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# A Comparative Study of Soil Stabilization Effect and Concrete Strength Development on Rigid Pavement Thickness

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## Abstract

The subgrade soil is the supporting part of the concrete road for transferring the different traffic loads from the road surface. The strength of this soil increases its ability to receive loads, increases the durability of the concrete road, and does not cause structural failure problems. If the soil is weak, it will decrease pavement service life and cause multiple types of failure on the road such as damage to joints, an increase in stresses and deflection, and cracking.

In addition, the soil stabilization process increases the soil's strength and its tolerance to high loads, so the laboratory results showed that the use of 4% of the asphalt emulsion led to improving the gypsum soil properties and increasing the California bearing ratio to 52%.

In the process of designing rigid pavement using the AASHTO design method and depending on concrete properties and subgrade properties before and after stabilization, it was found that alterations in the CBR value within the range of 27-52% and a compressive strength of 30 MPa resulted in a reduction of 7.5% in slab thickness during the design calculations. A reduction of 7.8% in slab thickness was observed upon alteration of the CBR value from a range of 27-52% and a compressive strength of 35 MPa. A reduction of 4.5% in slab thickness was observed with a variation in compressive strength from 30-35 MPa and a CBR value of 27%. A reduction of 4.8% in slab thickness was found with a variation in compressive strength from 30-35 MPa and a CBR value of 52%. Therefore, it was found that the effect of increasing the soil strength on reducing the thickness of the concrete road is greater than the effect of changing the compressive strength of concrete.

**Keyword:** Subgrade soil, soil strength, concrete, rigid pavement

## 1. Introduction

Rigid pavement is a layer of Portland cement concrete positioned on the prepared subgrade or a layer of granular material known as a sub-base. Concrete pavement is typically reinforced with steel bars or mesh to enhance tensile strength and control cracking. Transverse and longitudinal joints connect the isolated panels that make up the structure. Also, it is commonly used on highways, airports, industrial areas, and other high-traffic applications where long-term performance and durability are essential. Its strength, stiffness,

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and resistance to deformation make it a suitable choice for areas with heavy traffic and load requirements.

The subgrade soil for rigid pavement plays a crucial role in the overall performance and durability of the pavement. It must be able to support concrete slabs to prevent cracking, settling, and other damage from occurring. The soil should have a consistent, stable subgrade to support the pavement.

Aziz and Abdulsattar [1] selected a soil sample from a single site in the Al-Nda'a quarter, which is located west of the City of Al-Najaf. As part of the sampling process, soil samples were taken from a depth of three to four meters below the natural ground surface and had c and $\phi$ values of 2 kPa and 32°, respectively, and a gypsum content of 32 percent.

Generally, the west and central areas of Al-Najaf City have soil classified as poorly graded sand (SP) by the Unified Soil Classification System (USCS) and A-1-b by the AASHTO classification, whereas soil in the east is classified as silty sand (SM) by the USCS and A-2-6 by the AASHTO classification [2].

A soil stabilization process improves the engineering properties of soil for construction and other uses. In this approach, several techniques are used to improve soil strength, stability, and durability. Batra [3] used the Direct Shear Test to determine how cationic bitumen emulsion percentage (0, 2%, 5%, 6%, and 7%) affected soil shear strength. By increasing internal friction and lowering cohesiveness, a 6% bitumen emulsion enhanced the soil shear strength by 65%. Finite element modeling examines maximum dry density and CBR improvements.

Shah and Ahmad [4] showed that by using MS bitumen emulsion in the right way, the California Bearing Ratio (CBR) of subgrades can be greatly improved. The soil emulsion is at its most potent 5.5 hours after mixing. They found that the CBR value increased continuously from Case A to Case D. The experimental results indicate a 50% increase in CBR value over unmodified soil.

The pavement thickness varies from 175 mm to 400 mm depending on traffic, environmental conditions, base types (rigid, semi-rigid, or flexible), slab measurements, and concrete mixture properties. In addition, pavements are generally constructed with mixtures with C30 or C37 strength classes [5] and [6].

Concrete efficiency has a sizable impact on the thickness of the concrete slab as well. However, the integrity of the ground underneath the concrete slab is less significant. If the concrete slab cannot be upgraded, this does not indicate that efforts are not being made to enhance the soil qualities underneath [7].

Vaitkus [8] showed that reducing the concrete pavement's thickness by anywhere between 6 and 39% was possible by changing the concrete's compressive strength from C30/37 to either C40/50, C45/55, or C50/60.

## 2. Research Objective

Rigid pavement design is examined in this study as a function of soil stabilization and concrete compressive strength changes.

## 3. Materials and Testing

In this study, the subgrade soil sample is carried out from the west of Al-Najaf city from 1 m below the natural ground surface that is used for experiment work. This sample is composed of brown and medium-concentration gypsum, which is a dangerous soil condition when it comes to contact with water. Also, an asphalt emulsion (Polycoat RBE) is used to stabilize the soil containing 27% gypsum with different percentages (2, 4, and 6) %. This is the most reliable strategy for halting gypsum decay when the soil is wet. The properties of the soil sample before and after adding asphalt emulsion are shown in Table 1.

Additionally, the major concrete components (cement, fine aggregate, coarse aggregate, and water) with an admixture (Sika 905) are locally equipped and tested according to Iraqi standard specifications. The final product was created by combining the four main components (cement, fine aggregate, coarse aggregate, and water) with an admixture (Sika 905) using mix proportions calculated according to ACI 211, 2009.

Concrete has a compressive strength of 30 to 35 MPa. The mass of the concrete component is displayed in Table 2. along with a combination of its mechanical characteristics (compressive strength, rupture modulus, and elasticity modulus. Concrete component and mechanical tests are shown in plates 1 to 4.

**Table 1. Physical and Mechanical Properties of Subgrade Soil before and after Stabilization [9-15]**

| Properties | Natural soil | Stabilized soil with (Polycoat REB) | | |
|---|---|---|---|---|
| | | 2% | 4% | 6% |
| Void Ratio (e) | 1.58 | 1.03 | 1.01 | 0.92 |
| Specific Gravity | 2.64 | 2.6 | 2.6 | 2.6 |
| Max. Dry Density (gm/cm3) | 1.857 | 1.829 | 1.822 | 1.817 |
| Porosity (n) | 0.61 | 0.51 | 0.5 | 0.48 |
| Permeability (cm/sec) | 0.0245 | 0.0106 | 0.0128 | 0.0209 |
| Ø | 46.58 | 42,3 | 36.1 | 43.5 |
| C (KPa) | 0 | 10.17 | 6.6 | 1.99 |
| %OMC | 15 | 14.68 | 13.64 | 13.04 |
| %CBR | 27 | 43 | 52 | 41 |
| D10 | 0.18% | --------- | --------- | --------- |
| D30 | 0.37% | --------- | --------- | --------- |
| D60 | 1% | --------- | --------- | --------- |
| Cu | 5.56 | --------- | --------- | --------- |
| Cc | 0.76 | --------- | --------- | --------- |
| %Gypsum content | 27.1 | --------- | --------- | --------- |
| % Organic substances | 1.4 | --------- | --------- | --------- |
| %SO4 | 12.6 | --------- | --------- | --------- |

Table 2. Concrete Components Weights and Mechanical Properties [16-19]

| f’c | Cement | Fine Aggregate | Coarse Aggregate | Water | W/C Ratio | % Admixture (SIKA 905) |
|---|---|---|---|---|---|---|
| C30 | 407 | 787 | 1024 | 182 | 0.45 | 0.74 |
| C35 | ٤٦٠ | ٧٤٠ | ١٠٢٤ | ١٨٢ | ٠.4 | 0.7 |

|  | C30 | C35 |
|---|---|---|
| Compressive Strength (MPa) | 31 | 34.7 |
| Modulus of rupture (MPa) | 4.2 | 4.7 |
| Modulus of elasticity (GPa) | 26.7 | 28.4 |

Plate 1. Concrete Components and Admixture

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**Plate 2. Compressive Strength of the Cylindrical Specimen**

**Plate 3. Elasticity Modulus of Cylindrical Specimen**

**Plate 4. Rupture Modulus of Prisms Specimen**

## 4. Results and Discussions

According to the findings of soil tests conducted in a laboratory both before and after stabilization with asphalt emulsion, it was discovered that the optimal ratio of asphalt emulsion is 4% because of improved soil properties and increased CBR value from 27 to 52 percent. The AASHTO design method is used for finding rigid pavement thickness based on several design factors shown in Figure 1. the values of these factors are shown below:

- The equivalent 18 Kips single axle load for the analysis period (50 x$10^6$ )
- Modulus of subgrade reaction (k value) = 145 PCI (natural soil) (40 MN/m3) (27% CBR) and (k value) = 510 PCI (stabilized soil) (141 MN/m3) (52% CBR)
- Recommended load transfer coefficient for jointed plane concrete pavement J= 2.8.
- Water was removed within 1 day, and the quality of drainage is good. Percent of the time pavement structure is exposed to moisture levels approaching saturation (5–25) %. Drainage coefficient Cd= (1.10–1.00). Take Cd= 1.05.
- There are two levels of initial and terminal serviceability: 4.5 and 3, respectively. Design ΔPSI = 4.5 – 3 = 1.5.

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- Range of reliability R% is 80 to 99% for principal arterials. Take R= 90%.
- At the AASHTO road test, the rigid pavement had an overall standard deviation of 0.35.

It was observed that the thickness decreased with an increase in compressive strength and CBR as shown in figures 2 and 3.

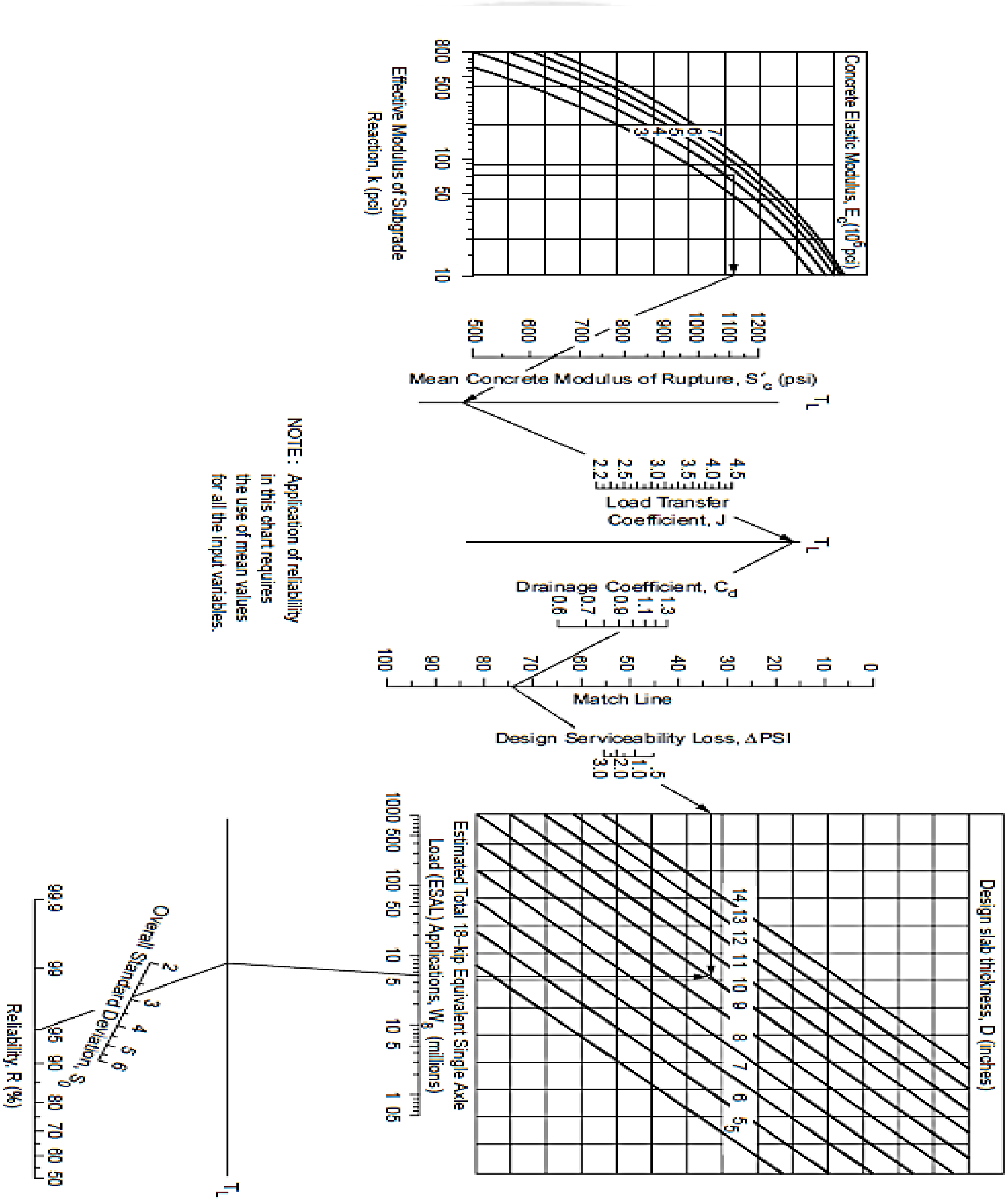

Figure 1. Rigid Pavement Thickness Design Chart [20]

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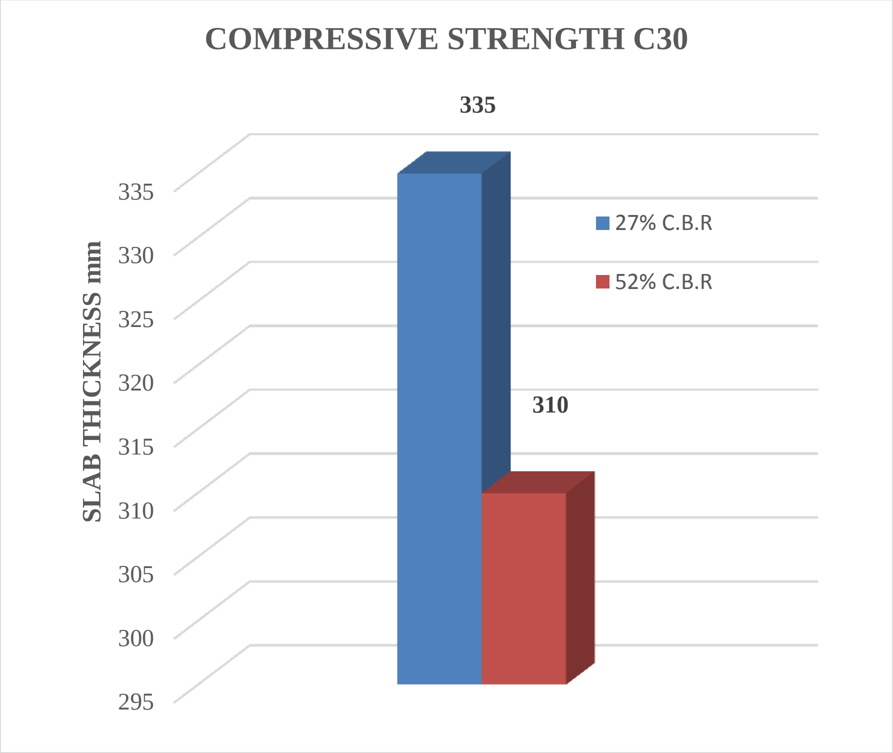

Figure 2. Rigid Pavement Thickness with Compressive Strength C30

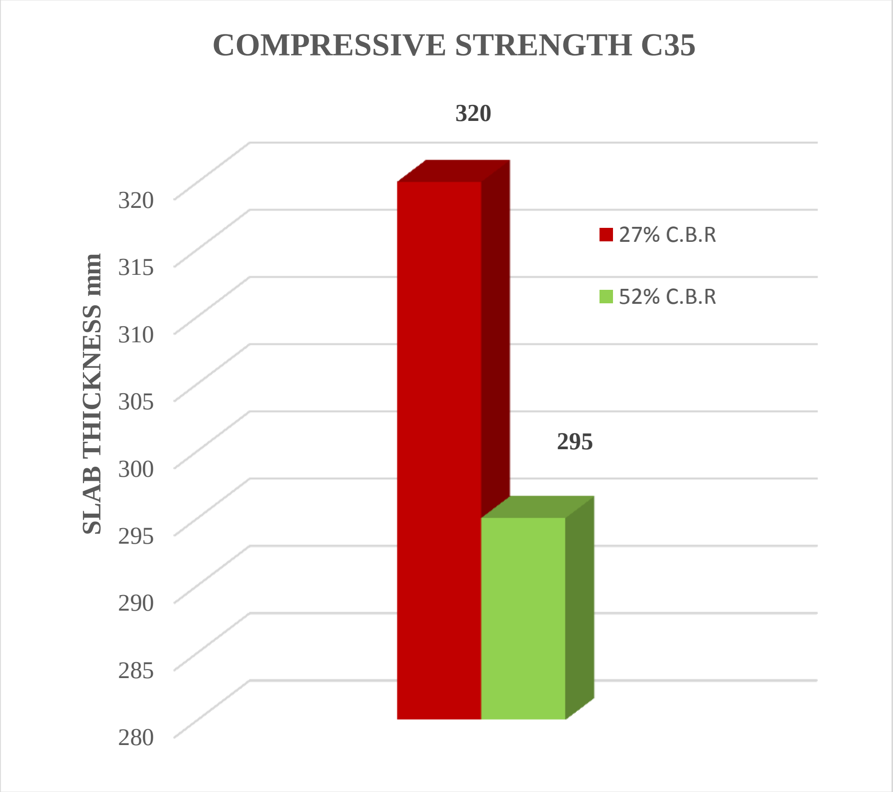

Figure 3. Rigid Pavement Thickness with Compressive Strength C35

## 5. Conclusions

It is concluded that:

1. The best percentage of emulsified asphalt is 4% by the weight of the soil because it is improved the properties of the soil and increases the California bearing ratio endurance by 92%. This is done when mixing the soil with different proportions of the asphalt emulsion with a range (2-6) %.
2. The slab thickness was reduced by 7.5% when the CBR value changed from (27-52) % and compressive strength (30 MPa).
3. The slab thickness was reduced by 7.8% when the CBR value changed from (27-52) % and compressive strength (35 MPa).
4. The slab thickness is reduced by 4.5% when compressive strength changes from (30-35) MPa and the CBR value (27%).
5. The slab thickness is reduced by 4.8% when compressive strength changes from (30-35) MPa and the CBR value is 52%.

## References

[1] Laith J. Aziz, Suhad Abdulsattar. The Bearing Capacity of a Circular Footing on Gypseous Soil Before and After Improvement. Paper Presented at Kufa Journal of Engineering (KJE), Iraq. 2014

[2] T. Sheer Ali and M. Kadum Fakhraldin, ‘Soil Parameters Analysis of Al-Najaf City in Iraq: Case Study’, 2016. [Online]. Available: www.stmjournals.com

[3] S.S. Batra, “Effects of cationic bitumen emulsion on shear strength parameters of the soil”, Int. J. Sci. Technol. Res. 3 (2) (2015).

[4] Khalid Akbar Shah and Dr. Esar Ahmad, “A Study on Alluvial Soil Stabilization using Bitumen Emulsion”, International Journal of Engineering Research & Technology (IJERT), Vol. 9 Issue 06, June-2020. Available: http://www.ijert.org

[5] Nasief, G.H.; Whited, G.C.; Loh, W.-Y. Wisconsin Method for Probing Portland Cement Concrete Pavement for Thickness. Transp. Res. Rec. J. Transp. Res. Board 2011, 2228, 99–107

[6] Mu, F.; Mack, J.W.; Rodden, R.A. Review of National and State-Level Calibrations of AASHTO Ware Pavement ME Design for New Jointed Plain Concrete Pavement. Int. J. Pavement Eng. 2018, 19, 825–831.

[7] I. M. Ramadan, Z. S. El-Din Hussein, and O. M. Mohamady, “EFFECT OF SOIL STRENGTHENING ON RIGID PAVEMENT THICKNESS”, Journal Of Al Azhar University Engineering Sector, Vol. 13, No. 46, January 2018, 46-56.

[8] A. Vaitkus, J. Gražulyt, O. Šernas, M. K.ˇcius, and R. Mickeviˇ, “Concrete Modular Pavement Structures with Optimized Thickness Based on Characteristics of High-Performance Concrete Mixtures with Fibers and Silica Fume”, Materials 2021, 14, 3423. https://doi.org/10.3390/ma14123423

[9] ASTM D422-63. Standard Test Method for Particle Size-Analysis of Soils. 2007.

[10] ASTM D854-05. Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer. 2014

[11] ASTM D698. Standard Test Methods for Laboratory Compaction Characteristic of Soil Using Standard Effort. 2012.

[12] ASTM D2216. Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. 2010

[13] ASTM D1883. California Bearing Ratio (CBR) of Laboratory-Compacted Soils. 2007.

[14] ASTM D2974. Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils. 2014.

[15] BS 1377: Part 3: Clause 5. Sulphate Content of Soil and Groundwater. 1990.

[16] ACI 211, 2009. Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.

[17] ASTM C39. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. 2017

[18] ASTM C78. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).2016.

[19] ASTM C469. Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression. 2014.

[20] American Association of State Highway and Transportation Officials (AASHTO), "AASHTO Guide for Design of Pavement Structures" (1993).

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# دراسة مقارنة لتأثير تثبيت التربة وتطوير قوة الخرسانة على سمك الرصيف الصلب

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## الخلاصة

تعتبر التربة الطبيعية هي الجزء السفلي الداعم للطريق الخرساني عند انتقال الأحمال المرورية المختلفة من سطح الطريق اليها فعندما تزيد قوة التربة فان قدرتها على استقبال الأحمال تزداد وبذلك تزيد من متانة الطريق الخرساني وديمومته وعدم التسبب بالمشاكل الإنشائية.

اما إذا كانت التربة ضعيفة، فسوف يؤدي ذلك إلى نقصان في العمر الخدمي للطريق ويسبب أنواعًا متعددة من الفشل مثل تلف المفاصل وزيادة الاجهادات والانحراف والتصدع.

بالإضافة إلى ذلك، فإن عملية تثبيت التربة تزيد من قوة التربة وتحملها للأحمال العالية، حيث أظهرت النتائج المختبرية أن استخدام ٤٪ من المستحلب الأسفلتي أدى إلى تحسين خصائص التربة الجبسية وزيادة نسبة تحمل كاليفورنيا إلى ٥٢٪.

ان عملية تصميم الطريق الخرساني باستخدام طريقة تصميم AASHTO واعتمادًا على خصائص الخرسانة وخصائص التربة قبل التثبيت وبعده، وجد أنه أثناء الحسابات التصميمية عند تغير في قيمة CBR في حدود ٢٧-٥٢ ٪ وقوة انضغاط الخرسانة ٣٠ ميجا باسكال نتجت في تقليل سمك الطريق بنسبة ٧.٥٪. لوحظ كذلك انخفاض بنسبة ٧.٨٪ في سمك الطرق عند تغيير قيمة CBR من نطاق ٢٧-٥٢٪ وقوة ضغط تبلغ ٣٥ ميجا باسكال. لوحظ ايضاً انخفاض بنسبة ٤.٥٪ في سمك الطريق مع تباين في مقاومة الانضغاط من ٣٠-٣٥ ميجا باسكال وقيمة CBR تبلغ ٢٧٪. بالإضافة الى انخفاض بنسبة ٤.٨٪ في السمك مع تباين في مقاومة الانضغاط من ٣٠-٣٥ ميجا باسكال وقيمة CBR تبلغ ٥٢٪، لذلك نجد أن تأثير زيادة مقاومة التربة في تقليل سمك الطريق الخرساني أكبر من تأثير تغيير مقاومة الانضغاط للخرسانة.

**الكلمات الدالة:** التربة الطبيعية، قوة التربة، الخرسانة، الرصيف الصلب.