513.1
CONCRETE 1985
0742

Reprinted from the Journal of the Institution of Engineers (India) vol 65, pt CI 5, March 1985

UDC 691.5.51:666.9

Chemical Admixtures for Lime-terracing Concrete

Dr Arjun Dass, *Non-member*

S P Mehrotra, *Non-member*

UDC 691.5.51:666.9

Chemical Admixtures for Lime-terracing Concrete

Dr Arjun Dass, *Non-member*
S P Mehrotra, *Non-member*

Laying of lime concrete over the flat roof surface (lime-terracing) for water-proofing and thermal insulation is popular in different parts of India. Different types of admixtures available locally in the form of extractives of vegetable origin such as methi, bael, kadukai and guggal are used as workability aids in the process of laying the treatment. Local practices of their use and type vary considerably from place to place, and the actual mechanism of their action is also not known. Investigations have, therefore, been carried out to examine the effects of these admixtures on the properties of lime mortars and concrete in order to rationalize the practices by substituting them with standard chemicals. Studies have shown that these admixtures act as retarders of the setting process of lime concrete. This helps in allowing more time for the process of laying and beating till the top layer of the concrete becomes compact and voidless and acts as a water-proofiing membrane. Tartaric acid and citric acid in low concentrations have similar effect on the concrete. It has been found that addition of integral water-proofers can also produce the desired properties without resorting to excessive beating.

INTRODUCTION

Lime concrete is used in different parts of India for (i) laying base concrete for foundations and floors, and (ii) providing water-proofing treatment over flat roofs. The latter application is of special interest and importance as it provides additional advantage of thermal insulation. There are some minor material variations in the material specifications and the method of laying from place to place but this system of water-proofing is followed in almost all regions of the country at places where good quality lime is available[1].

During laying of this treatment over the roofs, certain admixtures are added to the lime concrete mix in the form of solutions or water extractives from vegetative sources. These admixtures are believed to retard the phenomena of setting and hardening of the mix and allow more time for working to achieve a coherent, compact and voidless mass over the roof which can resist the ingress of water below. The effect is generally achieved by continuous beating of the top surface of the concrete in presence of admixtures which include jaggery solution, water extracts of *bael* (aegle marmelos) and *harad* (terminalia chebula) fruits and *methidana* (trigonella foenum-graecum). Local practices in the type of admixtures and the method of their use also vary from one region to another. While molasses are used with methidana mostly in Rajasthan[2] and *bael* (aegle marmelos) fruit in northern areas including Bengal, harad fruit extract with jaggery solution is more common in the southern region[3]. However, no systematic or scientific basis has been found out for these admixtures and no study has been carried out to standardize the proportions of these additives and know their effect on the concrete mix.

This subject has drawn attention of Central Building Research Institute (CBRI), Roorkee, and some preliminary investigations have been planned and carried out as guidelines to solve the problem mentioned earlier from two aspects : (i) To study the effect of traditional admixtures on the behaviour of fresh and set lime concrete to know the mechanism of their action and find out standard chemicals as substitutes for them. This will not only bring about rationalization of the practice but may also enhance the effectiveness of the treatment. Saving in cost is also possible in future in certain cases, for example, the cost of methidana admixture has gone up recently, and (ii) To look into the possibilities of use of certain integral modifiers to achieve *in situ* water-proofing effect. The proposed components are known to reduce the surface tension between solid-liquid components of lime concrete mix system and help in obtaining a voidless layer of concrete either without resorting to the process of beating or reduce the extent of beating. This can result in significant saving in the overall cost of the treatment.

MATERIALS USED

Lime

Lime used in the studies was hydrated lime belonging to class C as per IS : 712-1973.

Dr Arjun Dass and S P Mehrotra are with Central Building Research Institute, Roorkee (UP).
This paper (revised) was received on October 17, 1984. Written discussion on the paper will be received until May 31, 1985.

Surkhi

Reactive surkhi having lime reactivity value of 63.5 kg/cm² and conforming to IS : 1344-1968 was used in mortar compositions.

Brick Ballast

Locally available brick ballast of size smaller than 2.5 cm was used in making lime concrete.

Admixtures

Bael, methidana, harad and molasses were procured from the local market. Commercial varieties of sodium acetate, glacial acetic acid, citric acid, tartaric acid and sunlight soap were used. Sodium salt of oleic acid was prepared by the addition of sodium hydroxide pellets in saturated oleic acid stoichiometrically.

METHODS OF INVESTIGATION

Setting Time and Compressive Strength

Standard methods according to IS : 1727-1967 were followed for determining the setting time. For measurement of compressive strength of lime-surkhi mortars and concrete, 5 cm cubes were made for mortar compositions and 15 cm cubes for concrete. Curing and testing of these specimens were done according to relevant standard methods[4,5].

Water-Absorption

Water permeability of the set concrete compositions was determined as the rate of absorption of water by the mix. A 50 cm long graduated glass tube of 10 mm dia with a 7.5 cm dia glass funnel attached at one end was fixed over one face of the concrete cube such that funnel was sealed on the surface with wax. Funnel and tube were filled with water up to 30 cm mark. Fall in the level of water (as indicated in the tube) resulting from the absorption of water into the concrete was noted up to a maximum period of 24 hr.

RESULTS AND DISCUSSION

Effect of Traditional Admixtures

In order to understand the basic role and probable mechanism of action of the traditional admixtures used in lime terracing treatment, it would be desirable to study their effect on the properties of lime concrete during and after its laying. As per existing practice, the concrete is prepared by mixing together lime, surkhi and brick ballast in requisite quantity of water. During the process of mixing, a small pre-determined amount of any of the admixtures among *bael* (aegle marmelos) or *methi* (trigonella foenum-graecum) is also added at certain places. The extent to which the admixture is used varies according to local practices. For example, in Jaipur, the weight of *methidana* (trigonella foenum-graecum) used is about 0.35% on the lime-pozzolana, while in Jodhpur areas the quantity of methi is reduced to about half of that of Jaipur. This concrete is laid over the roof up to an average thickness of 10 cm. The mix is initially rammed with the help of a metal rod or bamboo sticks to eliminate visible voids and make it uniform. This is then followed by the prolonged beating of top surface of the concrete by means of wooden thapies or a tamping machine developed by CBRI[6] with simultaneous addition of water containing *gur* (jaggery) or molasses and extractives of any one of *bael* (aegle marmelos), *methi* (trigonella foenum-graecum), *guggal* (commiphora mukul) or *kadukai* (terminalia chebula).

The process of constant beating brings the lime-surkhi paste on to the surface and this eventually is the layer on the top which is primarily responsible for bestowing on the treatment of the desired water-resisting characteristics. This process generally continues from 4 to 7 days till the wooden thapi makes no further impact on the surface and leaves no impression. The function of admixtures in the top surface is understood to retard the softened state for a longer period to allow more time for the beating process to continue. This practice of laying and beating the lime concrete is common throughout the country but the type and quantity of the admixture used varies from place to place. In northern India, for example, jaggery water containing *bael* (aegle marmelos) decoction is mostly used. Overall quantities of these substances, that is, *bael* (aegle marmelos) and sugar (gur or molasses) used on the weight of lime-surkhi mix are 0.1% and 0.2%, respectively. In southern parts of the country, however, Kadukai (terminalia chebula) extract is used in place of *bael* (aegle marmelos). Its percentage remains the same while the amount of molasses is reduced to about 0.07%. In Rajasthan, where *methi* is added in the concrete mix and *guggal* (commiphora mukul) for the final finishing of the surface, the percentage of *methidana* on lime-surkhi varies from 0.15 to 0.35. Sugar is used along with *methidana* to the extent of about 0.05% to 0.35%. It is, therefore, evident from these details that admixtures mentioned earlier have been used in small amounts primarily as working aids for the laying of lime concrete mass as a water-proof layer. A systematic study has been made in the laboratory with a view to understand the effects of these and other admixtures on the setting behaviour and pattern of strength development of lime-surkhi mix. Results of traditional admixtures are given in Table 1 and those of chemicals are given in Table 2.

Results of Traditional Admixtures

The results obtained with *bael* (aegle marmelos), *methi* (trigonella foenum-graecum) and *kadukai* (terminalia chebula) show that all of them influence the setting as well as hardening of lime pozzolana mortar. They have a mild retardation effect on the initial setting time but the same effect is more pronounced in the later periods of setting in the range of concentrations used. *Methi* (aegle marmelos) exerts increased retardation of initial setting and hardening both but at a later stage the effect is reduced to a large extent. Sugar or molasses has a profound effect on setting as well as strength development, if used in concentrations higher than 0.1-0.2%.

Effect of Chemical Admixtures

Four standard chemical admixtures—citric acid, acetic acid, sodium acetate and tartaric acid—were chosen for study as substitutes for traditionally used admixtures in lime concrete. Similar examination of these chemicals was done and the results obtained are given in Table 2. It can be seen from the data that these compounds in concentrations as low as 0.05% to 0.2% by weight of lime surkhi mix exhibit retardation

effect both on setting and strength development like traditional admixtures. The effect, however, is more regular with concentration in the case of these compounds. Acetic acid and its sodium salt have a comparatively milder effect on setting and hardening than citric acid and tartaric acid which inhibit the setting severely. Similar effect of tartaric acid on the development of strength of the mix is although more pronounced in the earlier stages but makes up considerably later on. In case of citric acid, however, this effect is parallel to the one observed in the case of sugar at concentration higher than 0.1%.

A comparative study of the effects of traditional as well as standard chemical admixtures on the lime-surkhi mix as discussed earlier reveals that the behaviour of both types of compounds is fairly parallel in respect of the desired purpose. It offers the possibility of substituting traditional admixtures with chemicals to achieve the same effects of delaying the setting of lime surkhi component of the lime concrete. All the chemicals studied exert retardation effect but tartaric acid and citric acid are active in lower concentrations also. While the effective concentration of tartaric acid is 0.1%, the concentration of citric acid is still lower, that is, between 0.05% and 0.1% on the weight of lime surkhi. These ranges of chemicals have already been given laboratory scale trials within the Institute. Based on the work done, it is suggested that these chemicals should also be used in the same way as the traditional admixtures. The quantity of the chemical to be used should be decided as per the limits given earlier. For example, if citric acid is considered for use, its quantity per square meter of work should not exceed 0.1% on the weight of lime-surkhi. On the basis of 0.05% concentration, however, the amount of citric acid should be 36 g/m². Taking into account that about four litres of water is needed for every square meter of the concrete, bulk solution containing 9 g/litre of citric acid can be prepared. This solution should be used in small

TABLE 1 SETTING TIME AND COMPRESSIVE STRENGTH OF LIME-SURKHI MORTAR COMPOSITION (1 :2) CONTAINING TRADITIONAL ADMIXTURES

Admixture	Concentration, %	Setting Time		Compressive Strength, kg/cm²		
		Initial, m	Final, hr	7 days	28 days	90 days
Nil		120	18	9.0	33.0	41.0
Bael	0.05	120	24	4.4	39.0	45.2
	0.1	120	45.5	3.2	35.1	41.0
	0.2	120	119	1.0	12.2	31.4
	0.3	120	175	0.6	4.8	27.5
	0.4	125	200	0.5	3.0	27.2
	0.5	135	> 7 days	0.9	1.7	22.0
Methi	0.05	120	23	10.5	39.6	40.4
	0.1	195	33	6.2	32.4	58.9
	0.2	230	48	5.7	25.6	48.4
	0.3	290	76	7.4	28.9	41.6
	0.4	—	—	2.6	28.9	41.0
	0.5	—	—	—	—	—
Kadukai (harad)	0.05	120	26	9.9	56.1	58.5
	0.1	120	74	1.4	16.5	20.8
	0.2	130	77	0.8	15.2	—
	0.3	240	110	0.9	2.3	21.4
	0.4	270	300	0.8	1.0	20.8
	0.5	300	> 7 days	0.9	1.6	6.6
Molasses	0.05	150	48	4.83	15.0	47.9
	0.1	155	52	2.91	7.0	36.0
	0.2	17 hr	77	1.41	1.5	10.4
	0.3	36 hr	115	0.93	1.2	4.5
	0.4	72 hr	144	—	1.7	0.2
	0.5	7 days	—	0.20	—	0.2

TABLE 2 SETTING TIME AND COMPRESSIVE STRENGTH OF LIME-SURKHI MORTAR COMPOSITION (1 : 2) CONTAINING CHEMICAL ADMIXTURES

Admixture	Concentration on Lime-Surkhi, %	Setting Time		Compressive Strength, kg/cm²		
		Initial, m	Final, hr	7 days	28 days	90 days
Nil	—	120	18	9.0	33.0	41.2
Acetic Acid	0.05	150	26	8.5	17.4	31.2
	0.1	195	33	7.9	17.5	30.0
	0.2	290	48	5.4	16.9	29.9
Sodium Acetate	0.05	—	—	—	—	—
	0.1	170	25.5	11.2	37.9	43.8
	0.2	170	30.0	9.8	32.7	39.0
	0.3	250	44.5	6.3	11.2	28.0
Tartaric Acid	0.05	160	50.0	3.8	27.8	42.3
	0.1	335	66.5	0.9	16.0	37.7
	0.2	600	91.0	—	—	—
Citric Acid	0.05	210	76.5	3.6	9.2	36.2
	0.1	435	90.0	1.4	4.9	17.4
	0.2	960	148.0	—	—	—

amounts at a time so that it has less chance of permeating unnecessarily down into the concrete mass. Other chemicals examined for this purpose, that is, tartaric acid (0.1%), sodium acetate (0.1%) and acetic acid (0.1%) can also be used as 18 g/litre aquous solution in a similar way but citric acid can be favoured on account of its easy availability, use and price.

Effect of Integral Water-proofing Admixtures

Three substances, namely, ordinary soap, vinsol resin and sodium salt of oleic acid in the form of aqueous dispersions have been investigated as integral water-proofers in lime concrete. *Bael* (aegle marmelos) and citric acid have also been studied in a similar way for reference. These were added to 1 : 2 : 5 lime, surkhi and brick ballast concrete in the gauging water. Cubes of the concrete were cast at compaction factor of unity. Table 3 shows the results of studies carried out on the effects of these admixtures on the strength and water permeability of the concrete. Studies on the setting time were conducted on lime surkhi (1 : 2) mortar reported earlier.

The results show that a fair degree of water impermeability has been produced in the lime concrete containing soap, vinsol and sodium oleate. There is no adverse effect of these compounds on the development of strength in the concrete to any serious extent. Trials conducted at CBRI in this direction show that certain amount of ramming will be desirable in the beginning to lay a compact mass of the concrete and achieve better results. Field trials are, however, necessary to know to extent of efficiency of the treatment and possible saving in cost as compared to the traditional method of lime terracing using admixtures.

TABLE 3 SETTING TIME, COMPRESSIVE STRENGTH AND WATER ABSORPTION OF LIME CONCRETE MIXES CONTAINING INTEGRAL WATER-PROOFING ADMIXTURES

Admixture	Concentration % on LS	Setting Time of 1 : 2, Lime-Surkhi Mortar (Tables 1 and 2)		Compressive Strength, kg/cm²			Water Absorption, mm
		Initial,	Final,	7 days	28 days	90 days	Drop in Water Level in 24 hr
		m	hr				
Nil	—	120	18	6.5	21.2	33.0	No Resistance
Soap	0.5	125	45	5.8	18.3	31.0	13
Vinsol Resin	0.1	100	50	4.9	15.0	32.9	18
Sodium Oleate	0.5	90	50	6.2	15.4	29.4	1
Bael	0.1	120	45	3.0	28.1	37.0	No Resistance
Citric Acid	0.1	435	90	3.9	8.6	18.0	—

REFERENCES

1. National Buildings Organisation. 'Report on Study of Methods used for Water-proofing of Roof in India', January 1962.

2. Rajasthan PWD, *Specification*, vol 1, 1968.

3. IS : 3036-1965. 'Code of Practice for Laying Lime Concrete for a Water-proofed Roof Finish', *Indian Standards Institution*, New Delhi.

4. IS : 1625-1971. 'Code of Practice for Preparation of Lime Mortar for Use in Buildings', *Indian Standards Institution*, New Delhi.

5. IS : 2541-1974. 'Code of Practice for Preparation and Use of Lime Concrete', *Indian Standards Institution*, New Delhi.

6. J P Kaushik and S A Siddiquee. 'A Machine for Tamping Lime Concrete Terracing', *Invention Intelligence*, vol 2, no 9, April 1967.