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Stabilizing the Excavation Materials to be used in Fill Layers

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Abstract

Daily increase in the amounts of soil and wastes produced by excavation and demolishing of the old buildings in the urban worn out textures has caused great problems in large cities. The environmental issues due to the irrelevant and non-technical disposal of waste materials have attracted attention of researchers with the aim of recycling and use of these materials in the civil and construction activities. Old buildings constitute a significant portion of Sharestan Razavi Blvd in Mashhad which after demolishing of these buildings the area in this section is covered by the backfill materials and those remained from the demolishing of the buildings. In this research, maximizing use of the available materials and minimizing the transportation work as an execution order have been under focus of attention. Also through performing various tests, the possibility of recycling, stabilizing and implementing these materials at underlying layers of Sharestan Razavi Blvd has been evaluated and the results are presented.

Keywords: Construction Wastes; Recycling; Stabilizing; Lime; Cement; CBR Test.

1. Introduction

Recycling of the soil and construction wastes not only helps in preserving the natural sources and the environment but by incorporating the scientific methods it could have economic justification. The very large amounts of the soil and construction wastes and their irrelevant disposal have created environmental and sanitary problems together with the need for locations for waste disposal and creation of the polluted areas with an inappropriate view. The economic aspects of soil and construction wastes recycling are as important as the associated technical issues. The most important factors for justifying recycling of the soil and construction wastes are; the cost of waste transportation from the production point to the disposal point, cost of maintaining the land and essential facilities to create areas for unloading the soil and construction wastes, cost associated with waste disposal and preventing the related pollutions, and cost of preparation and transport of the appropriate materials from the borrow areas. It is quite clear that recycling of the soil and construction wastes is also costly and might not be economically justified. But daily increase in the primary materials' prices and un-compensable damages to the environment in long term has raised the importance of recycling of the soil and construction wastes [1]. One of the problems associated with urban solid wastes management system especially in the metropolitan cities, is production of thousands of tons of the soil and wastes where disposal of them in addition to the economic problems causes environmental pollution [2]. Growth and extension of the cities in the areas of construction wastes disposal has created many problems, including settlement of the buildings, blasting of the water and wastewater networks and sanitary problems including spread of diseases like leishmaniasis [3]. Unfortunately there are not any formal information concerning the areas that are backfilled by the soil and construction wastes in most of Iran's cities. Improper disposal of the solid wastes produced due to the civil projects and accumulation of large amounts of construction wastes in various points of the cities have caused many environmental problems, where by accurate management and recycling of the wastes one could alleviate some of the associated detrimental impacts. One of the solutions is incorporation of these materials in the road pavement layers [4], where there are special standards for

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implementing these materials [5]. Approximately 8.7 million tons of the recycled concrete materials, 1.3 million tons of broken brick and 1.2 million tons of reclaimed asphalt are collected in Australia [6]. The Environmental Protection Agency has estimated that about 73 million tons of used asphalt is recycled in the United States [7].

Stabilization is a common method for enhancing the strength and stability of the Construction and Demolition materials for the road making applications. The life cycle of the (C and D) materials shows that recycling is potentially useful in economic and environmental terms. Especially where efficient classification of (C and D) materials is performed and the transport costs are accurately managed [8-10].

In recent years, application of the (C and D) materials stabilized by cement, especially the Reclaimed Asphalt Pavement (RAP) as the pavement materials has been under focus of attention of various researchers [11]. Changes in the composition of the(c and D) materials have been well stated by the previous researchers and it is proven that when these materials are specifically improved could be useful for the local demands [6-7]. Cement stabilization is often used for stabilizing the pavement materials. Whereas use of the Portland cement has a significant carbon effect [12]. Alternate binders like fly ash, calcium carbide residue and slag have been previously used for stabilizing the granular materials [12-13]. Stabilizing with lime is one of the oldest forms of stabilization which is used also for stabilizing the pavement materials. Usually two types of lime are used for stabilization; the quick lime (CaO) and the hydrated lime ($Ca\ (OH)_2$). It is proved that the hydrated lime is effective for the bed stabilization [14]. Stabilizing with lime reduces plastic index of the soil and improves its stiffness, strength and water absorption [5]. In the study of Mohammadian et al (2017), the hydrated lime was used for stabilizing the (C and D) granular and recycled materials for improving the mechanical properties and endurance of these waste materials under compressive and cyclic pressures for application in the base and sub base layers in road pavements [16].

2. Case Study

The project is located in Khorasan-e Razavi Province in Mashhad, Sharestan Razavi Blvd., between Navab Safavi Street and Tabarsi Street with an approximate length of 1 km and width of 50 m. A large portion of the area designated for construction of this Blvd, is constituted of worn-out and old buildings. After demolition of some of these buildings some of the materials produced by the demolition are transferred to outside of the city, but a significant portion of the waste materials have been remained at the location of constructed Blvd. due to the depth of courts in these buildings and presence of basements or cisterns, etc. In addition to the remained waste materials due to demolition of the buildings, presence of the old buildings' foundations and base courses and also water and waste water well curbs,…. have created conditions that all the area of this zone is covered with the backfilled soil and construction wastes with an average depth of 2 meters (in some parts about 4 m depth).

While executing the first segment of Sharestan Razavi Blvd. (between Amir Al-Momenin Square and Tabarsi Street with a length of 350 m), based on the common and current methods the entire thickness of the backfilled soil and the construction wastes were excavated and replaced by proper materials (Ferdowsi mixture) and were compacted. But regarding the stated essentials, the issues of maximizing the use of the available materials and minimizing the transportation were considered as an execution order and thus all the feasibility studies and technical assessment concerning use of the available materials were performed by the stabilization method. The details and stages of implementing these studies and tests are described as follows.

3. Sampling from the Existing Materials

Sampling is performed at three different locations and at different time intervals in this project to identify the recyclable materials. The nomenclature and location of the samples are as follows:

- Location A in the area of Amir Al-Momenin Square
- Location B opposite to Sara Project (0.5-2.5 m depth)
- Location C opposite to Sara Project (1.5-3.5 m depth)

In Figure 1, the sampling position is shown.

Figure 1. Map of the project area

4. General Characteristics of the Sampled Materials

The existing buildings in the project area which are demolished are different in terms of the structure type and the used materials and thus the share of soil and construction wastes at different parts of the project are relatively diverse (Figures 2 and 3). Nevertheless, regarding the field observations during excavation (for execution of the first segment of Sharestan Razavi Blvd) and also considering the performed samplings at locations A, B and C which are sent to the laboratory and separated, one could determine the approximate weight percentage of various materials (in a layer with a thickness of about 2-3 m from the ground surface) as given in Table 1.

Table 1. Characteristics of the used materials

Stone, tile and … (%)	Asphalt (%)	Chalk (%)	Brick, concrete, mortar (%)	Fine-Grained soil and peels (%)
2 percent	2 percent	1 percent	10 to 25 percent	70 to 85 percent

Figure 2. A view of the demolished buildings materials

Figure 3. A view of the separated bricks from the excavation materials

5. Preliminary Identification of the Recyclable Materials in the Project

With respect to the general characteristics of the existing materials given in the above table, about 20% of the excavation materials are comprised of the coarse and inappropriate size to be used in the fill layers and it is essential to separate these materials which include the brick, rock and grout. Separation of the coarse materials larger than about 3 inches could be done using the sieves at the excavation site. Furthermore, in portions where the coarse materials are less in number, they could be collected and separated through distributing the excavation materials and using grader and human force.

It should be noted that a significant amount of the coarse grained materials included sound and recyclable bricks which could be sold with good prices regarding their quality (sound recycled bricks with good dimensions), thus the cost of separation of the excavated coarse materials could be compensated by selling the recycled bricks and thus becoming cost effective. Regarding the above explanation, while sampling from the excavation materials, first the coarser than half a brick size materials are separated from the sampled materials and then transferred to the laboratory for general identification of these materials in the laboratory. The preliminary tests include:

- Particle size distribution test using the sieves.
- Atterberg limits test.
- Modified Proctor compaction test.
- CBR test at saturated moisture condition.
- Uniaxial test.

The results of these tests are given in Table 2;

Table 2. Results of the gradation and Atterberg limits tests

Location of Sampling	The percentage of grains coarser than 3 inches	Specifications of materials (after separating parts larger than about 3 inches)				
		The soil percentage passed from sieve No. 4	The soil percentage passed from sieve No. 200	LL	PI	Natural moisture content
A	5	80	67	25	4	13
B	6	76	70	26	3.3	12
C	4	78	68	24.3	3.5	13
Medium	5	78	68.33	25.1	3.6	12.66

These results show that there is not a major and significant difference between the sampled materials from different points (after separation of the coarser than 3 inches materials) and these materials could be generally introduced as the fine grained (ML) soil.

In continuation and for further information concerning the above mentioned materials characteristics, the modified proctor test was performed and the maximum dry density and optimal moisture content were measured. Then samples of these materials were produced with different compaction percentages and the saturated CBR of these samples were measured. The results of these tests show that where these materials are compacted with compaction percentage of 95%, the corresponding CBR would not exceed 2 and it could be concluded that in case of using these materials in compacted fill layers and assuming an appropriate compaction percentage they would not yield a good and acceptable quality. Therefore the issue of enhancing and improving the technical specification of these materials by addition of the stabilizing compounds has been taken into consideration. In this respect, the necessary tests were accomplished and concerning the type and amount of the proper additive compounds the necessary research were performed and the results are described in detail in continuation.

6. Mix Designs for Stabilization Operation

Regarding the project condition and considering the existing and available additives which could be used for stabilizing the excavation materials, cement and lime (each separately) and cement and lime mixture are taken as the stabilizing compounds and different compositions of the tested materials were prepared by addition of different percentages of cement and lime. Each composition was designated with a mix design number and then the needed samples were made of them and tested (see Table 3).

Table 3. Percentages of lime and cement for the samples

Sampling position	Lime percentage	Cement percentage
A	1.5-3 - 5	-----
A	-----	1.5-3 - 5
A	1.5-3 - 5	1.5
B	1.5-3 - 5	-----
B	-----	1.5-3 - 5
C	1.5-3 - 5	-----
C	-----	1.5-3 -5

7. Performed Tests for Assessment of the Stabilization Operation

Addition of the stabilizing compounds causes reduced plastic properties, reduced swelling and shrinkage, change in the surface texture and increased strength and endurance of the soil. It should be noted that the pozzolanic reaction which causes increased strength and endurance of stabilized soil was not significant in some of the soils and regardless of the type and percentage of the stabilizing compound, there would not be significant increased strength of the soils. There are various tests for assessment of the soils stabilized with lime and cement. The uniaxial compressive strength and California Bearing Ratio (CBR) tests are accounted as the most applicable tests for assessing the technical specification of stabilizing compounds and therefore these tests are incorporated in the research.

8. CBR Tests Results of the Stabilized Samples (Sampling from Location A)

8.1. Stabilization with Lime

The stabilized samples with a diameter of 15 cm and height of 11.8 cm, with 1.5, 3 and 5% lime and minimum compaction percentage of 95% were produced in the laboratory and were cured in plastic and oven with 50 Celsius degrees for 48 hours (accelerated). Then for saturating the samples, they were laid in water at least for 96 hours and then tested. A summary of these test results is given in Figure 4.

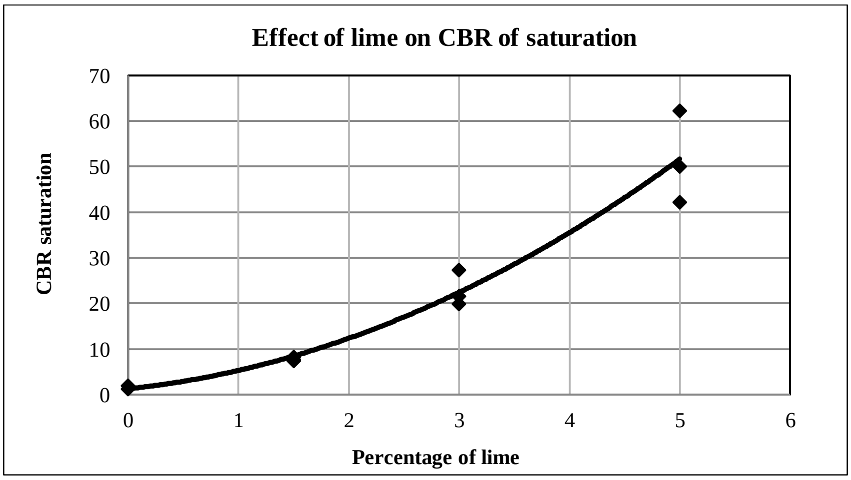

Figure 4. Variation of CBR with different lime weight percentages

8.2. Stabilization with Cement

Similar to that was done with lime, was performed with cement, and the samples stabilized with cement were made in molds of 15cm diameter and 11.8cm height with 1.5, 3 and 5% cement and minimum 95% compaction and were cured for 11, 28 and 42 days in water. The summary of these tests results is shown in Figure 5.

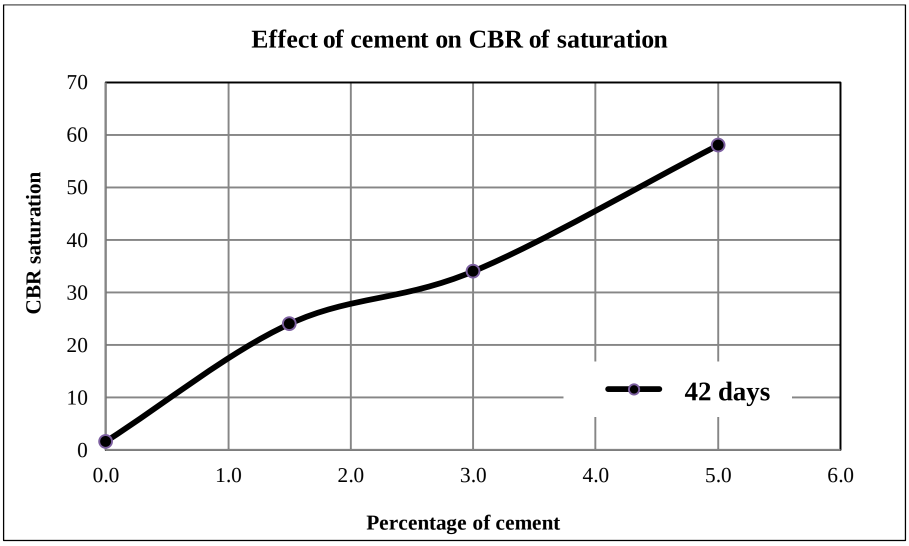

Figure 5. Variation of CBR with different cement weight percentages

8.3. Stabilization with Lime and Cement Mixture

To assess the simultaneous effect of both additives, a number of stabilized samples similar to the previous states were produced by a mix design of 1.5% cement and addition of 1.5, 3 and 5% lime in the laboratory. These samples were first laid in plastic and heated in oven at 50 Celsius degrees for 48 hours and then were cured for 11, 28 and 48 days in water. The summary of these tests results is shown in Figure 6.

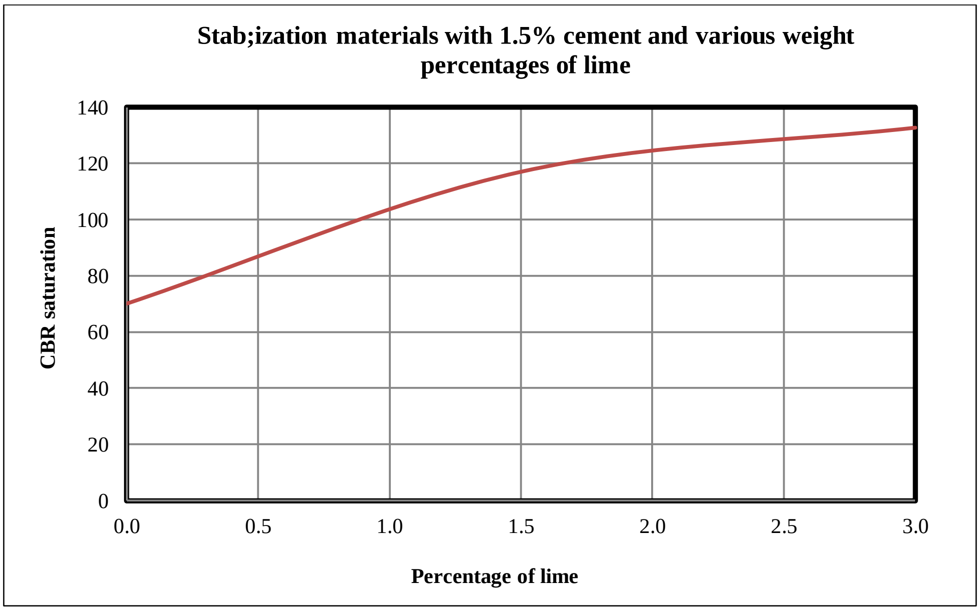

Figure 6. CBR of the stabilized samples with 1.5% cement and different lime weight percentages

9. Results of the Compressive Strength Tests for the Stabilized Samples (Sampling from Location A)

9.1. Stabilization with Lime

The stabilized samples with a diameter of 15cm and height of 11.8 cm with 1.5, 3 and 5% lime and minimum compaction percentage of 95% were produced in the laboratory and were cured in plastic and oven with 50 Celsius degrees for 48 hours, Figure 7.

9.2. Stabilization with Cement

Similar to that was done with lime, was also performed with cement, and the samples stabilized with cement were made in molds of 15cm diameter and 11.8cm height with 1.5, 3 and 5% cement and minimum 95% compaction and were cured for 42 days in water. The summary of these tests results is shown in the following diagram, Figure 8.

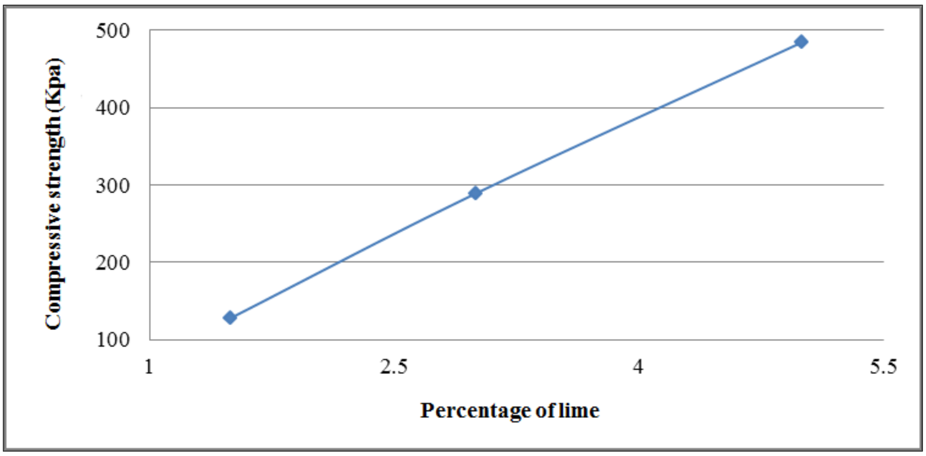

Figure 7. Results of the uniaxial test based on the increase in used lime percentage with compressive strength

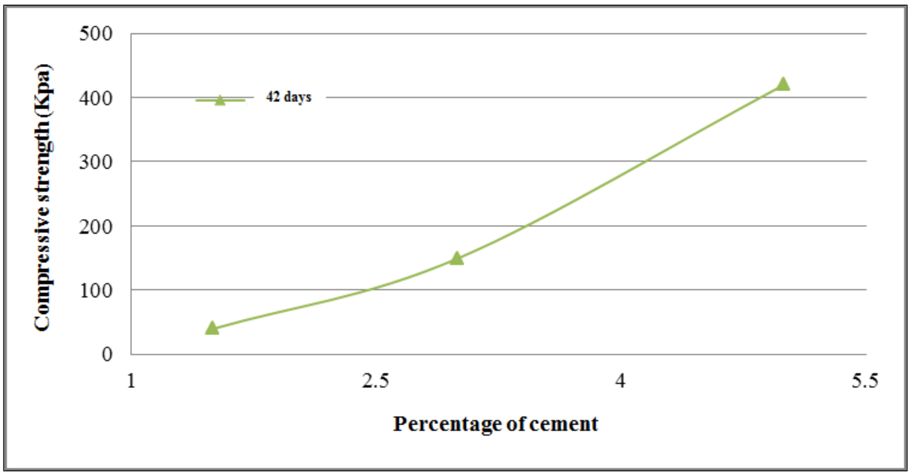

Figure 8. Variation of the compressive strength with percentage of the used cement

9.3. Stabilization with Lime and Cement Mixture

To assess the simultaneous effect of both additives, a number of stabilized samples similar to the previous states were produced by a mix design of 1.5% cement and addition of 1.5, 3 and 5% lime in the laboratory. These samples were first laid in plastic and heated in oven at 50 Celsius degrees for 48 hours and then were cured for 42 days in water. The summary of these tests results is shown in Figure 9.

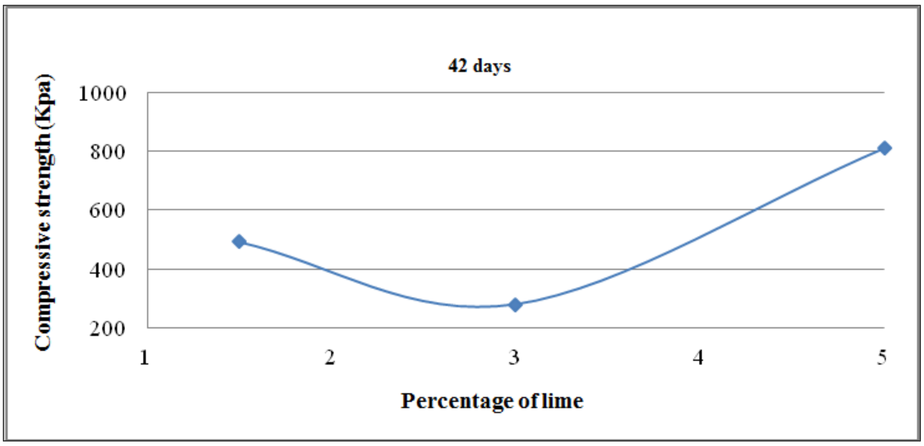

Figure 9. Variation in the compressive strength with different lime percentages

10. Results of CBR Tests for Stabilized Samples (Sampling from Location B)

10.1. Stabilization with Lime

The stabilized samples with 15cm diameter and 11.8cm height were produced with 1.5 and 3% lime and minimum compaction of 95% in the laboratory and were kept in plastic in the ambient temperature for 7 days and then tested. Also a number of samples were prepared and considered as accelerated one with 3% lime. For saturating the samples they were kept in water for minimum 96 hours and then were tested. The summary of these tests results is given in Figure 10.

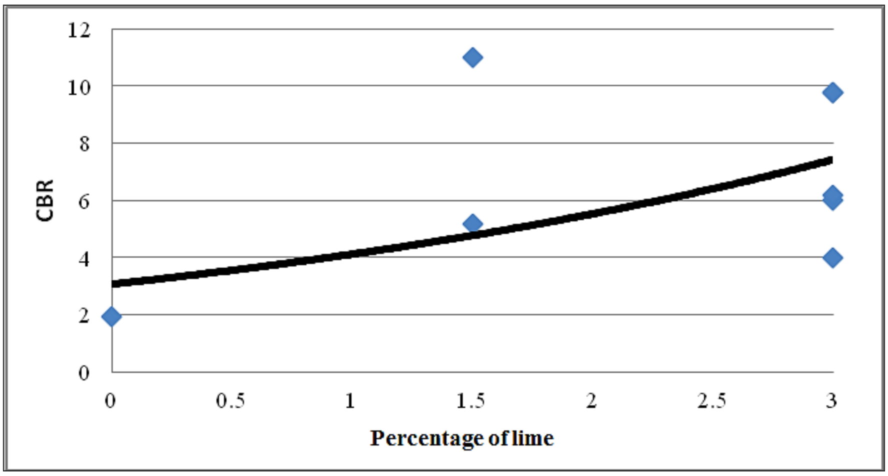

Figure 10. CBR variation with different lime percentages

10.2. Stabilization with Cement

Similar to that was done with lime, was also performed with cement and the samples stabilized with cement were made in molds of 15 cm diameter and 11.8 cm height with 1.5, 3 and 5% cement and minimum 95% compaction in the laboratory and were cured in the accelerated state . The summary of these tests results is shown in Figure 11.

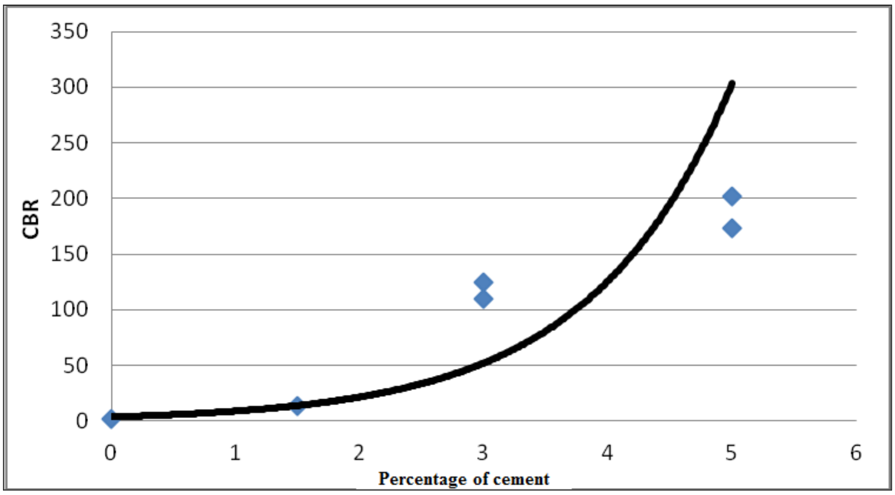

Figure 11. CBR variation with different cement percentages

11. Results of the Uniaxial Tests Performed on the Stabilized Samples (Sampling from Location B)

The stabilized samples with 15cm diameter and 11.8cm height and 1.5, 3 and 5% lime and minimum 95% compaction were produced in the laboratory and kept in plastic at the laboratory temperature for 7 days and then were tested. A sample was prepared as accelerated one with 3% lime and was cured in the oven at 50 Celsius degrees for 48 hours. Then for saturation they were laid in water for minimum 96 hours and tested. The summary of these tests results is shown in Figure 12.

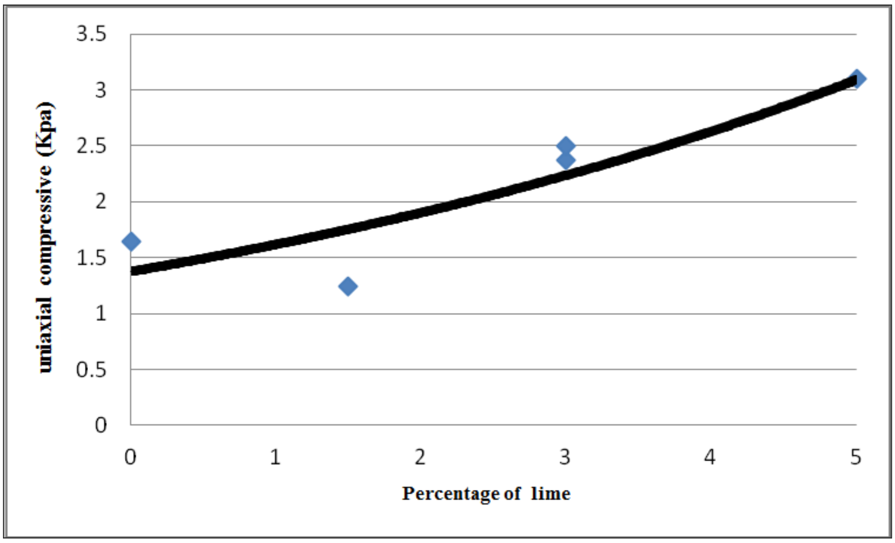

Figure 12. Diagram of the uniaxial compressive strength with different lime percentages

11.1. Results of the Performed Tests after Filling the Layers

In this research the results corresponding to 6 fill layers have been investigated. The materials were produced from the excavated soil of Energy tunnel. The existing layers for stabilization with cement and lime were prepared as shown in Figures 13 and 14, then the materials assigned for stabilization have been spread.

Figure 13. Cement distribution and stabilization with WR4500 equipment

Figure 14. Compaction with sheepsfoot roller

12. Used Percentages for Stabilizing the Fill Layers

With respect to the performed tests in stages A, B and C, percentages of the used materials for stabilizing different layers are determined and given in Table 4. The performed tests for stabilizing the fill layers are shown in Table 5.

Table 4. Percentages of the stabilized materials in fill layers

Layer number	Percentage of lime consumed (%)	Percentage of cement consumption (%)
1	1.7	0.7
2	1.7	0.7
3	1.7	0.7
4	1.7	0.7
5	1.7	0.7
6	2	1

Table 5. Performed tests for stabilizing the fill layers

Layer	Grading	Density	ITS	CBR	UCS
1	3	6	----	12	10
2	5	6	----	4	4
3	2	7	2	2	2
4	4	6	----	4	4
5	4	6	----	4	4
6	4	7	2	4	3
7	----	6	----	----	----

12.1. Stabilizing the First Layer

For stabilizing the first layer, lime is distributed over the bed, then WR4500 equipment moves over the bed and mixes soil and lime. The results of this test are given in Figures 15-17. For stabilizing the first layer use has been made of 0.7% weight percentage of the compacted soil and cement and 1.7 weight percentage of the compacted soil with lime. A number of samples were prepared using lime only and a number of samples were prepared using the mixture of cement and lime.

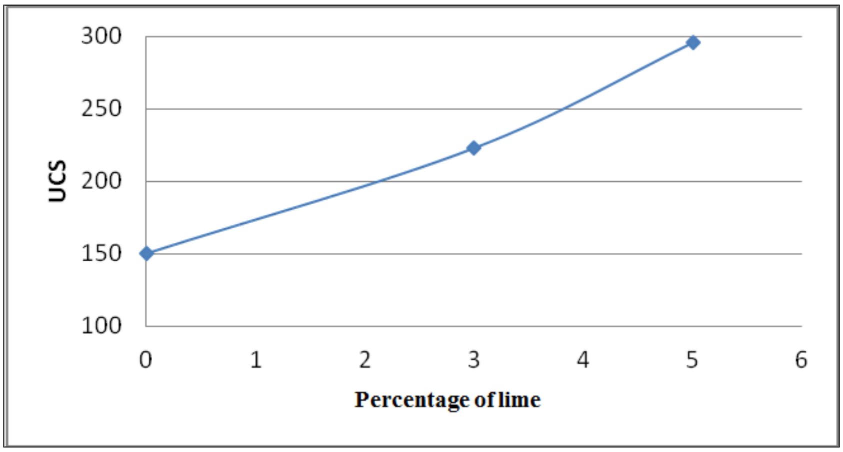

Figure 15. Variation of the compressive strength with different lime percentages

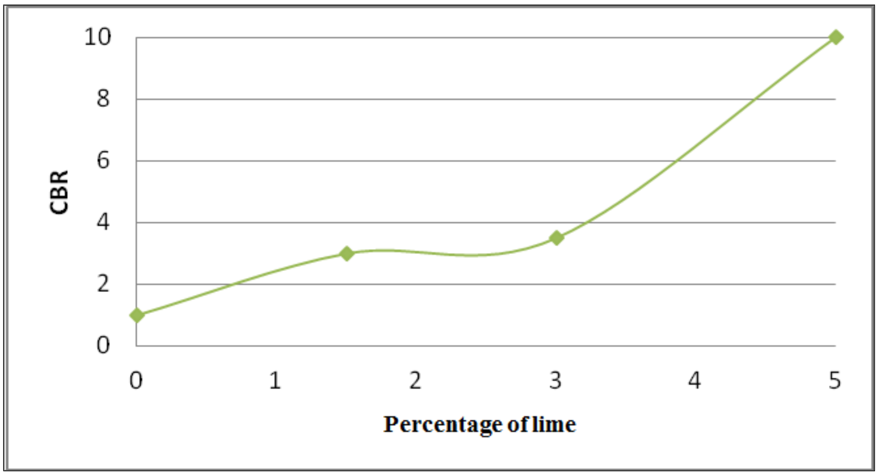

Figure 16. Variation of CBR with different lime percentages

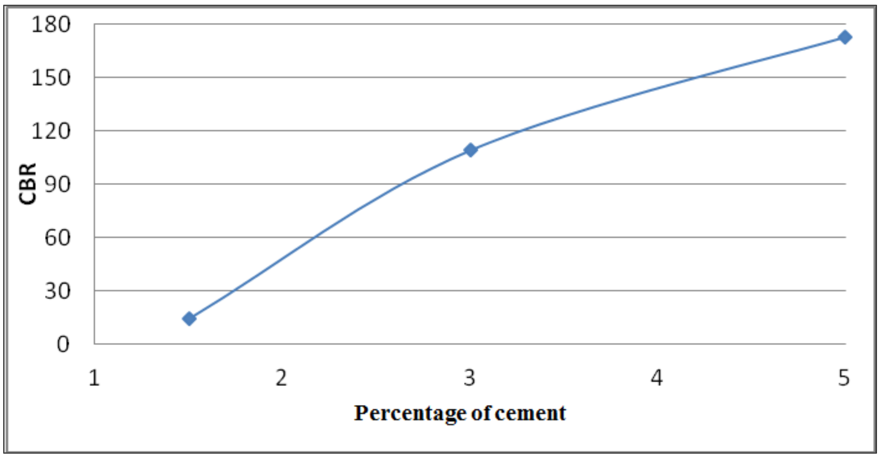

Figure 17. Variation of CBR with different cement percentages

13. Results of the in-situ CBR Test

To assess the strength of materials stabilized by lime and cement at the site and at layer 6, the in-situ CBR test is utilized. Considering Figures 15-17, it is observed that the results are acceptable. The CBR values at the selected points are given in Table 6.

Table 6. CBR results at layer 6

Layer	Distance (KM)	CBR
sixth	740	70
sixth	777	65

14. Sampling for the Uniaxial Test

With respect to Figure 18, for preparing the samples use has been made of the sampling equipment. For each sample, 3 attempts are made and none of the samples have been complete but have broken within the tube.

Figure 18. Sampling procedure for the uniaxial test

15. Plate Load Test (PLT)

The plate loading test over the soil and soft stones, its application, procedure, and interpretation includes the way it is performed, determination of the findings and also their interpretation. The test is performed with different arrangements and configurations. Loading is done in various ways, where for each case the corresponding limitations and interpretation aspects should be taken in to account. This test is performed to obtain the following parameters:

- Determination of the ultimate strength.
- Determination of the deformation parameters (modulus of elasticity and soil bed reaction coefficient).
- Settlement estimation.

Considering Table 7, one could observe the results of performed plate loading test. The procedure for loading is shown in Figure 19.

Table 7. Maximum stress, modulus of elasticity and maximum settlement of the layers for the plate loading test

Layer number	Distance (KM)	Maximum stress	Modulus of elasticity (kg/cm^2)	Maximum of settlement (mm)
5	740	5	1868	0.42
5	777	5	1655	0.39
6	740	5	3736	0.17
6	777	5	2145	0.19

Figure 19. Loading procedure

16. Conclusion

The large amounts of soil and construction wastes and their irrelevant disposal has created environmental and sanitary issues and created inappropriate view. Therefore recycling of the soil and construction wastes has had significant impact on reducing the environmental pollutions and decreasing the construction related costs. A large portion of Sharestan Razavi Blvd. in Mashhad City is comprised of old buildings which after their demolition the area is covered with backfilled soil and materials remained from their demolition. Hence in this article, to avoid environmental pollution, reducing the costs and maximizing use of the materials, the feasibility studies and technical assessment concerning application of the existing materials were conducted using the stabilization method and the results were presented. For stabilizing the existing materials the two materials of cement and lime were incorporated. Ultimately, with respect to the results of stabilizing of materials by cement and lime, the strength (CBR) found for the in- situ stabilized soil yielded a desirable value.

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