3 cement : sand at 0.45 w/c ratio and reduction in water cement obtained at same flow using various percentages of effluent

Sl. No.	Effluent (%)	Flow (%)	Reduction (%)
1	Control	32	–
2	5	46	6.25
3	10	60	7.95
4	15	70	10.50
5	20	75	12 50
6	30	75	14.00
7	50	80	15.50
8	100	90	18.50

The presence of lignin in the effluent was confirmed by UV spectrophotometric method. The homogenized sample was mixed with equal volumes of dioxane for carrying out UV spectroscopy. The absorbance of the solution was read at 281 nm in a cell with path length against a dioxane/water (1 : 1) reference. The UV spectrograph is shown in Fig. 1.

The effect of various dosages (5–100%) of effluent on the setting time of cement was determined according to IS 4031/1988. The results are given in Table 2.

The flow percent values of 1 : 3 cement : sand mortars at various dosages of effluent and at 0.45 water/cement ratio were determined (Table 3) according to IS 5512/1983. The results are presented in Fig. 2. The reduction in the water content at the same flow percent was also determined at various dosages of effluent. The results are shown in Fig. 3.

The compressive strength (kg/cm^2) of the 50 mm cubes (hand compacted) of 1 : 3 cement : sand mortar at various flow values and at the same flow were determined and the results are given in Tables 4 and 5, respectively.

DISCUSSION OF RESULTS

Table 1 shows the physical characteristics of the effluent. The pH of the effluent is 8.5, which will have no adverse effect on the properties of mortars. Further, this pH value is within the permissible limits (5.5–9) for any type of discharge either in a stream or for land disposal [9, 10]. The total solid content of the effluent is very high (8600 mg/l). This load is not within the permissible limit of discharge in a stream or land disposal as it reduces the fertility of a field due to deposition of solids on the top layer of soil. The solids are mainly lignin and its derivatives ; lignin is desirable for its water reducing properties in cement mortars.

The values of sulphates (730 mg/l) and chloride (390 mg/l) are within permissible ranges for discharge into public sewer or for irrigation water [9–11]. According to

Table 4. Compressive strength of 50 mm cubes of 1 : 3 cement : sand mortar at various dosages of effluent

Effluent (%)	Flow (%)	Compressive strength (kg/cm^2)	
		7 days	28 days
Control	32	180	240
5	46	227	250
10	60	240	254
15	70	225	260
20	75	255	260
30	75	250	265
50	80	280	280
100	90	284	290

Table 5. Compressive strength of 50 mm cubes of 1 : 3 cement : sand mortar at same flow of control mortar

Effluent (%)	Flow (%)	Compressive strength (kg/cm^2)	
		7 days	28 days
0	32	180	240
5	32	300	320
10	32	280	285
15	32	270	280
20	32	320	355
30	32	310	330
50	32	272	340
100	32	260	300

the Indian Standard IS 456/1978 the limits for sulphates and chlorides are 500 and 2000 mg/l, respectively. The high value of sulphate may have an adverse effect on strength due to the possibility of expansion in the hardened mass [12], but its amount in the mixing water is likely to be low due to the reduced water/cement ratio. Further, the increase in density and low permeability may also compensate for the possible adverse effect.

The sugar content (8 mg/l) of the effluent is very low and may not cause a serious effect on the setting properties of cement. The high values of chemical oxygen demand, COD (4800 mg/l) and BOD (1545 mg/l), are due to the presence of lignin and its derivatives. The high values of COD and BOD destroy the fauna and flora of water courses and disturb the ecosystem of rivers. However, there is unlikely to be any effect on the properties of cement mortars due to these high values.

Figure 1 confirms the presence of lignin in the effluent as lignin gives a clear UV peak at 281 nm [8].

There is a slight delay in the setting time with increase in the dosage of effluent, as observed from Table 2. However, this delay is well within the the prescribed IS limits (4031/1988) of 600 minutes. It is clear from Table 3, column 3 showing the flow values, that flow percent values increase as the effluent dosage is increased. There is almost 170% increase in flow over the control mortar having no effluent. The increase in flow can be attributed to the presence of lignosulphonate anions, which get adsorbed on the cement grains and produce the electrostatic repulsion and bring about rapid dispersion of the individual cement grains. In so doing, water trapped within the original flocs is released and can then contribute to the mobility of the hydrating cement particles in the paste and hence to the increase in flow of the mortars. The effect of effluent addition on the flow is shown in Fig. 2. A remarkable change is observed in the flow percent with the addition of 5–20% of the effluent.

Table 3 also gives the percent redution in water content at the same flow of 1 : 3 cement : sand mortar at various dosages of effluent. It is found that as the effluent dosage is increased there is decrease in the water content and for 100% effluent the reduction in water content is 18.5%, as shown in Fig. 3. This 18.5% reduction in water content indicates that the effluent works as an effective water reducing agent. Normally plasticizers are capable of reducing water content by up to 10% and superplasticizers are capable of reducing by up to 30%. The effluent studied thus falls between the two categories.

Tables 4 and 5 give the 7 day and 28 day compressive strengths (kg/cm^2) of 1 : 3 cement : sand mortar, 50 mm cubes (hand compacted) in two different conditions, i.e. at various flows and at same flow of mortar, respectively. In the case of the control, the gain in compressive strength of cubes at 7 days is 180 kg/cm^2 and it increases to 240 kg/cm^2 after 28 days of curing. The gain in this period is about 30%, while in the cubes made with the effluent additions the 7 day strength varies from 227 to 280 kg/cm^2 with varying percentages of the effluent and the 28 day strengths of the respective cube samples vary between 250 and 290 kg/cm^2. Similarly, in the case of cubes made at the same flow, with reduced water (Table 5), the 7 day strength varies between 270 and 320 and the 28 day strength between 280 and 355 kg/cm^2 with varying percentages of the effluent. The maximum strength has been obtained in the case of 20% addition of effluent. The increase in 7 day strength of effluent-added cubes in comparision to the control has been found to be 40–80% whereas this gain is 5–10% when compared between 7 and 28 day strengths.

The results in both Tables 4 and 5 show that the 7 day cube strength in all the cases where effluent had been added was higher than the 28 day strength of the control cube, indicating that cement in these cases had already hydrated to an appreciable extent during the first seven days. This early gain in strength may be attributed to better compaction under the influence of effluent, cement–water interaction due to formation of dense mass, and the presence of small amounts of sulphate and chloride ions in the effluent, which may have accelerated the hydration and resulted in early strength development.

CONCLUSION

The following can be concluded from the above study with the effluent obtained from a small capacity paper mill.

- There is an increase in the flow of cement sand mortar with the addition of effluent. An increase of about 170% in flow values over the control has been observed.
- There is no adverse effect on the setting properties of mortars.
- The chloride content is well within the IS limits and therefore it can be utilized for ferrocement works also.
- There is 30–50% gain in compressive strength over

the control during the first seven days. This initial gain in strength can be utilized for early demoulding of precast units.

— The effluent which contains high BOD, COD values and cannot be disposed of without treatment in streams or on land can be utilized as a water reducing agent/workability aid for cement mortars. This effluent is available free of cost and therefore will not add to the cost of mortar work, if used. The increased mortar flow can be useful for plastering, flooring and jointing work, the mortar will be less permeable and the shrinkage will also be less compared to that of control mortars.

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