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CRI TECHNOLOGY DIGEST

FAST SETTING, HIGH STRENGTH CEMENT COMPOSITE FOR MINING, TUNNELLING AND OTHER SPECIAL APPLICATIONS

CEMENT RESEARCH INSTITUTE OF INDIA

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INTRODUCTION

In mining and tunnelling fast setting, high strength cementitious compositions are required for such special applications as installing anchor bolts for strengthening or reinforcing members in rock formations and structural bodies in emergency repairs, wherein high strength development is required in a very short time. Both resin type and inorganic type cementitious composites are widely used for such applications. The main function of roof bolting in mines is to clamp together several layers to form a thick composite beam which is much stronger than the individual stratum. Other things being equal the strength of beam varies directly as square of the depth thickness. Thus if a compound beam is formed using five individual identical beams in it, the resulting beam will be 25 times as strong as an individual beam. The composites are also used to suspend immediate weak roof from a stronger stratum above by anchoring bolt. In general, either fully bonded bolts or point anchor bolts are employed. In the point anchor system, the bolts are anchored at their extremity while in the fully bonded type, full column anchoring is done.

Full column anchoring has been regarded as one of the most important techniques in strata control wherein the bolts are inserted into drill holes in the formation or body, and often are fixed or anchored therein, at their inner end or substantially over their entire length, by means of a grouting material which hardens around the bolt and attains high strength rapidly.

Grouting compositions which harden and attain high strength in a few hours are suitable for roof bolting and similar other applications and generally include hardenable synthetic resins or inorganic cement grouts. Synthetic resin based formulations have shown superior performance and have been used as effective measures for anchoring the bolts with the following advantages:

a) The resin bolting is very easy and handy.

b) Curing time of the resin is short and bolts can be anchored within five minutes and as such chances of bed separation are eliminated.

c) No internal stresses are generated as resin anchor bonds the bolt to rock.

d) Resin can be used under watery and very bad roofs as a means of permanent support of trunk roadways and can match with fast rates of driving.

However, these formulations are not preferred in the present context mainly due to their flammable character, uncertain availability and high cost. Inorganic cementitious binders are gaining more popularity due to increased safety and lower cost.

CEMENTITIOUS FORMULATIONS

Inorganic cementitious grouts for roof bolting denote a particulate inorganic composition that sets and hardens to a strong dense monolithic solid when mixed with a liquid and allowed to stand. The above term includes hydraulic cements, i e, those capable of setting and hardening due to interaction of the constituents of cement rather than by evaporation of liquid vehicle or by reaction with atmospheric CO_2 and/or O_2. Examples of such cements are portland cement, high alumina cement and gypsum plasters which set into hard mass when mixed with water; lead oxide which sets when mixed with glycerin and the more rapid hardening metal oxide compositions like magnesium oxide which set when mixed with phosphoric acid or phosphate solution, etc. However, these products are designed to meet specific requirements and most of the information about them is patented.

Application of such formulations in anchor bolts is limited in India due to non-availability of both resin and inorganic cement based composites.

R & D WORK IN CRI

In view of above and increasing awareness towards safety measures in coal mines and tunnels and non-availability of suitable indigenous cementitious composites, CRI undertook R & D work on the development of a fast setting, high strength inorganic cement composite suitable for roof bolting in coal mines, tunnelling and other areas of application

considering the following product acceptance criteria for field application :

i) The installation of roof bolt should be completed in a total period of $\simeq$ 15 minutes.

ii) Compressive strength development should be very fast and compressive strength should be $>$ 150 kg/cm^2 at the age of two hours and $>$ 350 kg/cm^2 at 8 hours so as to make the bolt self-supporting in short time.

iii) The pull-out strength in anchorage test of a 20 mm ϕ bolt should not be less than 2 tonnes after one hour.

iv) The formulation should be expanding type in order to provide excellent bond with the rock.

v) The composite should have a shelf life of 4-6 months.

A critical review of various performance and expansion characteristics and mechanism of strength development of various cementitious materials indicated the following :

a) The composition should be rich in alite.

b) Hydration of alite should be accelerated by means of suitable accelerations.

c) The composition should have expansive character similar to M-type expansive cement, wherein the expansion arises due to formation of ettringite and ultimate expansion is achieved in 7 days of water curing.

Based on above considerations, CRI has developed a fast setting, high strength cement composite containing high strength ordinary portland cement conforming to IS : 8112 — 1976, high alumina cement, admixtures *A* and *B* and graded fine sand. The characteristics of selected batches of the composite are given in Table 1.

The cement composite is of expansive type; an expansion of 0·20 percent has been observed in the grout most of which is obtained in 3 days and no significant expansion is observed beyond 14 days (Fig 1). The cement composite has given an anchorage strength of the order of 4 tonnes at 1 hour indicating that the product is capable of developing very good bond with anchor bolts.

TABLE I

PERFORMANCE CHARACTERISTICS OF SELECTED BATCHES OF CEMENT COMPOSITE

Sample No	Fineness* cm^2/g	Hardening time (minutes)	W/C	Compressive Strength (Kg/cm^2)**					
				2 *h*	4 *h*	7 *h*	1 *day*	3 *days*	7 *days*
C — 1	4820	15	0·22	210	315	420	650	700	750
C — 2	4880	15	0·22	190	—	410	—	720	—
C — 3	4750	15	0·23	180	—	395	—	660	—
C — 4	4820	15	0·22	180	—	400	705	—	—
C — 5	4790	15	0·22	216	—	—	755	822	—

*Without sand
**3 inch cubes

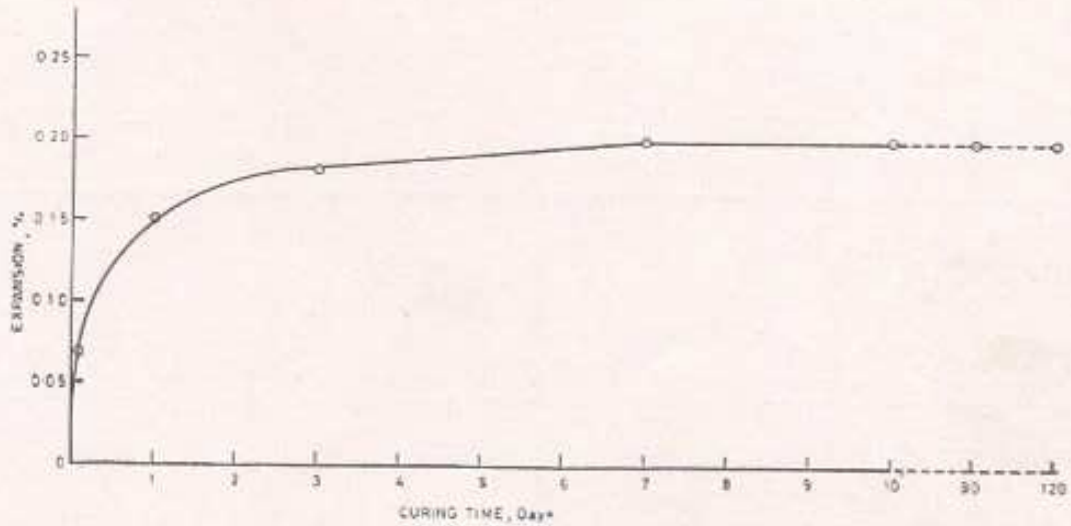

Fig 1 Expansion characteristics of the cement composite

Shelf life of the cement composite packed in polythene bags stored in a dry place has been monitored upto 180 days and the compressive strength data at various storage periods indicate that there is no deterioration during storage in the strength development up to 6 months (Table 2). Studies have indicated that strength development at 2 h is a function of fineness of cementitious component for which a minimum fineness of 4700 cm^2/g is desirable. However, satisfactory strength at 6 h can be achieved with a fineness level of $\simeq$ 4300 cm^2/g. Similarly the effect of W/C ratio is predominant during early ages of strength development, i e, up to 7 h and as such a close control on W/C ratio is essential. Higher W/C is not desirable for certain applications like roof bolting due to practical problems during grouting.

TABLE 2

SHELF LIFE OF THE CEMENT COMPOSITE

Sample No	Fineness* cm^2/g	W/C Ratio*	Shelf Life (days)	Compressive Strength (Kg/cm^2) 2 *h*	7 *h*	1 *day*	3 *days*
		0·203	Fresh Sample	210	402	701	820
C — 4	4800	0·203	50	180	430	700	805
		0·203	100	170	450	710	810
		0·203	180	175	450	—	760

* Without Sand

MODE OF APPLICATION OF CRI CEMENT COMPOSITE IN ROOF BOLTING

CRI cement composite for application in roof bolting in coal mines is filled in specially designed capsules of appropriate sizes. Application

of the capsules containing cement composite involves following steps:

a) Soaking the capsule in water and allowing it to absorb water until bubbling ceases. (Fig 2A)

b) Removing the capsule from water and inserting it immediately into the drill hole. Pushing the capsule to the end of the hole and tampering firmly with a stemming rod until the required number are installed. (Fig 2B)

c) Inserting the rock bolt into the drill hole and pushing it as far as possible by rotation. (Fig 2C)

d) Fixing the plate and nut. (Fig 2F)

It is important that steps (a), (b) and (c) above must be completed within a total period of 15 minutes.

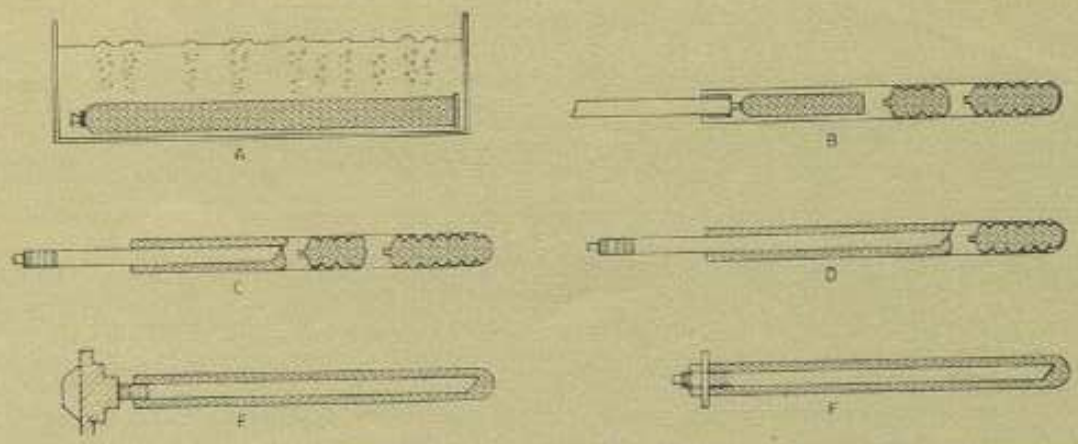

Fig 2 Application of CRI fast setting, high strength cement composite in roof bolting

Other Areas of Application

CRI fast setting, high strength cement composite due to its performance characteristics can also be utilised in areas like emergency repairs of dams, water tanks and pipes, airports, installation of heavy machinery and a number of other defence installations, wherein fast setting and high strength requirements are essential.

Cost of Cement Composite

Preliminary cost estimates towards the production of cement composite based on landed cost of various ingredients used have indicated the cost of composite as Rs 3500/tonne.

CRI'S ASSISTANCE

CRI will extend technical and technological assistance to parties, who wish to adopt the CRI technology of manufacturing fast setting, high strength cement composite for mining, tunneling and other special applications under the Institute's technology transfer scheme.

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