Grout Investigation for Shear Stringer Zone at Ukai Dam

by

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Introduction

GROUTING is normally undertaken to reduce the permeability and/or increase the bearing capacity of rock or soil formation. Various materials to be used such as cement, sand, silt, clay, bentonite, chemicals depend upon the purpose of grouting and nature of formation to be grouted.

The grouts can be classified in two main groups depending upon their constituent elements (*i*) coarse grout, (*ii*) fine grout. Coarse grout generally consists of sand, sawdust and fibres with or without binding material such as cement. Fine grout contains cement, clay bentonite, chemicals, *etc.* Selection of grouts depends upon the granulometry of the formation to be grouted as each type of grouts has got its own limitations. Coarse grout can be grouted only in large cavities and faults of rocks. Fine grouts can be grouted in coarse to fine sand depending upon its constituent elements.

The properties of grouts required vary with the purpose of grouting and job condition. The strength of the grout is important when the grouting is made to increase the structural strength of formation. The groutability, permeability and permanence of grout are of main importance when grouting is made for impermeabilization. The composition of grout mix can be determined from the various required characteristics such as granulometry of constituent elements, viscosity, setting time, strength, permeability, penetrability and economy. The laboratory tests can be conducted to assess the properties of various grout mixes.

Shear Stringer Zone

The rock encountered between Ch. 3109 m. and 3261 m. in the foundation of right bank earth dam at Ukai was more jointed, fractured and fissured. The intensive geological investigation revealed that the rock was travelled by three bands of very poor recovery. These bands of rock were termed as shear stringer.

Trial grouting was done in order to know the successful method of drilling through this weak rock. It was observed that drilling in rock by usual methods was possible without side collapse. In order to confirm the degree of weakness of rock, a 99·1 cm. (39 in.) diameter shaft was

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This paper was received on 20 June 1970. It is open for discussion up to September 1971.

taken at 4·9 m. (16 ft.) upstream of the trial grout plot. It revealed that the general weakness was there, but at the same time it was possible to drill the hole without side collapse.

Grouting in the shear stringer zone was done by drilling three rows of holes. The outer holes were grouted with clay-cement-bentonite grout irrespective of water losses. The centre row was grouted with three successive grout injections being :

(*i*) Clay-cement-bentonite grout.

(*ii*) Bentonite-chemical grout.

(*iii*) Pure-chemical grout.

Clay-cement-bentonite grout was injected to reduce the groutable voids for the successive injection. Bentonite-chemical grout served as a cheap finer filler so as to reduce the consumption of costly chemical grouts. Pure-chemical, the finest grout formed the final treatment to seal minute cracks and voids in the foundation. The following grout mixes were adopted for grouting the shear stringer zone :—

(*i*) *Clay-cement-bentonite Grout*

Clay	*Bentonite*	*Cement*	*Water*	*P.A.*
0·4	0·2	0·6	6	2%

(*ii*) *Bentonite-chemical Grout*

Bentonite slurry marsh cone 32 sec.	Monosodium phosphate solution Sp. gr. 1·21	Sodium silicate solution 40% silicate + 60% water.
2500 cc.	80 cc.	150 cc.

(*iii*) *Pure-chemical Grout*

Sodium silicate	Sodium aluminate	Water
300 cc.	12·69 gm.	500 cc.

Laboratory Tests

The following tests were conducted in the laboratory to assess the properties and suitability of grout mixes :—

(*i*) Specific gravity.

(*ii*) Marsh cone.

(*iii*) Bleeding.

(*iv*) Jellifying time.

(*v*) Needle penetration resistance.

The author has not endeavoured to give the detailed procedure of laboratory tests in the present paper as it is well discussed elsewhere[8].

Clay-Cement-Bentonite Grout

INGREDIENTS

The properties of the materials used in the laboratory tests are enumerated below :—

(*i*) *High Grade Bentonite* : Particles less than 0·002 mm. size not less than 80 per cent, liquid limit 350 per cent, swelling index (after 24 hours) 13, specific gravity 2·8. The grain-size distribution curve is shown in Figure 1.

(*ii*) *Ordinary Portland Cement Conforming to IS : 269-1958* : Specific surface more than 2250 sq. cm./gm., specific gravity 3·1, expansion in soundness test not more than 10 mm., initial setting time not less than 30 minutes, final setting time not more than 600 minutes Compressive strength after 7 days not less than 175 kg./sq. cm., tensile strength after 7 days not less than 25 kg./sq. cm².

(*iii*) *Clay* : The clay available from Tarkeshwar village near Ukai is rich in montmorillonite minerals and was, therefore, used in the clay-cement-bentonite grouts. It contained 75 per cent particles below 2μ (microns), liquid limit 100 per cent, plasticity index 60, specific gravity 2·6, swelling index (after 24 hours) 3. The granulometry of clay is shown in Figure 1.

(*iv*) Sodium-hexameta-phosphate was used as deflocculating agent. It was observed that 2 per cent D.A. was most appropriate and hence it was kept constant in all tests for clay-cement-bentonite grout.

PREPARATION OF GROUT MIX

The sequence of adding the various ingredients in preparing grout mix is extremely important ([2]) ([4]). The water was poured first, Tarkeshwar clay was added and mix was stirred by high speed electric stirrer in order to get uniform clay slurry. The clay slurry was then passed through 100 B.S. sieve. Bentonite, cement and D.A. were successively added and the mix was stirred to get homogeneous grout mix for further testing. The

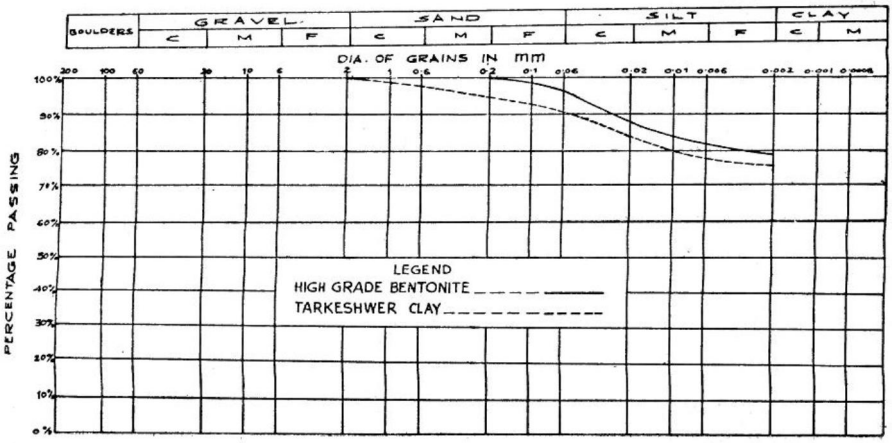

FIGURE 1.

grout was stirred while adding new material. Materials should always be poured slowly into a mix. Material added in the mix must be thoroughly dispersed and wetted before adding the next one.

LABORATORY TEST RESULTS

The following sets of tests were carried out to study the effect of various ingredients on viscosity, jellifying time, bleeding and needle penetration resistance. The proportions of various ingredients used in trials were as under :—

	Tarkeshwar Clay		*Bentonite*		*Cement*		*Water*		*D.A.*
(*i*)	varying from 0·25 to 2	:	0·25	:	0·5	:	8·0	:	2%
(*ii*)	0·5	:	0·25	:	varying from 0·25 to 2·00	:	8·0	:	2%

The test results of marsh cone, bleeding, jellifying time and needle penetration resistance are shown in Figure 2.

DISCUSSION OF RESULTS

The study was confined to the influence of clay and cement on the bleeding, setting time, viscosity and strength characteristics of clay grouts.

The results revealed that keeping other constituents constant, increase in clay reduces the bleeding and setting time.

The viscosity of the grout increases with the increase of clay content. The increase in marsh cone with a lapse of 20 minutes is considerably high after 1·075 specific gravity of clay slurry.

The strength of the grout is increased with increasing clay content. This is due to increase of solid/water ratio of grout.

Increasing the quantity of cement, bleeding and setting time increases first, accelerates for certain range and then decreases.

The viscosity of the grout increases with increase of cement. The increase in viscosity after lapse of 20 minutes is marginal.

The strength of the grout increases with increase of cement content.

Bentonite-Chemical Grout

The following materials were used for bentonite-chemical grout :—

(*i*) High grade bentonite : as specified above.

(*ii*) Sodium silicate : Specific gravity 1·3, alkalinity ratio $\frac{SiO_2}{Na_2O}$ 3 . 2 to 3·4, $CaO+MgO+K_2O_3$ less than 2 per cent.

(*iii*) Monosodium phosphate : Monosodium phosphate acts as dispersing agent for bentonite and jellifying agent for silicate. Specific gravity of 1·21 and P_2O_5 content less than 55 per cent.

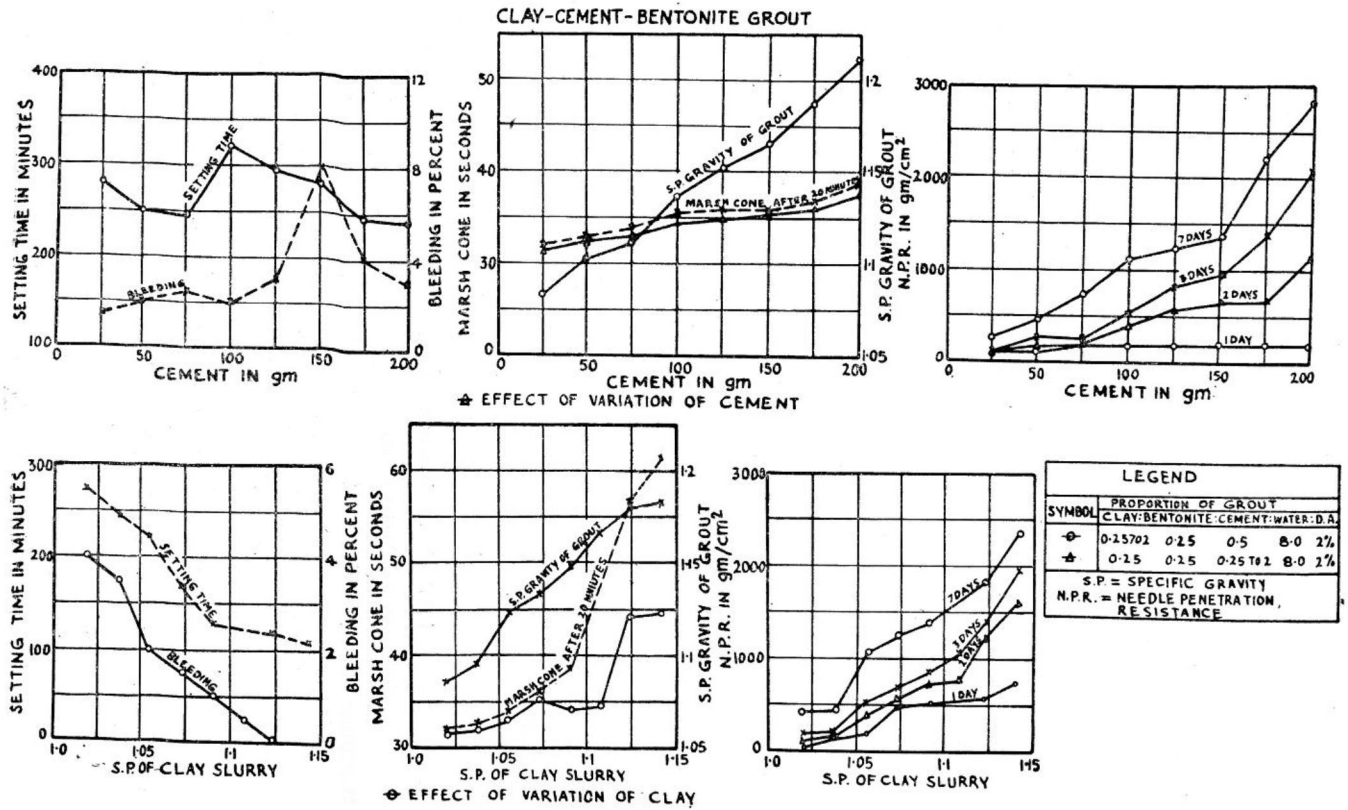

FIGURE 2 : Clay-cement-bentonite grout.

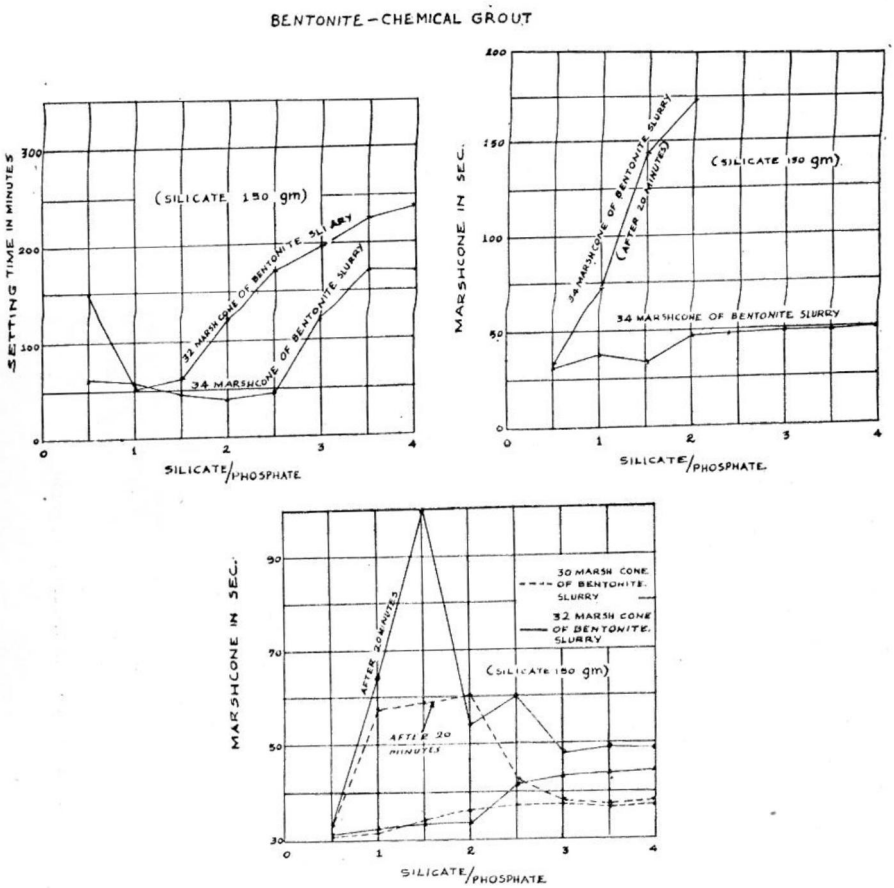

FIGURE 3 : Bentonite-chemical grout.

ORDER OF MIXING

Bentonite slurry of required viscosity (checked by marsh cone) was prepared and monosodium phosphate was added first as it acts as dispersing agent for bentonite. The silicate solution was added in the last. The grount was stirred by high speed mixer at the time of adding new material.

LABORATORY TEST RESULTS

Various trials were carried out with different proportions of monosodium phosphate and fixed proportion of other ingredients. The details of proportions are specified below :—

Bentonite (with 32, 34 and 36 seconds marsh cone).	Sodium silicate (silicate : water 60 : 40)	Monosodium phosphate (specific gravity 1·21)
2500 cc.	150 cc.	300 cc. to 37·5 cc.

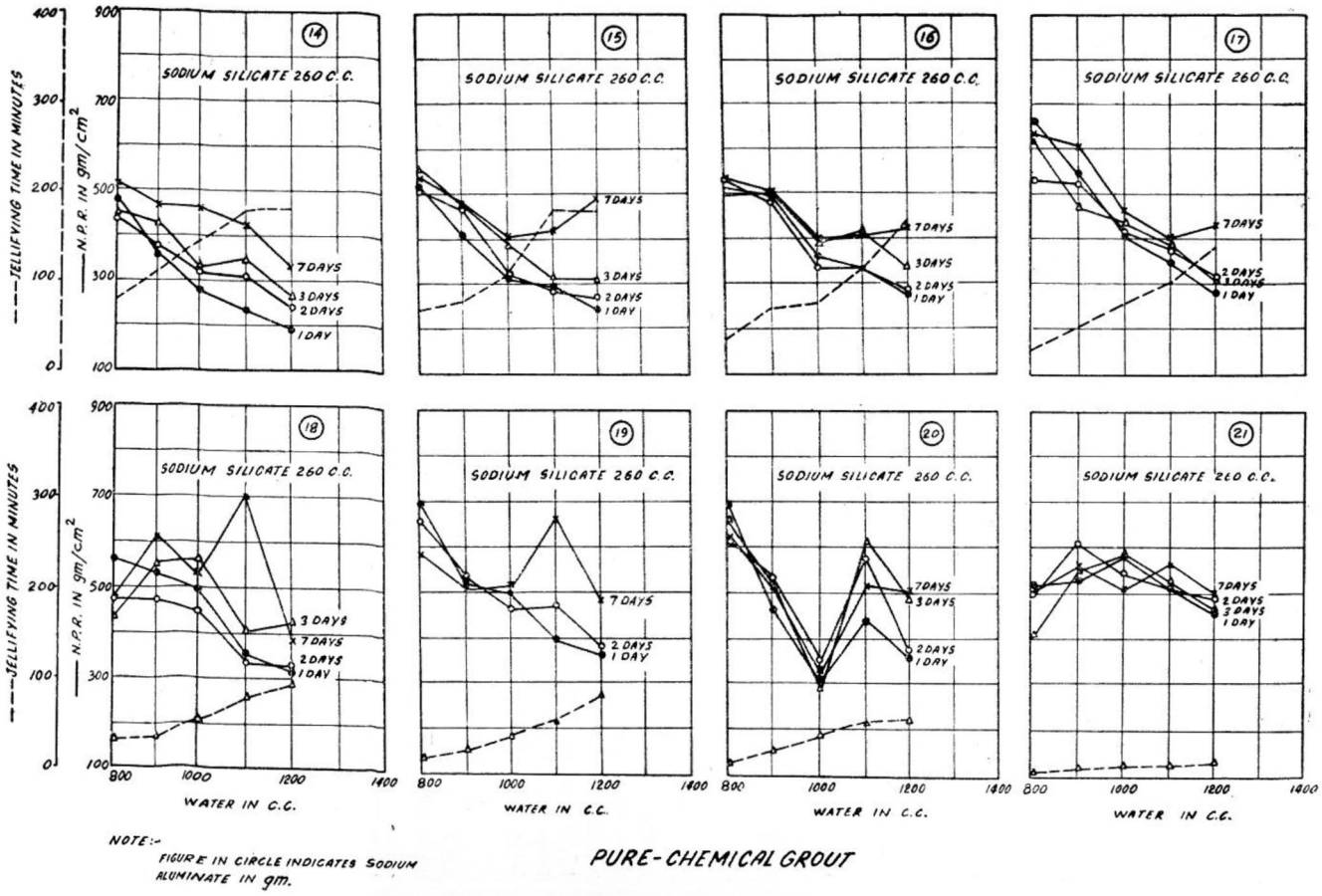

FIGURE 4 : Pure-chemical grout.

The test results are plotted in Figure 3.

DISCUSSION OF RESULTS

It can be observed from the test results that with increase in silicate/phosphate ratio the setting time reduces up to certain ratio and then increases considerably. Short setting time could be established during study. However in practice setting time should not be less than 30 minutes in order to allow mixing, pumping and penetration in ground on the field.

Increase in silicate/phosphate ratio increases the viscosity of the grout. The difference between initial viscosity and viscosity after 20 minutes increases with increase in silicate/phosphate ratio up to 1·5 to 2 and then the difference is marginal.

Pure-Chemical Grout

The chemicals used for pure-chemical grouts were sodium silicate and sodium aluminate, the latter being used as precipitant.

The tests were carried out with various proportions of water and sodium aluminate and constant amount of sodium silicate being 260 cc. The results of needle penetration tests and jellifying time are plotted in Figure 4.

DISCUSSION OF TEST RESULTS

Setting time increases with increase in water/silicate ratio. With increasing quantities of reagent (sodium aluminate) the setting time decreases and becomes very short for certain range. Strong reagent solutions make the setting more difficult to control and mixing operation more hazardous. Extremely diluted solutions will give only slow setting time and low rigidity gels. The balance between two should be made to achieve practical grout mix.

Strength decreases with increase in water/silicate ratio up to certain amount of reagent. The strength characteristic is erratic beyond certain amount of reagent.

Conclusions

Various types of grouts have been developed and used on various projects. The type of grout to be used depends on the type of formation to be grouted and the purpose of grouting. Investigation studies should be made to find out the best suitable grout mix coupled with economy.

Studies made for clay-cement-bentonite grout, bentonite-chemical grout and chemical grouts with various proportions of ingredients at Ukai Project are presented in the paper. Study can be utilised for knowing general behaviour of various constituent elements in each grout mix.

Acknowledgement

The author wish to acknowledge the thanks to Shri C.C. Patel, Chief Engineer (I.P. & Ukai) and Joint Secretary for his encouragement in preparation of the paper. The author is also thankful to Shri S.G. Shah, Superintending Engineer, Ukai (Civil) Circle, for valuable suggestions.

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