April 1983

CRI TECHNOLOGY DIGEST

CEMENT RESEARCH INSTITUTE OF INDIA

DEVELOPMENT OF CEMENT BASED NON-SHRINK GROUT

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1. NEED FOR NON-SHRINK GROUT

Shrinkage of cement mortars or concrete, which takes place during drying in service, can cause stresses in the structural members, if such movement is restrained. The resultant stresses are tensile in the matrix and compressive on the reinforcing steel. Since cement concrete is weaker in tension than in compression, the stress release is obtained either by failure of the bond or by the cracking of concrete. In case of grouting on composite constructions, such shrinkage can also impair the bond between the two concretes, thereby preventing monolithic action. The problem can be alleviated through the adoption of prestressing which may not be practicable and economical in all situations. Alternatively, the problem is solved through modification of cement composition and control on hydration kinetics with the use of non-shrinkage or expanding agents or with expansive cements.

Of these two, non-shrinkage formulations have found wider application, particularly in precision grouting of heavy machineries to their foundations. These non-shrinkage formulations not only offset the effects of subsequent drying shrinkage but also ensure proper bonding of the grout with holding-down or anchor bolts on the one hand, and with the old concrete of the foundation base on the other.

While in USA and Japan, the production and use of such formulations have exceeded 1 million tonne per year, in India either these materials were imported or expensive alternatives like epoxy formulations used, till 1974 when CRI developed an indigenous non-shrink grout for foundations of heavy machinery. The CRI non-shrink grout has since been used at a number of major fertilizer projects at Mangalore, Haldia, Ramaguandam and Sindiri, thus resulting in substantial savings in foreign exchange and time. Moreover, it costs less than other alternatives. This Technology Digest reports the developmental and application features of the first indigenous cement-based non-shrink grout developed by CRI. (First reported in the May 1982 issue of this Digest)

2. BASIS OF NON-SHRINK FORMULATIONS

Several types of expansive cements are produced the world over, but the common feature in almost all these cements is that they have ordinary portland cement as the base component. The differences amongst expansive cements are essentially in the matter of how the expansion is achieved during the initial moist curing. Some of the commonly used formulations are based on the reaction of additives, such as aluminium powder or activated metallic iron powder. The slow reaction of aluminium with calcium hydroxide liberated by the hydration of cement, results in the evolution of hydrogen gas which is locked inside the matrix in the form of tiny bubbles and causes a volume expansion of the latter. The kinetics of expansion are controlled by the particle size of the aluminium powder. This approach, however, increases the porosity of the matrix and thereby a reduction in the ultimate compressive strength. In formulations based on metallic iron powder, the volume expansion is effected by the slow rusting of metallic particles inside the matrix. Here again, the kinetics of expansion are mostly controlled by the particle size of the additive and its surface activity.

Besides the above approaches, several chemical reactions are known to cause expansion of cement mortars and concrete and, therefore, can be used as the basis for formulation of non-shrinkage cements. Amongst these, hydration of CaO to $Ca(OH)_2$, hydration of MgO to $Mg(OH)_2$ (brucite), and C-A-$\bar{S}$-H systems are used for non-shrinkage formulations. The former two are easy to achieve but are very sensitive to physico-chemical controls and temperatures. The C-A-$\bar{S}$-H based expansive agents have been commercially exploited the world over and have found wide application. In this system, the formation of tricalcium sulpho-aluminate hydrate, ie, ettringite ($C_6A\bar{S}_3H_{32}$) is the basis of commercial formulations.

The practical application of expansive cement is dictated by the control on the kinetics and extent of ettringite formation and its stabilization. While in USA, the expansive cements are marketed in the integral form, in Japan the practice is to market expansive agents to be added at site.

3. CRI NS GROUT

CRI Non-Shrink Grout, when used in specified proportions at site

with different types of cements and well-graded sand conforming to IS : 383-1970, yields cement mortar grout of controllable expansion required to offset the subsequent shrinkage (Fig 1). The strength characteristics of the formulation can be controlled in reference to the parent cement.

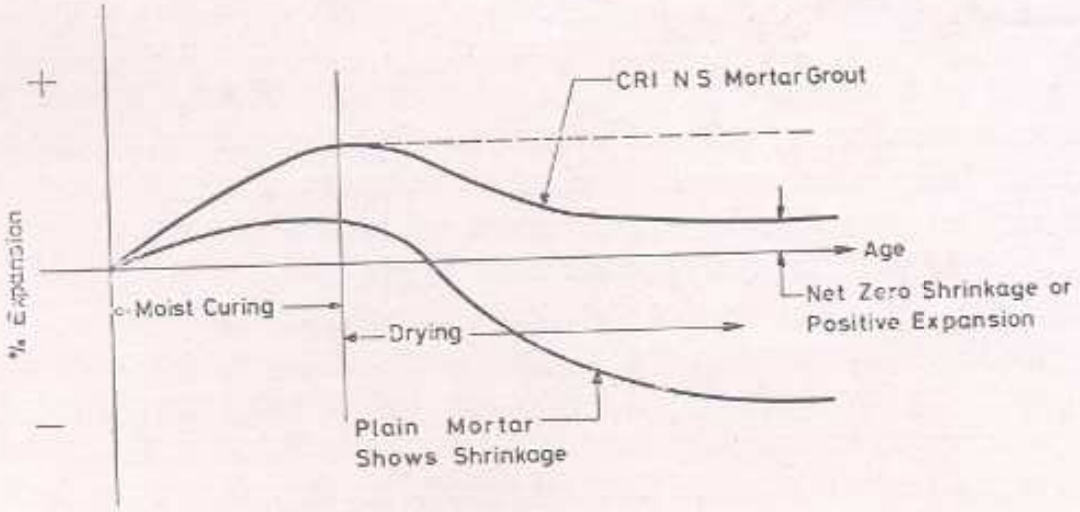

Fig I Expansion and shrinkage characteristics of plain and non-shrink mortar grouts

A three component additive formulation basically belonging to C-A-$\bar{S}$ system resulting in expansion on hydration through ettringite formation was developed at CRI to obtain controlled expansion within the specified time. The composition has additional feature that it has activated metallic iron in the grout to ensure restraint and additional impact strength of the grout. The composition of the additive is adjusted keeping in view the cement composition with which it is to be used. The ratio of the additive to cement is formulated to obtain a predetermined expansion in limited time, generally the initial 7 to 10 days. The components have to conform to certain specified compositional requirements to yield the desired results. The formulation can be made comparable for use both with OPC and slag cement.

In addition to the usual requirements of grouts, such as workability and ease of placement etc, the two essential requirements fixed for the grout to be developed were a minimum 28 days compressive strength >350 kg/cm^2 when tested according to IS : 4031-1968 and the mortar grout having stabilized moisture movement with practically no shrinkage or negligible excess expansion only.

Another stipulation which was kept in view was that the expansion should stabilise quickly—say with the end of the moist curing period which was fixed as minimum 10 days, since expansion in such formulations occurs only under moist conditions. If all the expansion potential is not exhausted during the curing period, subsequent exposure to moist conditions could cause further expansion when mortar has acquired a higher modulus of elasticity and would cause large undesirable stresses accompanied with cracking. The results of expansion characteristics and strength characteristics of CRI-NS Grout are shown in Table 1.

TABLE 1

EXPANSION AND STRENGTH CHARACTERISTICS OF NON-SHRINKAGE GROUT

Trial Mix	Expansion (%)			Drying Shrinkage (%)	Compressive Strength kg/cm²				
	1 day	7 day	Total		3 day	7 day	28 day	90 day	5 years
I	0·14	0·15	0·15	0·11	177	244	356	450	—
II	0·122	0·22	0·23	0·13	168	260	412	—	—
III	0·13	0·17	0·18	0·10	183	315	434	—	500
IV	0·10	0·14	0·16	0·09	229	355	605	695	710
V	0·09	0·13	0·15	0·08	176	335	520	—	—

From the results it is clear that most formulations achieved expansions in the range of 0·1-0·23% till they are stabilised. In the free state the shrinkage has been of the order of 0·1-0·12% thus resulting in net zero expansion or marginal excess expansion.

Setting time of mortars is in the same range as for OPC mortars and therefore, no special attention is necessary for applications of CRI-NS Grout on this consideration.

Formulation is backed by basic studies (XRD and DTA) over 5 years on characteristics of hydration as well as strength measurements. Results of such studies (Fig 2) and significant increase in strength development over the period confirms the stability of formulation.

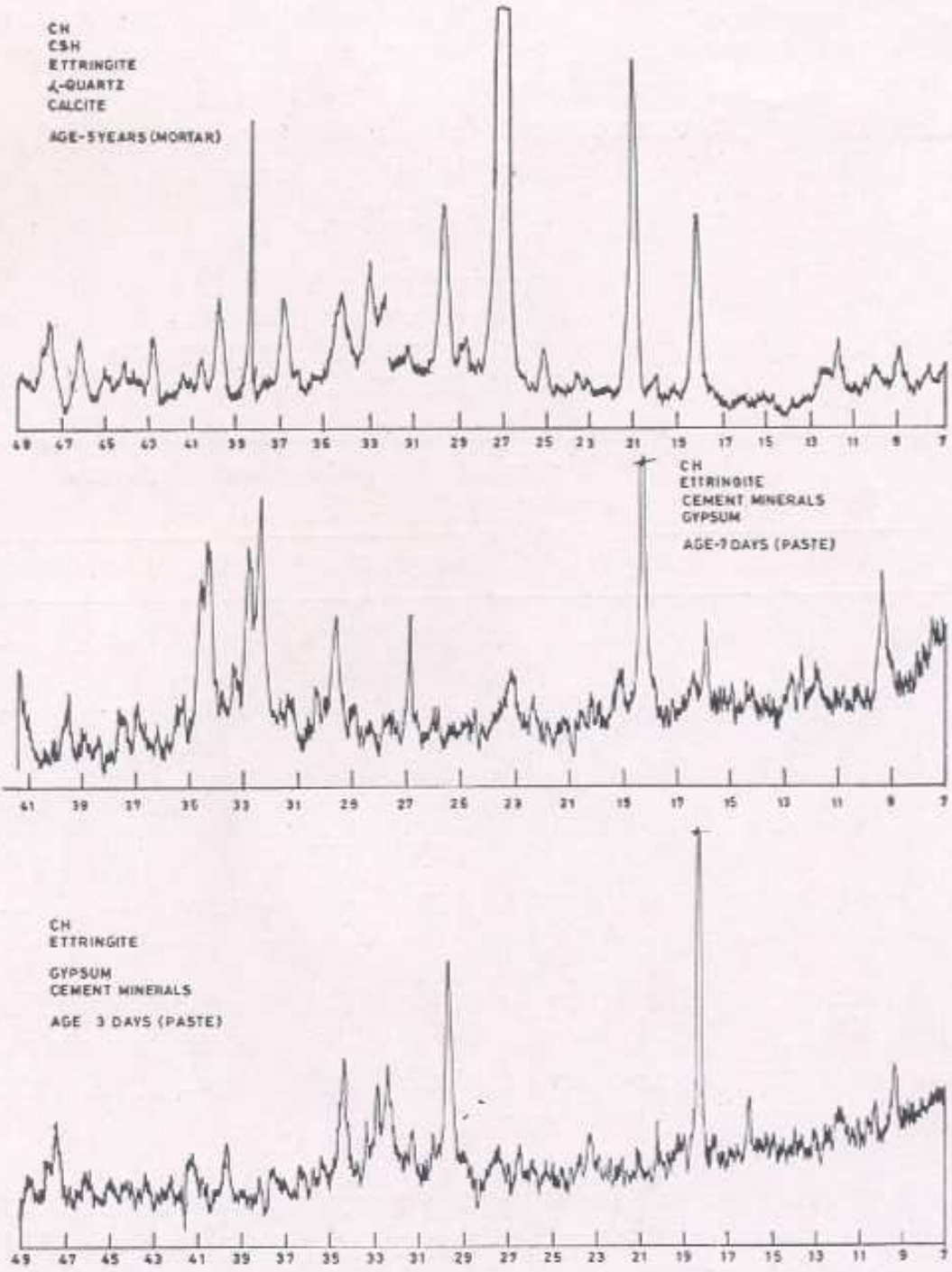

Fig 2 XRD patterns of CRI-NS grout formulations made with OPC

4. APPLICATION

CRI-NS Grout has mainly been used for grouting of heavy machinery to their foundations at major fertilizer complexes. After designing the grout mortar for predetermined expansion and strength characteristics with the cement available at site, trial experiments were carried out and the optimum dose of expanding agent was determined. The expanding agent prepared at CRI was then taken to the site where it was thoroughly blended with cement in required proportion in a ribbon blender. The cement expanding agent blend is then transferred to concrete mixer and mixed with specified quantities of sand and water. The grout mortar is obtained in almost flowing conditions which is then placed and vibrated with the help of needle vibrator. After sufficient time has lapsed for hardening, the grout mortar is cured under moist conditions followed by ponding with water or sprinkling of water for a period of 14 days. Generally the foundation grouting is completed in two stages, the second stage being taken up after the final alignment of machinery has been completed on completion of first stage grouting. Typical drawing for one of the grouting sections is shown in Fig 3.

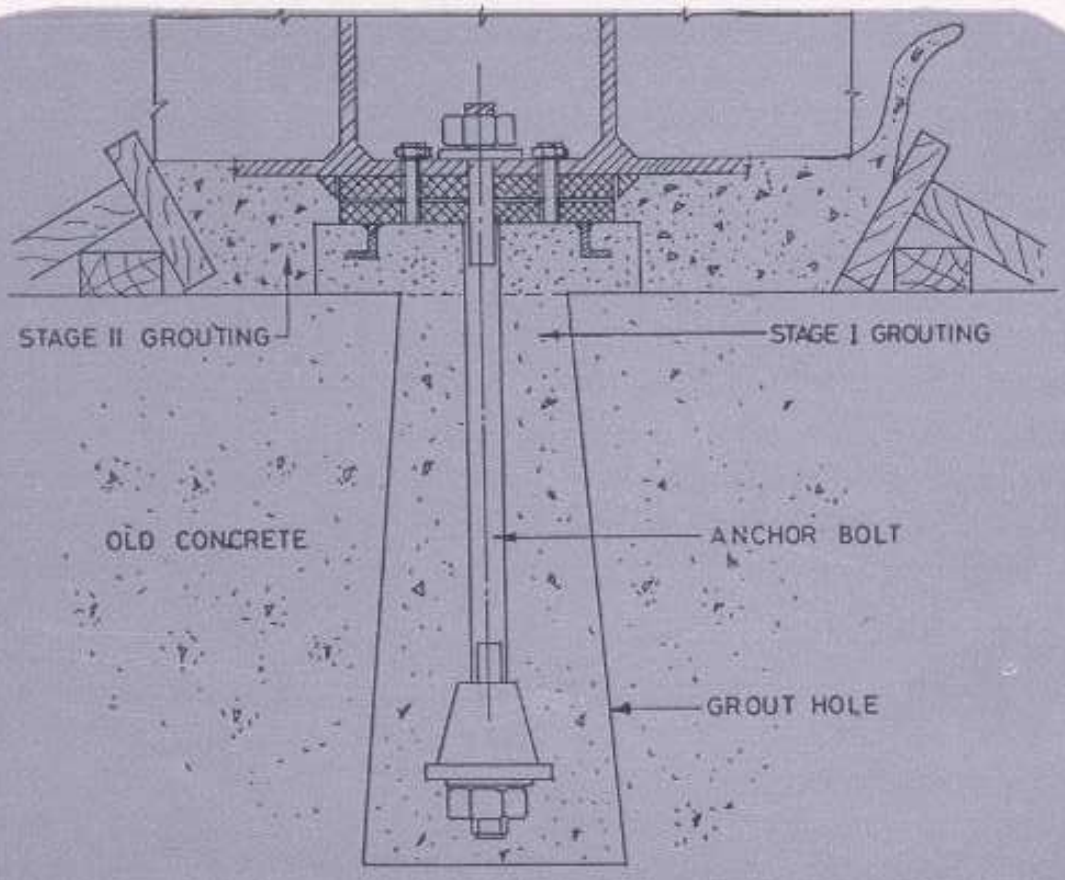

Fig 3 Typical arrangement for grouting machinery foundation with NS grout

5. AVAILABILITY

CRI-NS Grout is marketed as ready-to-use material, in which case only water needs to be added at the site or as an expansive component, to be site-mixed with cement, sand and water.

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