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Investigating the feasibility of using basalt powder instead of cement in two-component backfilling grout in mechanized tunneling

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Abstract

Nowadays, tunnel excavation projects in urban environments have witnessed significant growth. Given the shallow depth of tunnels in such environments, they are mostly excavated inside the soft ground using the earth pressure balance machine (EPBM). Considering the high volume of grout injection in this type of excavation, using cement replacement materials can lower the cost and the environmental risks of two-component grout. One of these replacement materials is basalt powder (BP) obtained from basalt quarry stone cutting. The present study assesses the feasibility of using BP obtained from quarry stone cutting as a substitute for cement in the two-component backfilling grout. The results showed that BP can be used as a very suitable substitute for cement in the composition of the two-component grout. Based on the obtained results, the strength of the basalt-containing two-component grout is almost equal to that of the grout that contains cement without basalt. Also, the results obtained for the mix design with 30% BP are in good agreement with those of the mix design containing only cement in terms of bleeding, gelling time, and Marsh funnel tests. As a result, using industrial waste significantly reduces grouting costs and grout's environmental risks.

I. INTRODUCTION

Cement grout injection is one of the common methods in improving the conditions of structures related to the ground, which is carried out to improve the geomechanical performance and bearing capacity of the rock mass or reduce its permeability. In rock environments, grout injection is also used behind the concrete lining of tunnels in order to better connect the lining and the ground. Injection in rock environments is different from injection in soil due to the type and characteristics of discontinuities and their relationship with the type of grout injection. In this method, the grout is injected under a certain pressure and this mixture moves throughout the existing openings, joints and cracks, reducing the effect of discontinuities [1-4]. Also, grouting is a crucial process and a key technology for controlling the tunnel axis. The grout materials and grouting quality greatly influence tunnel. On one hand, grouting materials can fill gaps during tunnel construction and stabilize the tunnel position. However, if the materials and parameters are not properly chosen, the grout's hardening strength and setting time will be inappropriate, and the tunnel may not be restrained effectively [5-8].

The backfilling grout properties are among the most important parameters in excavation with a tunnel boring machine (TBM) and reducing ground surface settlement in urban environments. Therefore, many studies have recently investigated the properties of this type of grout. Among various types of backfilling grout, the two-component grout has drawn more attention because of the high speed of gelation and the lack of grouting lines blockage. Furthermore, the grout penetration into the soil around the segment can increase the strength of the surrounding soil, decrease the permeability, and reduce the flow of water behind the segment. If the grout fails to achieve the required fluidity, it cannot penetrate or fill the desired space. The properties of two-component grout are influenced by parameters such as water-cement ratio, accelerator, and bentonite. Cement is one of the most important components of two-component grout and includes the main cost of this type of grout. However, using cement is harmful to the environment due to the consumption of resources and energy and the production of harmful gases (CO_2, SO_2, and NOx). Besides, using this material is associated with high economic costs. Many attempts have recently been made to improve the performance of grouting materials, and some green materials have been successfully used in grouting as an alternative to cement. Since green material grouting incorporates waste and industrial by-products, it can improve the grouting performance and reduce the economic and environmental impacts. Using BP as a substitute for cement in grout can reduce the cost of grout and environmental impacts because it involves industrial waste. Various studies (Toutanji, 1999; Sharghi *et al.*, 2017; Pedrotti *et al.,* 2017; Hallaji Dibavar *et al.*, 2019; Mohtadinia *et al.*, 2020; Sun *et al.,* 2021; Koksal *et al.,* 2021; Rahmati *et al.,* 2022; Vijayan *et al.,* 2023; Barri *et al.*, 2024) have been conducted on the effect of cement on the properties of two-component grouts and surface settlement and the use of other materials and waste in the composition of grouts, which are briefly presented in the following lines [9-17].

Sharghi *et al.* (2017) investigated the mechanical properties of grout, such as compressive strength, modulus of elasticity, and Poisson's ratio. They performed experiments with different proportions of materials to explore the effect of each component on the properties of two-component grout. These researchers conducted numerical modeling using the FLAC3D software to examine the effect of grout properties on surface settlement. Their numerical results showed that too much increase in the amount of grout cement would only lead to additional costs and does not have much effect on settlement control. Therefore, a grout with strength as much as the soil strength is sufficient to fill the empty space and prevent surface settlement [10].

Rahmati *et al.* (2022) performed laboratory tests to investigate the properties of two-component grout, such as flowability, bleeding, gelling time, and uniaxial compressive strength (UCS). The results showed that the increase in the amount of bentonite and cement leads to an increase in the marsh funnel time, thereby decreasing the flowability of the grout. Moreover, increasing the amount of bentonite and decreasing the water-to-cement ratio caused a decrease in the fresh grout drainage. Based on these results, increasing the amount of cement and sodium silicate (accelerator) and reducing the water-cement ratio increased the UCS. Bentonite also increased the compressive strength in the short term but decreased it in the long term [18].

Sun *et al.* (2021) evaluated the feasibility and environmental impact of using zeolite powder (ZP), BP, and unprocessed coarse fly ash (UFA) as grouting materials. The rheological properties, workability, and compressive strengths of cementitious systems containing cement, ZP, BP, and UFA were tested. The results showed that adding ZP, BP, or UFA to the grout improved the cohesiveness and bleeding rate of the grout. Also, the blends of BP and UFA retained cohesiveness and segregation strength and exhibited good rheological properties and compressive strengths. The economic evaluation indicated that using ZP and BP reduced resource and electricity consumption, harmful gas emissions, and economic costs. In this respect, BP's annual production and mining costs were better than those of ZP. According to this research, UFA production had a negative impact on resource consumption and environmental pollution but had the best economic effect among the three waste materials. A blend with 10% BP and 10% UFA was the optimal combination, which could simultaneously meet the requirements of the grouting performance and economic cost [14].

Koksal *et al.* (2021) explored the effect of zeolite powder (ZP) and BP on cement grout properties (fluidity, rheology, cohesiveness, segregation strength, and mechanical properties). The results show that incorporating ZP or BP can effectively reduce the bleeding rate and improve the cohesiveness of cement paste. This improvement became more significant with the increase in the ZP and BP content and the w/c ratio. The cement paste can also have good compressive strength and rheological properties when used in the appropriate dosage. A small amount of BP negatively affects the flow parameters of cement paste, while a large amount of it can increase its fluidity. The flow distribution and flow rate of cement paste become the worst when the BP content is 10% and the best when the BP content is 20%. Both ZP and BP can effectively increase cohesiveness and reduce the bleeding rate of cement paste. This effect increases with increasing the w/c ratio and mineral additive content [15].

Vijayan *et al.* (2023) introduced silica fume (SF) as an additive in cement composition. The pozzolanic effect of low-calcium silicon present in SF causes the denser C-S-H (Calcium-Silicate-Hydrates) gel to react with unhydrated cement particles, leading to a uniform and dense concrete structure [16].

Toutanji (1999) analyzed the corrosion rate of steel reinforcement and the durability of samples under the influence of nano-waste materials and NS in high-performance HPC. Nanoparticles, including nano-silica fume (NSF), nano-coal (NC), and nano-fly ash (NFA), were replaced in concrete with different ratios of 1, 2, 3, and 4 wt.% of cement and NSF. Next, the aggressive attack of water was investigated by immersing the samples in water for six months. The results showed an increase in the durability and corrosion strength of all nanoparticles and NS produced by HPC [9].

Pedrotti *et al.* (2017) used colloidal silica (CS) as a low-viscosity injection technology, for example, for injecting rock fractures in nuclear waste disposal facilities. They proposed the potential of CS as a desirable injection material regarding its low initial viscosity, low hydraulic conductivity after gelation (of the order of 7-10 cm/s), very low injection pressures required, controllable setting gel/time (from minutes to several days), environmental inefficiency, small particle size (less than hundreds of nanometers), and its cost-effectiveness [11].

Dobiszewska et al. (2019) investigated the use of waste basalt powder as a cement substitute to increase cement hydration and mortar properties. Experiments were conducted to determine the effect of basalt powder on cement hydration as well as compressive and flexural strength. The results showed that adding basalt powder as a cement substitute improved the flexural strength of mortar [19].

In the study of Barri et al. (2024), the mechanical behavior of the grout during injection into the space between the soil and the excavation machine was investigated. Also, the effect of the mechanical properties of the grout mixed with soil on the ground settlement was analyzed using numerical modeling. The results of laboratory studies showed that mixing the grout and soil significantly increases the mechanical properties of the grout. Increasing the soil in the soil- grout mixture by 40% increases the uniaxial compressive strength by 300%, the elastic modulus by 156%, and the cohesion by 100%. On the other hand, according to the results of numerical modeling, the appropriate injection pressure can significantly reduce the ground settlement. Increasing the injection pressure from 0 to 120 kPa had a 17% effect on reducing the ground settlement [20].

In the study of Miri Darmarani et al. (2025), the feasibility of using recycled fibers to improve the mechanical properties of shotcrete was investigated. In this study, recycled steel fibers from worn tires and basalt stone chips were used to make laboratory samples. The laboratory samples had five different mixing designs including regular shotcrete, shotcrete containing 0.5%, 1%, 1.5% and 2% recycled fibers. The results of laboratory studies showed that recycled fibers from worn tires can significantly increase the mechanical properties of shotcrete, such that with a 2% increase in the amount of fibers, a twofold increase in compressive strength occurred. In addition, the addition of basalt stone chips not only improved the compressive strength of the samples, but also had a significant effect on increasing the tensile strength [21].

Also, previous studies (Wang et al., 2000; Xu and Fan, 2009; Xiao et al., 2010) revealed that acid sodium silicate-based grouts exhibited improved gel strength as the content of $CaCO_3$ increased (at constant H_2SO_4 content), and the critical point of gelation time was obtained [22].

Concrete and grout production consumes significant natural resources, leading to environmental concerns and sustainability challenges. Sustainable alternatives, such as industrial byproducts, have been explored to replace aggregates. Basalt powder (BP) is a promising option due to its physical and chemical properties, including its better particle size distribution and compatibility with cementitious composites, and studies have highlighted its pozzolanic activity and its potential to improve mechanics properties (compressive strength, flexural strength, and durability). Using basalt powder as a raw material could transform it into a mineral byproduct, benefiting the new material and reducing waste volumes. Considering the high volume of grout injection in excavation, using cement replacement materials can lower the cost and the environmental risks of two-component grout. One of these replacement materials is basalt powder (BP) obtained from basalt quarry stone cutting. The present study aims to assess the feasibility of using BP obtained from the industrial waste of mines. To this end, the laboratory modeling of backfilling grouting conditions was performed to investigate the physical and strength parameters of the two-component grout containing basalt (substitute for cement). Finally, the penetration of this type of grout into the surrounding soil in the simulated conditions was investigated under dry and wet conditions. The methodology of tests performed of this study is shown in Fig. 1.

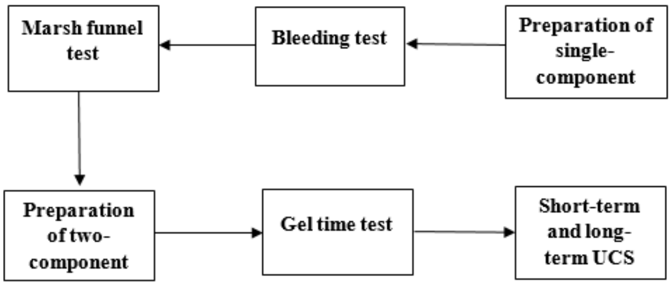


Fig. 1. The methodology of tests performed of this study

II. MATERIALS

The ingredients of two-component grout are components A and B, composed of water, bentonite, cement, fillers, and additives. The water used in this study is potable water according to the ASTM D1293 (2018) standard (The pH of the water used is 7.2) [23]. The experiment was conducted using two cement materials, ordinary Portland cement (OPC) and BP. Table 1 presents BP's chemical composition based on X-ray fluorescence (XRF) spectroscopy. BP was prepared as an industrial by-product obtained from the basalt mine of Sari Qayah, Sarab.

Table 1. Chemical compositions of BP and cement

Parameters	**Value (%)**	
	BP	**cement**
SiO_2	50.3	21.32
Al_2O_3	14.9	5.33
Fe_2O_3	10.6	3.77
FeO	0.27	-
CaO	9.95	63.35
MgO	7.6	2.44
Na_2O	2.3	0.24
K_2O	0.8	0.63
TiO_2	1.1	-
P_2O_5	0.42	-
MnO	0.7	-
L.O.I	-	**1.2**
I.R	-	**0.55**
SO_3	-	**1.98**
CaO (Free)	-	**1.12**

SiO_2, Al_2O_3, and Fe_2O_3 contents in the chemical compositions of BP were about 50.3%, 14.9%, and 10.6%, respectively. These contents are all above the minimum requirement (70%) specified in ASTM C 618 (2017) [24]. The chemical composition of BP was analyzed by XRD. The XRD peaks for the confirmed basalt sample show that most of the phases found were similar to the XRF analysis results (Fig. 2).

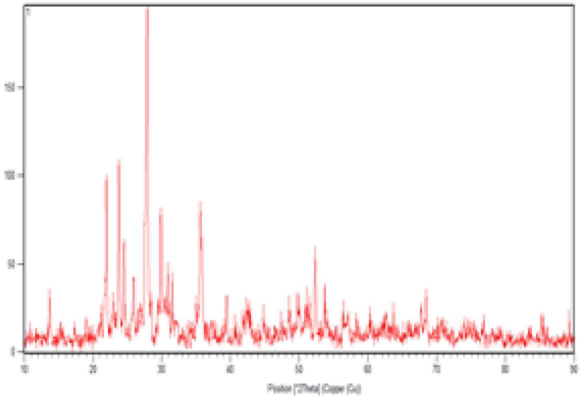


Fig. 2. Results of XRD analysis

Fig. 3 presents the main materials used in the grout composition in this study, including Portland cement, basalt, and bentonite. The analyzed mix designs are given in Table 2. Our designs were used to examine the influence of BP on the mechanical and physical properties of the grout. The first design included two-component cement grout, while the subsequent ones included 20, 30 and 40% basalt replaced for the cement of the first design.

Fig 3. Materials used in the grout mixture

Table 2. The analyzed mix designs

No.	Cement (kg)	Water (l)	Bentonite (kg)	Sodium silicate (kg)	BP (kg)	SiO_2/Na_2O	W:C
1	360	799	40	90	0	3.1	2.22
2	288	798	15	90	72	3.1	2.22
3	252	770	40	90	108	3.1	2.22
4	216	744	40	150	144	3.1	2.22

In this research, first, bentonite was kept in a suitable place for 24 h with a specified amount of water, which caused the bentonite particles to swell and absorb water. Next, the required bentonite was mixed with 85% of the water in the mix design using a mixer until the mixture became free of bentonite lumps. Afterward, the other components of component A of the grout, including cement, the remaining water, and BP, were added and stirred for a few minutes using a mixer until obtaining a uniform grout with high fluidity. Finally, component B was added to the mixture. The ASTM C940 (1999) standard was used to perform the grouting test of the grout, the ASTM D6910 (2004) to perform the flow test, ASTM C191 (2004) to perform the Vicat test, and ASTM C109 (2008) to perform the uniaxial compressive strength test [25-28]. The samples evaluated for compressive strength included 2-h, 24-h, and 7-day grout samples. Three samples were prepared for each time frame, followed by undergoing a UCS test. The preparation method of UCS samples is shown in Fig. 4.

Fig. 4. The preparation method of UCS samples

III. LABORTORY RESULTS

In this section, the laboratory results are presented in two parts: 1) physical and mechanical studies of the grout and 2) grouting studies.

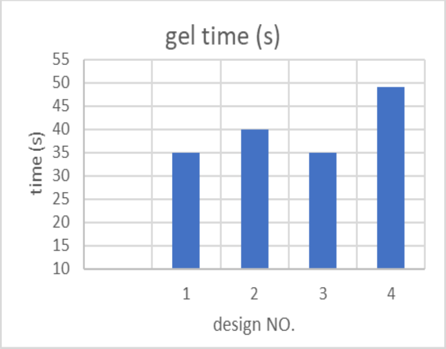
A. Physical and mechanical studies of the grout

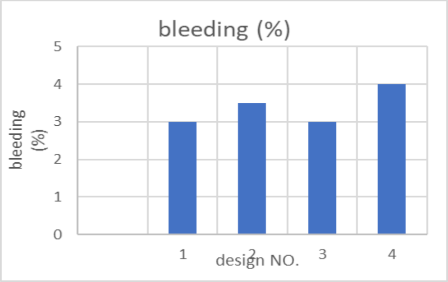
Table 3 gives the results of the Marsh funnel, bleeding, and compressive strength tests. In addition, Fig. 5 gives the changes in gelling time, Marsh funnel, and bleeding.

Table 3. Test results

Scheme No.	Bleeding (%)	Marsh funnel	gelling time (S)	UCS (2-h) (MPa)	UCS (1-day) (MPa)	UCS (7-day) (MPa)
1	3	35	35	0.01317	0.189	0.278
2	3.5	36	40	0.01317	0.0965	0.218
3	3	35	35	0.02340	0.1676	0.2297
4	4	40	49	0.05929	0.18089	0.27869

According to Fig. 5, an increase in BP has caused 0.5 to 1% changes in the bleeding of the designs. The gelling time changes are also similar to the changes related to the bleeding, ranging from 5 to 14 s. Regarding the Marsh funnel, an increase in the BP in smaller amounts (10 to 30%) does not significantly change Marsh funnel values. Meanwhile, a 40% increase in its values creates a significant increase in the values compared to the previous situations. In all graphs, the mix design with 30% BP is in good agreement with the mix design containing only cement.





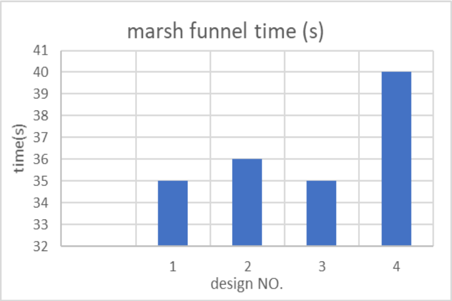


Fig. 5. Gelling time, Marsh funnel time, and bleeding

UCS variations of the two-component grout for the various designs are given in Fig. 6. As can be seen, a 20% increase in basalt leads to a two-time increase in the UCS of the 2-h grout compared to the basalt-free blend. This increase reaches 4 times for the mix with 40% basalt. Regarding the 1- and 7-day strengths, the grout with 40% BP has an equal strength to that without BP.

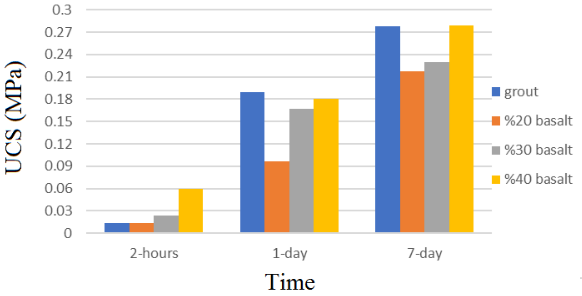
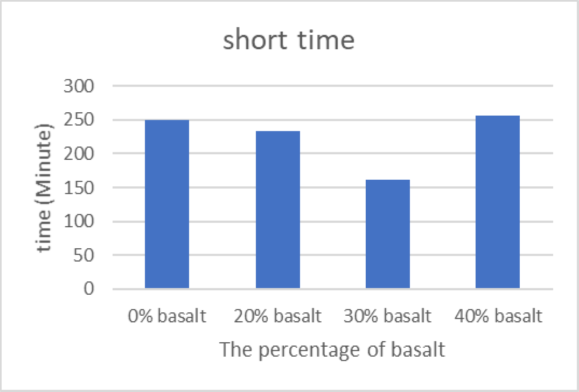


Fig. 6. UCS variations for different mix designs versus time

The setting time consists of two parts: initial and final parts. The initial setting time starts from the moment of making the injection mortar and continues until the complete injection of the mortar behind the segments. This time varies depending on the type of project, the distance from where the grout is made to where it is injected, the excavation speed, and the grouting pressure. The higher the percentage of cement and the more fine-grained it is, the larger the specific surface area of hydration and the faster its setting time. In the laboratory, this time is measured using a Vicat needle. The initial setting includes the time required to insert the needle into the grout sample by 25 mm. During the final setting, the needle will not be inserted into the sample and will not have a noticeable effect on it. However, the injection time should be less than the initial setting time. Fig. 7 illustrates the variations in initial and final setting times.



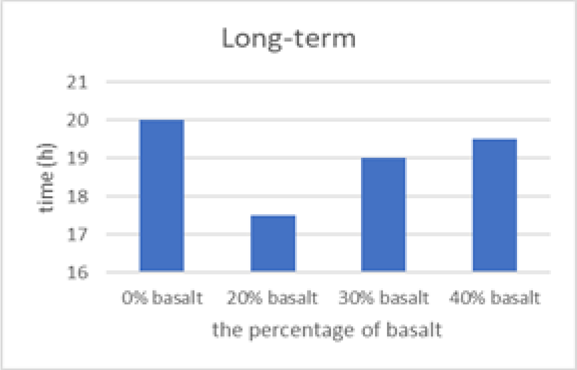


Fig. 7. Setting time variations for different mix designs based on the Vicat test

According to Fig. 7, an increase in BP by less than 30% reduces the initial setting time of the grout, but an increase in BP leads to an increase in the initial setting time, and a 40% increase in it causes it to be almost the same as the setting time of the two-component basalt-free grout. The final setting time decreases in the composition containing 20% BP.

B. *INJECTABILITY OF GROUT*

In this research, grout penetration length was evaluated by fabricating a laboratory injection system. Fig. 8 depicts the structure and dimensions of the injection simulation system. The test system consists of an injection simulation test frame, injection system, and monitoring system. In the injection process, the grout was injected into the center of the circular space inside the soil tank before the injection operation. Next, a stress loading system loaded the pressure of the injected environment. Finally, the soil inside the tank was completely saturated with water until the environment inside the tunnel was fully simulated. Moreover, the effect of BP on the amount of injection was investigated by designing four states with the same pressures based on which the test was performed (Table 4). The diagram of soil grading used in the test is given in Fig. 9.

Fig. 8. Injection system simulator

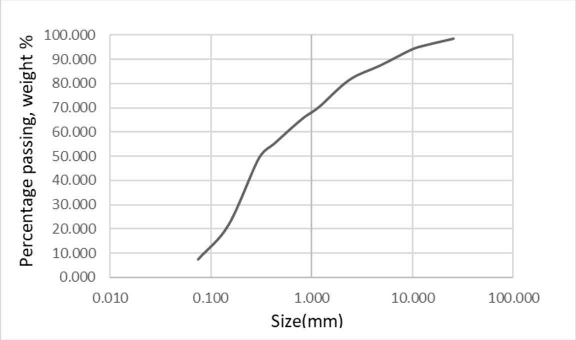


Fig. 9. The grading diagram of the soil used in the injection test [29].

To perform the test, first, component A (the grout) and component B (the accelerator) are poured into separate tanks, followed by injecting them into the soil tank. The compressor applies the earth pressure to the soil tank, and the compressor connected to the grout tank and accelerator is used to supply the injection pressure.

Fig. 10 presents the injected areas in different designs. According to Table 5, adding 20% BP creates no changes in the penetration rate of the grout in the soil compared to the BP-free designs (Designs 1 and 2). However, the presence or absence of water inside the chamber has a significant effect on the penetration rate of the grout inside the soil. The flow inside the chamber also has a small effect on the grout penetration inside the soil.

Table 5. Penetration rates in two different designs

Scheme No.	Height of grout (cm)	Height of water (cm)	Grout penetration (cm)
1	6.8	6	1.3
2	6.1	6.7	1.3
3	7	-	1
4	7.3	-	2.3

IV. DISCUSSION

The results of this study highlight the potential of basalt powder (BP) as an effective substitute for cement in two-component backfilling grout. The mechanical properties, particularly compressive strength, showed that BP can match or even exceed the performance of cement in certain short-term applications. This is consistent with the findings of Sun et al. (2021), who reported enhanced rheological properties and compressive strength when industrial by-products like BP were used in cement-based systems [14]. Additionally, Koksal et al. (2021) also emphasized the role of BP in improving grout cohesiveness and reducing bleeding rates, further confirming its suitability as a cement replacement [15].

In practical terms, the ability of BP-based grout to perform similarly to cement-based grout in critical areas such as gelling time, bleeding, and Marsh funnel values suggests that BP can be adopted in real-world tunneling and construction projects without significant changes to current operational practices. The injectability tests demonstrated that BP-containing grout can achieve comparable penetration rates, especially under wet conditions, making it a viable option for use in mechanized tunneling with TBM. This is especially important in urban environments, where minimizing surface settlement is crucial, as indicated in the studies by Sharghi et al. (2017) and Rahmati et al. (2022) [10 & 18].

One of the most significant benefits of using BP lies in its environmental impact. Cement production is known to be one of the largest sources of CO_2 emissions globally, and replacing a portion of cement with BP, a waste by-product from basalt quarrying, can help reduce these emissions. Studies by Gao et al. (2017) and Kurad et al. (2017) have pointed out the environmental benefits of using industrial waste in cementitious systems, and this study reinforces that finding. In fact, the use of 20-30% BP offers an optimal balance between maintaining mechanical properties and reducing environmental impact, as confirmed by the similar behavior of BP-based grout to that of cement-only grout in terms of bleeding and gelling time [30 -31].

Economically, the use of BP is advantageous, as basalt is readily available and less expensive compared to cement. The economic benefits are compounded by the reduced energy consumption and lower costs associated with BP production. This supports the conclusions of Vijayan et al. (2023), who highlighted the cost-effectiveness of using industrial by-products in concrete and grout formulations. The reduction in cement use not only lowers material costs but also aligns with the increasing demand for sustainable construction practices [16].

Future research could focus on optimizing the mix designs further, especially in relation to higher BP percentages. While this study found that 20-30% BP substitution is optimal, higher percentages may affect grout fluidity, which could limit its use in certain applications. Investigating different soil conditions or grout compositions with varying BP content could provide deeper insights into how to extend the use of BP-based grout in other geotechnical projects. Additionally, exploring the long-term durability of BP-based grout in more aggressive environments would be beneficial in understanding its broader applicability.

Overall, the findings of this study suggest that BP is a promising material for sustainable construction, providing both environmental and economic benefits while maintaining the desired mechanical properties of two-component grout. By reducing cement consumption and utilizing industrial waste, BP contributes to the growing movement toward greener construction practices.

Fig. 10. Penetration rates in four different designs

V. CONCLUSIONS

BP is a material produced as industrial waste from basalt stone cutting. Using this substance in the backfilling injection can have a significant effect on reducing environmental pollution in addition to economic benefits. Therefore, this article investigated the feasibility of using BP as a substitute for cement. The process involved two parts. The first part includes investigating the physical and mechanical properties of the BP grout to determine whether this material can be used as a backfilling injection material. In the second part, the injectability of BP was evaluated using the built simulator. The results of the tests show that:

- An increase in the amount of BP by up to 30% reduces the initial setting time of the grout. However, an increase in BP leads to an increase in the initial setting time increases and a 40% increase in it causes it to be almost the same as the setting time of the two-component basalt-free grout. In the end, the final setting time decreases in the composition containing 20% BP.
- An increase in the amount of BP mixed in the grout increases the UCS during the first hours of injection. This increase is more significant than 1-day and 7-day strengths in the backfilling injection process.
- An increase in BP has caused the same changes in the designs' bleeding and gelation time. As for the Marsh funnel, an increase in BP in smaller quantities (10 to

30%) does not lead to significant changes in the Marsh funnel values. The mix design with 30% BP is very similar to that containing only cement in terms of bleeding, gelling time, and Marsh funnel tests.

- Adding 20% BP creates no changes in the grout penetration rate in the soil compared to the BP-free design.
- Replacement ratios greater than 40% are suggested for future studies. It is hoped that this will be studied in the future and provide new and more accurate insights.

Overall, BP can be used as a very suitable substitute for cement in the composition of two-component grout. Therefore, the injection of BP, as an industrial waste and by-product, reduces cement consumption and groundwater pollution. Using this industrial waste as a partial substitute for cement is associated with environmental and economic benefits, including the conservation of natural resources and energy, the reduced emission of greenhouse gases and pollutants, and the reduced waste disposal rate.

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بررسی امکان‌سنجی استفاده از پودر بازالت به جای سیمان در دوغاب پرکننده دو جزئی در تونل‌سازی مکانیزه

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چکیده

امروزه با توجه به گسترش شهرنشینی، نیاز به حفاری تونل در محیط‌های شهری به‌صورت فزاینده‌ای در حال افزایش می‌باشد. در محیط‌های شهری، با توجه به عمق کم تونل، اغلب، حفاری در داخل محیط‌های خاکی و با استفاده از اشین حفاری مکانیزه EPB-TBM انجام می شود. به منظور کاهش نشست زمین، یکی از پارامترهای مهم این نوع ماشین ها، دوغاب پشت سگمنت و خصوصیات فیزیکی و مقاومتی این نوع دوغاب‌ها می‌باشد. از طرف دیگر، با توجه به حجم بالای تزریق دوغاب در این نوع حفاری، استفاده از مواد جایگزین سیمان مناسب می‌باشد. یکی از موادی که می‌تواند علاوه بر کاهش هزینه، موجب کاهش خطرات زیست محیطی دوغاب دوجزئی گردد، پودر بازالت حاصل از خردایش سنگ معدنی بازالت می‌باشد. در این مطالعه، به منظور امکان سنجی استفاده از پودر بازالت در محدوده مورد مطالعه، از مدلسازی آزمایشگاهی استفاده شد و ضمن بررسی شرایط تزریق پشت سگمنت، پارامترهای فیزیکی و مقاومتی دوغاب دوجزئی حاوی بازالت (جایگزین سیمان) و نفوذ آن در خاک اطراف بررسی شد. نتایج حاصل از مطالعات، نشان داد استفاده از پودر بازالت می‌تواند جایگزین مناسبی برای سیمان در ترکیب دوغاب دوجزئی باشد، طوری که مقاومت دوغاب دوجزئی حاوی بازالت تقریباً برابر مقاومت دوغاب حاوی سیمان با درصد مشابه می‌باشد. این موضوع می‌تواند تأثیر زیادی در کاهش هزینه‌های دوغاب تزریقی و همچنین کاهش خطرات زیست محیطی دوغاب به دلیل استفاده از ضایعات صنعتی داشته باشد.

واژگان کلیدی حفاری مکانیزه، EPB ، دوغاب، پودر بازالت، خصوصیات مکانیکی