

Comparative Study of Grout Materials for Dam Repair

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Abstract – Grouting techniques in dams is one of the most emerging technique used now a days for repairing of dams. For strengthening of dams, various methods are used depending upon several challenges. Dam grouting improves the situation spillage anticipation and leakage control. It is exhibited method for presenting up-tendency and down-incline preventions in dams. Grouting is consistently considered to restore water snugness and movement congruity in broke strong dams. Determination of suitable materials for grouting process is necessary. In this paper, effect of various materials on grout are examined. Impact of different materials on properties such as viscosity, bleeding, shrinkage, strength etc. are studied. This paper will provide baseline for selection of appropriate materials for grout depending on the requirements.

Key Words: Dam Repair, Grouting, Grout material.

1. INTRODUCTION

General upkeep and observing of dams is essential to guarantee dams stay in a protected and working condition. [14] Due to the low tensile strength of concrete, massive unreinforced concrete dams are likely to experience cracking. [8] Repairs of dams is dependent on several challenges right from type of dam, structure of dam, selection of the terrain, soil condition, materials, methods, type and designs of construction to supervision and assurance of quality in repairs of dams. Grouting is one of the efficient ways to seal and strengthen the ground in geotechnical projects. [19] Grouting is necessary when inaccessible voids require filling to improve ground stability, increase the bearing capacity, and reduce the permeability of the soil where dams, foundations, buildings and retaining walls can be constructed. [23]

In the application the grout is placed by using injection method, with pressure or by its own weight only. [13] Grouting is utilized in process of injection of fluid through pressure into cracks, voids, fissures, in the construction of the dams to reduce the permeability an increase the mechanical stability of the structure. [18] Grout injection into cracks and voids in masonry is a common repair technique. Injection of grout into cracks may be used as a form of repair a damaging event to restore the masonry to its original structural condition. Grouting is the process of injecting liquids, mixed suspensions, or semi-solid mixtures under pressure to achieve one or more desirable end results in terms of improving engineering properties. These grout

materials that eventually harden into voids, fissures, or cavities in rock, concrete or soils. [1][3][8][9][15] It is used in both of the soil and rock environments with the same main purposes but different methods/technologies. Depending on the specific application, grouting is used as either the primary or sole means of effecting property improvement, or it may be used in conjunction with other technologies and methods. [3]

In the early days, the conventional grouting method was mostly commonly used, in which pressure could be decreased by increasing thickness of grout mix in addition to unstable grout mix. [10][11] Grouting in civil works activities is performed as:

- (1) An element of permanent construction,
- (2) A post-construction remedial treatment, or
- (3) An element of expedient construction or repair. [3]

Types of grouting (dam repair)

- Injection grouting

It is a process of filling the cracks, voids or honeycombs under pressure in concrete or masonry structural members for repairing of cracks, strengthening of damaged concrete or masonry structural members.

- Curtain grouting

It is a barrier that protects the foundation of a dam from seepage and can be made during initial construction or during repair. Additionally, they can be used to strengthen foundations and contain spills

2. GROUT MATERIALS

A grout is injected with high pressure into small voids and cracks which may be present in masonry structure. Different grout materials need to be developed for different grouting situations. Requirements for grouting and grout materials depend both on the environment around the underground facility and on the use of the underground facility. Properties of grout material like penetration ability and rheology are always of interest. In case of deep repositories also chemistry, durability and pH are very important. The performance of cement based grout can be extended by the use of admixtures such as fly ash (FA), bentonite (B) and silica fume (SF). [23] In the case of FA replacement there is

also a significant cost reduction.^[7] Various materials used by the researchers are listed in Table 1.

Table -1: Materials used by researchers

Sr. No	Name of Researcher	Material used
1	M. H. Mohammed, N. Al-Ansari, R.Pusch, S. Knutsson and J. E. Jonasson	Cement (MC), palygorskite (P), quartzite aggregate ^[20]
2	Mohammed Hatem Mohammed, Roland Pusch, Sven Knutsson, Gunnar Hellström	Aggregate, Talc, clay additive, Merit 500, Palygorskite, portland cement ^[21]
3	Kurt F. von Fay Gregg Day	Polyurethane resin, Epoxy Resin, Polyurea Resin, and Ultrafine Cement ^[16]
4	Sina Kazemian, Bujang B. K. Huat, Maassoumeh Barghchi	Kaolinite, Calcium Chloride, Cement ^[24]
5	Fernando S. Fonseca, Chair Richard J. Balling Paul W. Richards	OPC, Fly Ash, GGBS ^[7]
6	Haixue (Michael) Xu, Ph.D., P. Eng, Bryan S. Elledge, P.G. Douglas M. Heenan	Water, Bentonite, Cement ^[12]
7	Mohammad Reza Azadi, Ali Taghichian, Ali Taheri	Cement, Water, Bentonite, Sodium carbonate, Sodium silicate, TEA ^[19]
8	Fonseca, Fernando S.1 and Siggard, Kurt	OPC, Fly Ash, GGBS ^[6]
9	K. H. Khayat, A. Yahia, and M. Sayed	OPC, Fly Ash, GGBS, Silica Fume ^[17]
10	Iman Satyarno, Aditya Permana Solehudin, Catur Meyarto, Danang adiyatmoko, Prasetyo Muhammad, and Reza Afnan	Water, Cement, and Sand ^[13]
11	Miehael P. SehuJler, Richard H. Atkinson, and Jeffrey T. Borgsrnijler	Cement, Lime, Fly Ash, Micro Silica, Sand, Superplastisizer, Grout Aid ^[22]
12	Er. Mahavir Bidasaria	Cement, Clay, Silicates, Bentonite, ^[5]
13	Chan Man Piu	Cement, Clays, Colloidal Components, Sodium Silicate, Bentonite, Hardner ^[2]
14	E. J. G. Gustin, U. F. A. Karim And H. J. H. Brouwers	Water-Cement and Water-Cement-Bentonite ^[4]

3. IMPACT OF VARIOUS MATERIALS ON PROPERTIES OF GROUT

There are various materials affecting properties of grout. Some of them are listed below.

Bentonite - Viscosity of bentonite water mixture increases with time.^[19] It used for avoiding sedimentation of cement during grouting, it helps in increasing cement binding time, enhancing penetration in compact soils, decrease in setting time index.^[2] Bentonite decreases permeability of grout, increases plastic viscosity, decreases bleeding of cement based grouts.^[4]

Calcium chloride - Increase in calcium chloride increases shear strength and beyond specific limit decreases shear strength, highest shrinkage can be achieved by increasing calcium chloride.^[24]

Cement - Used as binder.^{[2][5][22][13][19][12][24][20]}

Palygorskite (P) - It is used as clay additive.^[21] Increase early gelation of cementitious material due to its thixotropic properties, gets high strength and density, increase in strength with increase in palygorskite, increases yield stress.^[20] Used as filter to prevent fine particles to pass through the fractures.^[21]

Fly Ash - It is used as replacement to OPC but to certain amount (about 25%) used reduces the use of OPC and gives the required compressive strength.^[7] Fly ash slows the rate of gain in compressive strength acts as plasticizer and hence improves workability.^{[2][6]} Use of fly ash decreases slump.^{[2][17]}

GGBS - It is used with fly ash as a replacement to OPC increases strength when replaces to certain amount.^[7] Use of GGBS reduces carbon dioxide emissions is highly cementitious and hydrates like Portland cement.^[6] It increases plastic viscosity when replaced to OPC.^[17]

Kaolinite - It is used as accelerator to the grout mix and filler, if there is increase in kaolinite it increases shear strength and decreases shrinkage^[24]

Merit 500 - It increases setting time, Less initial compressive strength as compared to Portland cement.^[21]

OPC - It is binder material and increases compressive strength.^[7] It reduces setting time and gains more compressive strength as compared to merit 500.^[21]

Polyurethane resin - It is used for sealing small leaking cracks in concrete and have low viscosity and gain strength in short period^[16]

Quartzite aggregate – It minimizes segregation effect in permeation grouting work [20]

Silica Fumes - Use of silica fume decreases slump. [17]

Sodium carbonate – It is used to decrease the bleeding value. [19]

Sodium silicate - Increase upto 0.3% increases the strength of grout, used as alkali activator,[19] Temperature of silicate decreases its viscosity increases.[2]

Talc – It is used as superplasticizer and used for lubrication, when added with clay minerals does not form gel.[21]

TEA – It is used as emulsifier in grout mix, used as organic additive to grind cement clinker, produces gas bulbs when added in grout mix which helps in reducing surface tension.[19]

4. RESULTS AND DISCUSSION

Chemical additives shows significant impact on grout properties. Impact of various materials on property of grout is shown in Table 2.

Table -2: Impact of material on property of grout

Properties Materials	Viscosity	Setting time	Permeability	Bleeding	Shear Strength	Shrinkage	Strength	Density	Yield Stress	Workability
Bentonite	↑	↓	↓	↓						
Calcium chloride					↑	↑				
Palygorskite							↑	↑	↑	
Fly Ash										↑
GGBS	↑						↑			
Kaolinite					↑	↓				
Merit 500		↑					↓			
OPC		↓					↑			
Polyurethane resin	↓						↑			
Silica Fumes				↓						
Sodium carbonate				↓						
Sodium silicate	↑						↑			
TEA						↓				

5. CONCLUSION

Grouting is an effective and widely used technique for repair in dams. Various chemicals added to grout have direct impact on properties of grout. The chart presented in this paper shows the impact of materials on each property of grout. This chart will provide baseline for selection of appropriate materials for grout depending on the requirements.

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