Crimson Publishers
Wings to the Research

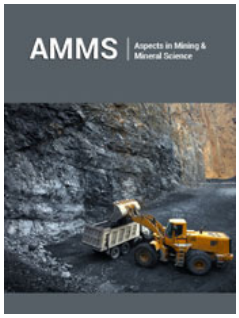
Mini Review

Effect of Mixing Procedure and Injection Pressure on Injectability of Cement-Based Suspension Grouts

Christodoulou Dimitrios*

Department of Environmental Sciences, University of Thessaly, Greece

ISSN: 2578-0255



Abstract

The improvement of properties along with the mechanical behavior of soil formations is often achieved by the execution of an injection program that is designed accordingly and adapted to the needs of the specific technical project. The grouts used to make permeation grouting are mainly suspensions and chemical solutions. The suspensions penetrate well into soils with granulometry up to coarse sand. The injectability and penetrability of cement-based slurries are significantly affected by factors such as cement granulometry, water-to-cement ratio, grain size and degree of sand compaction, type and dosage of slurry admixtures, mixing process and the impregnation pressure. The objective of this work was to evaluate the effect of the mixing process and the impregnation pressure on the injectability of cement suspensions.

Keywords: Permeation grouting; Suspensions; Mixing procedure; Injection pressure; Injectability

***Corresponding author:** Christodoulou Dimitrios, Assistant Professor, Department of Environmental Sciences, University of Thessaly, Campus Gaiopolis, Larissa, Greece

Submission: December 06, 2022

Published: December 15, 2022

Volume 10 - Issue 3

How to cite this article: Christodoulou Dimitrios. Effect of Mixing Procedure and Injection Pressure on Injectability of Cement-Based Suspension Grouts. Aspects Min Miner Sci. 10(3). AMMS. 000738. 2022.
DOI: 10.31031/AMMS.2022.10.000738

Introduction

The design related on the shear behavior of a soil material is of particular interest because it has a direct impact on practical problems of bearing capacity [1,2], stability of slopes and embankments [3,4] as well as permanent seismic movements of slopes [5,6]. The use of permeation grouting is a method of improving the properties and mechanical behavior of the soil that generally has a high cost and its choice depends on the relative cost to other alternatives. The method is based on the replacement of water (or air) in soil voids or rock mass cracks by grout injected under low pressure so as not to disturb the soil formation. It is the oldest injection method and is usually applied to soil zones of relatively small volume that are located at a great distance from the ground surface. The method is used in technical projects with the aim of: (a) controlling underground flows, (b) increasing the shear strength of the soil formation, (c) reducing deformations or subsidence and (d) filling voids [7]. From the 80s onwards, a shift in technological development was observed in the direction of limiting the use of chemical solutions and the development of new non-toxic materials composed of inorganic components and less burdensome on the natural environment [8]. In this context, the effort to investigate and develop new fine-grained cements, which were and are still widely used today in injections, was included. In the literature there are several sources, in which grouts are classified into categories based on different criteria (purpose of use, practical application, etc.). Despite this, the most popular categorization of grouts is based on their rheology and cost [9] so they are distinguished into the following (EN 12715:2000): (a) suspensions, (b) solutions and (c) mortars.

Injectability and Penetrability of Suspension Grouts

The term “injectability” describes the ability of a specific suspension to impregnate a specific soil under a specified impregnation pressure. The term “penetrability” describes the maximum length from the injection point that a specific suspension can penetrate into a specific sandy soil under a specified maximum infiltration pressure. The assessment of injectability

has been and continues to be the subject of extensive research [10-13]. Most research efforts have focused on conducting laboratory tests simulating the injection process in the field. Based on laboratory and on-site observations, general criteria and empirical relationships were formulated, while in recent years efforts have been underway to investigate injectivity using numerical and analytical methods. From the study of the literature it emerged that the methods mainly used for the assessment of injectability concern the performance of one-dimensional injections using long and short laboratory columns. Arrangements involving matrices are also used, while methods for manual preparation of specimens and injections in three dimensions or large-scale injections have been developed. The injectability and penetrability of cement-based suspensions are significantly affected by factors such as cement granulometry, water-to-cement ratio, grain size and degree of sand compaction, type and dosage of slurry admixtures, mixing process and the injection pressure.

Effect of Mixing Procedure on Injectability of Cementitious Grouts

The effect of mixing process, and more specifically mixing speed on injectability, was studied by Toumbakari et al. [14], who used two different procedures. Specifically, a mechanical mixing process and one using ultrasound were followed. The first process involves mixing the materials mechanically with a 2400rpm mixer. The second process combines 28kHz ultrasonic dispersion and a simple 300rpm mechanical stirrer. The cement used was a common Portland cement (CEM I 42.5 LA HSR). To investigate the penetration, tests were carried out on sand columns according to EN 1771:2004. The smallest and largest diameters of sand used to pack the column were 1 and 2mm. For grouts that did not successfully impregnate the column, their composition was varied with changes in water-to-cement ratio and percentage of superfluidizer until a successful combination was found. In general, when the suspensions were prepared using a high-speed mixer, the presence of aggregates was observed, which was not observed when mixing was done using sonication. These aggregates did not prevent the penetration of the grout, as their sedimentation was very fast. However, in some cases, they blocked the exit of the grout from the pump and stopped the flow through the column. In these cases the failure was not attributed to the grout, but to the process of its preparation. When the suspension contained silica fume, the high-speed mixer preparation process did not ensure optimal injectability unless the water and superfluidizer were significantly reduced. In contrast, the ultrasonic grout preparation process allows the production of grouts of high penetration with a low water-to-cement ratio, even when silica fume is added. This is due to the high ability of this mixing method to prevent the formation of agglomerates. Based on the results of the impregnations carried out by Toumbakari et al. [14], the utility of mixing the grouts with ultrasound emerges, as with this process the formation of aggregates is limited and at the same time the limited use of water and superfluidizer is ensured.

Effect of Injection Pressure on Injectability of Cementitious Grouts

The effect of injection pressure on the strength and permeability of cement slurries was studied by Santagata et al. [15] by applying two different pressures during laboratory injections. Specifically, the cement injections were performed with pressures of 200kPa and 50kPa, and the results obtained are detailed in Table 1. The results obtained confirm the finding that the impregnation pressure affects the penetration length for a grout The results given viscosity, and indeed make it clear that an increase in the impregnation pressure causes an increase in the penetration length. In tests conducted by Akbulut et al. [16], the relationship between impregnation pressure and injectability was examined. It is noted that during the execution of the impregnations, the pressure was increased until sufficient impregnation was achieved. Based on the results, they concluded that the increase in pressure positively affects injectability but is not the main factor in injection success. It is emphasized, in fact, that its effect is imperceptible when the soil to be impregnated contains a significant percentage of minutes. Mollamahmutoglu [17] investigates the relationship between impregnation pressure and injectability by injecting slurries of two cements: an Ordinary Portland Cement (OPC) and a fine Portland cement (Microcem H900). The sand used is listed as coarse - medium and the water-to-cement suspension ratio was 1.2:1. From the test results, it emerged that with the Microcem H900 slurries - although it was necessary to increase the pressure to 80 kPa - complete impregnations were achieved, in contrast to the common Portland cement slurries which - even when the pressure was increased to 250kPa - they impregnated only 1/5 of the height of the column.

Table 1: Penetration length as a function of impregnation pressure [15].

Water-to-Cement Ratio	Superfluidizer Dosage	Penetration Length (cm)	
		Pressure of 200kPa	Pressure of 50kPa
1:1	0.4	4.5	0
1:1	0.8	11	3
1:1	1.2	46	16

Conclusion

a. The improvement of properties and the mechanical behavior of soil formations can be achieved on the spot by performing an appropriate injection program. The injection program may: (a) be performed as a part of the preliminary field work prior to the commencement of a project's construction, (b) be a part of the construction of the main project, or (c) be designed and executed as a "treatment" when unforeseen circumstances arise during the construction of a project.

b. Injections are generally intended either to increase the shear strength, density and stiffness of the soil or to reduce compressibility and permeability.

c. The grouts used to make permeation injections are mainly suspensions and chemical solutions.

d. The ultrasonic grout preparation process allows the production of grouts of high penetration with a low water-to-cement ratio, even when silica fume is added. This is due to the high ability of this mixing method to prevent the formation of agglomerates.

e. The increase in pressure positively affects injectability but is not the main factor in injection success. It is emphasized, in fact, that its effect is imperceptible when the soil to be impregnated contains a significant percentage of minutes.

References

1. Lokkas P, Papadimitriou E, Alamanis N, Papageorgiou G, Christodoulou D, et al. (2021) Significant foundation techniques for education: A critical analysis. WSEAS Transactions on Advances in Engineering Education 18(2): 7-26.
2. Lokkas P, Chouliaras I, Chrisanidis T, Christodoulou D, Papadimitriou E, et al. (2021) Historical background and evolution of soil mechanics. WSEAS Transactions on Advances in Engineering Education 18(10): 96-113.
3. Alamanis N (2017) Failure of slopes and embankments under static and seismic loading. American Scientific Research Journal for Engineering, Technology and Sciences (ASRJETS) 35(1): 95-126.
4. Papageorgiou GP, Alamanis N, Xafoulis N (2020) Acceptable movements of road embankments. Electronic Journal of Structural Engineering 20(1): 30-32.
5. Alamanis N, Dakoulas P (2019) Simulation of random soil properties by the Local Average Subdivision method and engineering applications. Energy Systems 12: 841-861.
6. Alamanis N, Dakoulas P (2021) Effect of spatial variability of soil properties on permanent seismic displacements of slopes with uniform load. 14th Baltic Sea Geotechnical Conference, Helsinki, Finland.
7. Atmatzidis DK (1990) Improvements of soils with injections. University Notes, University of Patras, Greece.
8. Saada Z, Canou J, Dormieux L, Dupla JC, Maghous S (2005) Modelling of cement suspension flow in granular porous media. International Journal for Numerical and Analytical Methods in Geomechanics 29(7): 691-711.
9. Bruce AD, Littlejohn S, Naudts CA (1997) Grouting materials for ground treatment: A practitioner's guide. Proceedings, Conference on Grouting: Compaction, Remediation, Testing. In: Vipulanandan C (Ed.), Geotechnical Special Publication, Logan, Utah, USA, 66: 306-334.
10. Christodoulou DN, Droudakis AI, Pantazopoulos IA, Markou IN, Atmatzidis DK (2009) Groutability and effectiveness of microfine cement grouts. Proceedings, 17th International Conference on Soil Mechanics and Geotechnical Engineering. In: Hamza (Ed.), The Academia and Practice of Geotechnical Engineering. IOS Press, Alexandria, Egypt, 3: 2232-2235.
11. Christodoulou DN (2009) Groutability ratios' investigation and improvement of suspensions for soil grouting. PhD Thesis, Department of Civil Engineering, Democritus University of Thrace, Xanthi, Greece.
12. Pantazopoulos IA, Markou IN, Christodoulou DN, Droudakis AI, Atmatzidis DK, et al. (2012) Development of microfine cement grouts by pulverizing ordinary cements. Cement and Concrete Composites 34(5): 593-603.
13. Markou IN, Christodoulou DN, Papadopoulos BK (2015) Penetrability of microfine cement grouts: experimental investigation and fuzzy regression modeling. Canadian Geotechnical Journal 52(7): 868-882.
14. Toumbakari EE, Van Gemert D, Tassios TP, Tenoutasse N (1999) Effect of mixing procedure on injectability of cementitious grouts. Cement and Concrete Research 29(6): 867-872.
15. Santagata MC, Santagata E (2003) Experimental investigation of factors affecting the injectability of microcement grouts. Proceedings of the 3rd International Conference on Grouting and Ground Treatment. In: Johnsen FL, Bruce AD, Byle JM (Eds.), New Orleans, Geotechnical Special Publication, USA, 120(2): 1221-1234.
16. Akbulut S, Saglamer A (2002) Estimating the groutability of granular soils: A new approach. Tunnelling and Underground Space Technology 17(4): 371-380.
17. Mollamahmutoglu M (2003) Treatment of medium to coarse grained sands by fine grained Portland cement (FGPC) as an alternative grouting material to silicate-ester grouts. Cement, Concrete and Aggregates, ASTM International 25(1): 1-6.