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Chemical Stabilisation of Sand : Part VIII-Furan Resins as Dune and Coastal Sand Stabiliser

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ABSTRACT

Studies on furan resin as dune sand stabiliser are presented. Influence of acid catalysts, viz. phenol disulphonic acid, sulphuric acid, hydrochloric acid and phosphoric acid and other catalysts, viz. trichlorotoluene and benzoyl chloride along with promoters, zinc chloride and ferric chloride, on the strength of stabilised furan resin-sand specimens has been discussed. Optimisation studies on resin content, catalysts and promoters and curing conditions have revealed that maximum strength of 260 kg/cm^2 of the standard specimens made by compaction of coastal sand using furan resins (10 per cent), sulphuric acid (9N, 30 per cent) and a curing time of 2 hr at 40°C is higher than the 170 kg/cm^2 of specimens made of Rajasthan desert sand. Sandy patches stabilised by seepage technique recorded a maximum strength of 125 kg/cm^2. Physico-chemical characteristics of this system and effect of environment on stabilised specimens have also been studied and field trials conducted successfully. This resin-catalyst system would be extremely useful in humid and saline field (coastal) areas for different military applications.

1. INTRODUCTION

The present study was taken up to develop a quick setting resin-catalyst system for consolidation of sand. The earlier systems' developed for desert areas recorded low strengths under humid and saline conditions thereby restricting their applications in coastal field areas. Furan resin-catalyst systems have been studied and found adequate for stabilisation of coastal as well as desert sand for different military applications.

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Furan resins are not new and have been used[2-4] to prepare corrosion resistant mortars for over 30 years. Their resistance to most acids, alkalis and organic chemicals has been well-established. The resins can be produced from a variety of natural products, such as corn cobs (mainly) and bagasse via furfural and furfuryl alcohol and resinified in the presence of strong acids which give a highly exothermic cure. This property of exothermic heat of reaction has been utilised for rapid stabilisation of sand in field during exigencies. The stable products formed are highly cross linked, resinous and infusible and are characterised by their outstanding chemical resistance and properties at elevated temperatures and high humid conditions.

2. EXPERIMENTAL DETAILS

(i) Sand – Desert sand from western Rajasthan and coastal sand from Kerala (coastal Cochin), Goa (coastal Colva) and Tamilnadu (coastal Poompuhar) were used for making the standard specimens by consolidation. Sandy patches within laboratory area were stahilised by seepage technique. All studies have been carried out with desert sand used in our earlier studies'. Coastal sand (coarse sand, 0.5 per cent; medium sand, 49.5 per cent; fine sand, 48 per cent and slit and clay, 2.0 per cent) wherever used has been specifically mentioned.

(ii) Furan resin – The resin for laboratory studies was prepared according to the method described by Manas Chanda[4] and procured from M/s IVP Ltd, Bombay for field studies. Physico-chemical characteristics of the resin are given in Table 1. Acid catalysts-phenol disulphonic acid (PDSA), sulphuric acid, hydrochloric acid, phosphoric acid, trichlorotoluene (TCT) and benzoyl chloride (BC) and promoters – zinc chloride and ferric chloride of analytical grade were used. Resin, catalysts and promoters have been taken by weight with respect to sand. Dilute sulphuric acid (aqueous solution, 25 per cent or 9N) has been used as catalyst.

Table 1. **Physico-chemical characteristics of furan resins**

Sl. No.	Parameter	Characteristics
1.	Availability	Available in the range from low viscosity liquids to higher ones and solids
2.	Colour	Dark brown
3.	Solubility	Soluble in organic solvents
4.	Stability	Good shelf life (over 1 year)
5.	Specific gravity	1.17 at 29°C
6.	Viscosity	19 CP at 29°C
7.	pH	6.15-6.20
8.	Activation	Activated by acid catalysts and cured through the exothermic heat of reaction into black infusible solids
9.	Curing	At elevated temperature curing is faster. Cured sand-resin *specimens are* resistant to moisture, acids, alkalies and solvents

(iii) Preparation of test specimens – Sand, resin, catalysts and promoters were used in the preparation of standard cylindrical specimens' (79 mm dia and 60 mm height) using Jodhpur Mini-compactor[5]. Required amount of sand was weighed and divided into two roughly equal portions. The required amount of resin was added to one portion and the required amount of catalyst or catalyst and promoter to the other. Both the homogeneously mixed portions were mixed together and when sufficient heat was liberated the mass was transferred to the mould, consolidated by applying a tied number of rammings and cured at ambient temperatures.

Sandy test patches of 10 cm length; 10 cm breadth and of varying thickness were stabilised by consolidating the resin-sand mix mortars and by seepage technique by spraying solutions of resin and catalyst on undisturbed sandy soil.

(iv) Seepage technique – Stabilisation was effected by first spraying furan resin (15 per cent BWS) and then aqueous sulphuric acid catalyst for different depths. UCS was recorded under simulated as well as field conditions.

(v) Determination of UCS – Unconfined compression strength (UCS) of stabilised specimens was determined using standard AIMIL make Load frame 9B, 200 kN with proving ring PR-20 calibrated by the National Physical Laboratory (NPL), New Delhi. The data given in tabies and figures are averages of three readings.

(vi) Field studies – Field studies in sandy areas of western Rajasthan and coastal areas of Cochin were also undertaken to assess effectiveness of chemically stabilised sand pads under desert and humid conditions for different military uses.

3. RESULTS AND DISCUSSION

Standard specimens of furan resin and desert sand were prepared with different content of resin (Table 2) taking aqueous sulphuric acid as catalyst and allowing a 2 hr curing time. It is observed that maximum UCS of 170 kg/cm^2 is obtained at the optimum 10 per-cent concentration of resin. Comparative studies on effect of acid

Table 2. Effect of varying resin content on the strength of furan resin-sand stabilised specimens*

Sl. No.	Resin content (%)	Strength (kg/cm^2)
1.	5	30
2.	7	70
3.	10	170
4.	12	170
5.	15	160

* Sulphuric acid [illegible] : 9N, 30 per cent; and curing time : 2hr

catalysts after a curing time of 1 hr were also undertaken (Fig. 1). Studies on the effect of curing time on strength of specimens, using different catalyst and promoter systems were undertaken, and the results are shown in Fig. 2. It is observed from

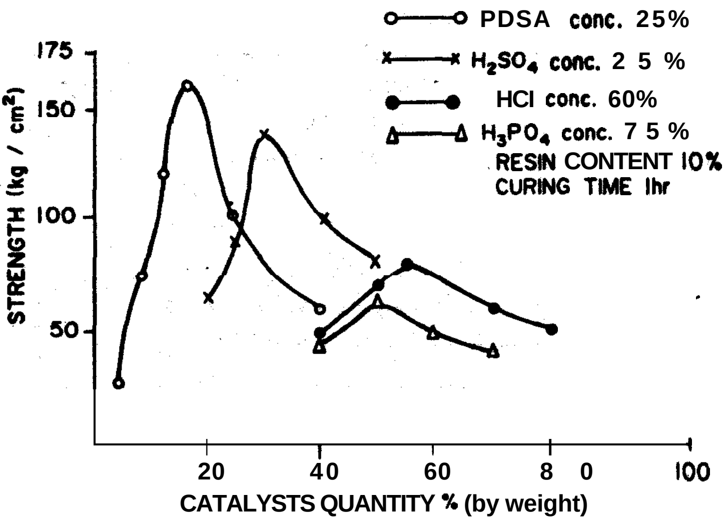

Figure 1. Effect of acid catalysts on the strength of stabilised furan resin-sand specimens.

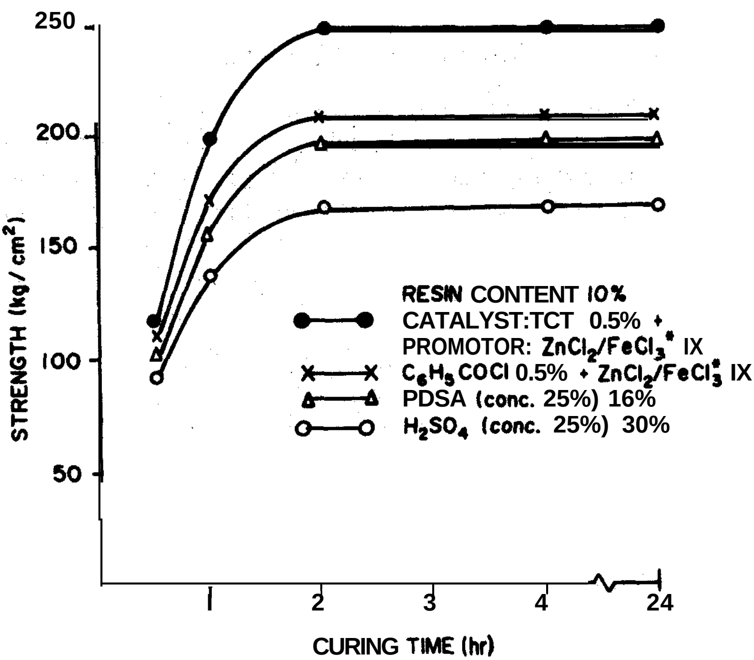

Figure 2. Effect of curing time on the strength of stabilised furan-resin sand specimens (10× 10x4 cm^3) using different catalysts end **promoters.**

Figs. 1 and 2 that PDSA (25 per cent) is the best catalyst, recording maximum strength of 190 kg/cm^2 after optimum curing time of 2 hr. It is also. observed that maximum strength in respect of all catalysts is attained after 2 hr of curing time (Fig. 2) and thereafter the UCS of respective sample remains unaffected. PDSA (UCS, 190 kg/cm^2) and aqueous sulphuric acid (UCS, 170 kg/cm^2) were found to be most suitable catalysts for this study. Aqueous sulphuric acid, because of its easy handling, availability and cost, was selected for detailed examination.

Studies on catalysts (TCT and SC) and promoters (zinc chloride and ferric 'chloride) were also undertaken (Table 3). The maximum strength of standard

Table 3. Effect of catalysts and promoters on the strength of stabilised furan resin-sand specimens[a]

Sl. No.	catalyst (%) TCT/BC	Promoter (%) $ZnCl_2/FeCl_3$[b]	Strength (kg/cm^2) TCT	BC
1.	0.5	1	200	175
2.	1.0	1.5	200	175
3.	1.0	2	100	80
4.	1.0	3	70	55
5.	1.5	1.25	200	175

[a] Resin content : 10 per cent ; and curing time 1 hr.

[b] Zinc chloride and ferric chloride gave identical results.

specimens was found to be 200 kg/cm^2 in the case of TCT (0.5 per cent) and 175 kg/cm^2 in the case of BC (0.5 per cent) at an optimum concentration of the promoters (zinc chloride or ferric chloride, 1 per cent). It is also seen from Fig. 2 that TCT (0.5 per cent) and zinc chloride or ferric chloride (1 per cent) system recorded higher strength 250 kg/cm^2 than that of 210 kg/cm^2 obtained from BC (0.5 per cent) and zinc chloride or ferric chloride (1 per cent) system. Studies on effect of curing time on strength clearly indicate (Fig. 2) that the UCS starts increasing and attains maximum strength after 2 hr. Zinc chloride and ferric chloride gave identical results (Table 3 and Fig. 2).

Effect of curing temperature on the strength of specimens was also studied up to 60°C, the maximum temperature attained by the desert sand during summer. It is found that the strength of the specimens cured at 10° to 60°C varied from 135 to 145 kg/cm^2 after 1 hr of curing time and 160 to 170 kg/cm^2 after 2 hr of curing time. Comparing these values with the data given in Figs. 1 and 2, it is concluded that curing of furan resin is through exothermic heat of reaction catalysed by aqueous sulphuric acid used and it is not significantly dependent on environment or curing temperature (external).

Effect of humidity on the strength of specimens is depicted in **Fig. 3. It** is seen that there is. a direct linear relationship with relative humidity and **UCS** at 45 per cent relative humidity increases from **140** to 240 **kg/cm²** at **90** per cent relative humidity.

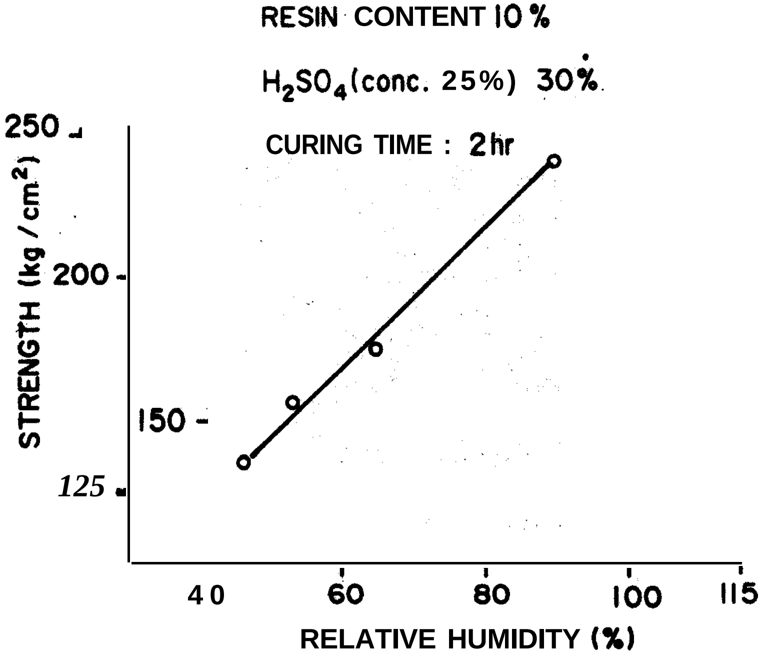

Figure 3. Effect of humidity on the strength of furan resin-sand specimen (10×10×4.5 cm³).

Desert sand and coastal sand from Kerala, **Goa** and Tamilnadu were also studied (Table 4) for chemical stabilisation using **furan** resins. It is found that the coastal **sand** recorded high **UCS** values ranging **from 190** to 260 **kg/cm²** due to high relative humidity, against the low value of **170 kg/cm²** given by Rajasthan desert sand under field environment.

Table 4. Strength of furan resin stabilised patches (10×10×4.5 cm³) having different types of sand*

Sl. No.	Type of sand	Source	Strength (kg/cm²)
1.	Desert sand	Rajasthan desert	170
2.	Coastal sand	Coastal Cochin (Kerala)	220
3.	Coastal sand	Coastal Colva (Goa)	190
4.	Coastal sand	Coastal Poompuhar (Tamilnadu)	260

* **Resin content : 10 per cent ; sulphuric acid : 9N, 30 per cent; and curing time 2 hr.**

Chemical stabilisation of sand by seepage technique was also studied as an alternative; to provide a solution to the **Services** during exigencies. Studies on concentration of aqueous sulphuric acid used as catalyst [Table **5)** reveal that, with change in concentration of acid from **9N** to **10N**, the strength increases from 30 to 125 **kg/cm^2** and then drops to 60 **kg/cm^2** at higher concentration **(10.8N)** after **4 hr** of curing time. Curing time of 4 hr in seepage technique gave optimum strength under field conditions.

Table 5. **Effect of concentration of sulphuric acid on strength of sandy patches (10×10×3 cm^3) stabilised by furan resin using seepage technique***

Sl. No.	Concentration of H_2SO_4 (N)	Strength (kg/cm^2)
1.	9	30
2.	9.5	50
3.	10.0	125
4.	10.44	75
5.	10.8	60

* **Furan** resin : 15 per cent; sulphuric acid : 13 per Cent; and curing **time : 4 hr.**

Results on the effect of thickness on the strength of sandy patches stabilised by spraying **furan** resin and **sulphuric** acid show that the'strength increases with increasing thickness of the stabilised surface, from 25 **kg/cm^2** for 1 cm to 125 **kg/cm^2** for 3 cm thickness {Table 6). Seepage beyond 3 cm thickness is not possible.

Field studies on stabilisation of sand for different military applications were undertaken employing both mixing and seepage techniques. It is concluded that the optimum thickness in seepage (UCS, 125 **kg/cm^2)** and mixing **(UCS, 170-260** kg/cm*) techniques which were found to be 3 and 5 cm respectively, is adequate for heliborne operations and trafficability purposes in desert as well as coastal areas. However

Table 6. **Effect of thickness on the strength of sandy patches stabilised by furan resin using seepage technique***

Sl. No.	Thickness of the stabilised surface (cm)	Strength (kg/cm^2)
1.	1.0	25
2.	1.5	40
3.	2.0	75
4.	2.5	100
5.	3.0	125

* (**Furan** resin : 15 per cent ; sulphuric acid; **10N**, 13 per cent and curing time : 4 hr.

experimental roads and helipads of thickness 5 to 6 cm constructed on more or less permanent specifications have been found suitable after field trials[6,7] using soluble sodium silicate and urea formaldehyde systems, although these systems were not found resistant to humid climate.

REFERENCES

1. Gopal, R., Singh, J. & Das, Ganshyam, *Def. Sci. J.*, *38* (1988), 169-175.
2. McDowall, R. & Lewis, P., T... Plastics *Inst.*, 22 (1954), 189-204.
3. Rathi, A.K.A. & Chanda, Manas, *Popular Plastics*, December (1973), 28-34.
4. Chanda, Manas & Dinesh, S.R., Die Angewandte *Makromolekulare Chemic*, 69 (1978), 85-98.
5. Singh, Alam & Punmia, B.C., *Roads and Road Construction*, 41 (1963), 106.
6. Dwivedi, C.D., Singh, Y.P., Singh, J., Mathur, C.P., Sharma, R.N., Das, Ghanshyam & Singh, Sampooran, *Indian Highways*, 5 (1977), 12-19.
7. Gopal, R., Singh, Y.P., Bhati, O.P., Singh, J., Bhati, J., Singh, I., Ghosh, P.K., Parihar, M.S. & Das, Ghanshyam, *Def. Sci. J.*, 31 (1981), 323-327.