Using Geotextile to Reduce the Required Thickness of Sub Base Layer of the Road and Improvement in CBR Value

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Abstract: Soil fabrics (geotextiles) are a permeable textile structural composition, and are mainly use in civil engineering applications associated with soil, rocks, or water. The American specifications (ASTM-D1316) indicated in the definition of this type of fabrics that they are use in some installations for civil and structural engineering, as the traffic increases day by day, many road related problems happen. Due to the heavy volume and heavy traffic the roads were damage very early, to avoid such a situation, we can use the geotextile. Geotextiles can be roughly in to two-type woven and nonwoven, in this research, non-woven (geotextile-50 pressed) was use in the work. The effect of geotextile sheets on improving the load-settlement characters of five-layered soil (three-layer clay, two-layer recycle concrete aggregate); moreover, the use of geotextiles has been study to reduce the required thickness of the sub-base layer of the road. Given the widespread use of bearing testing rate in the projects of road construction, it has used this test in this research, it was a test California bearing ratio (CBR) on the soil of five layers including the rubble of recycled concrete layer recycled (RCA) in the top (sub base) ) and the clay soil place bottom(subgrade)

These tests were conduct different the situations, including the use of test geotextile and test not use geotextile. In this research, the performance of nonwoven geotextiles, interconnect between the soft subgrade and the sub-base of the recycle of the recycle concrete aggregate (RCA) in the flexible paving system was good as the Geotextiles improve and increase the CBR value about (20%) of the road layers as well as the geotextile worked on reduce permeability about (50%).

Geotextile also worked to separate or (isolate) two materials that are not alike, such as two soil layers with different properties, such as separating the subgrade layer from the subbase layer.

Keywords: geotextiles, woven, nonwoven, RCA, California bearing ratio,

1. Introduction
The term geotextile is use to denote fabrics that are used in all types of civil and construction engineering for lining the soil, making insulators, making insulators, reinforcing road layers and to prevent cracking, deformation, and preserving them from various ground factors, and it includes the fabrics used in lining the sides of rivers, tributaries and seas to protect.
Current pavement construction and repair strategies depend heavily on geotextiles. The paper gives an overview of existing geotextile developments and highlights the roles geotextiles play in improving the efficiency and expanding the service life of paved roads, with a focus on transportation applications. [5]. Geotextiles have proved to be one of the most adaptable and cost-effective field improvement products available. They are now use in almost every aspect of civil, geotechnical, environmental, maritime, and hydraulic engineering. [1]. Mechanical stabilization with dense granular layers or geosynthetics and an aggregate sub base has the ability to strengthen the subgrade's strength over time; however, this is seldom included in the pavement section's construction, and the geosynthetics are not responsible for any increase in structural reinforcement [2]. Geo-grid stabilization given between the subbase courses, subgrade soil carries the shear stress produced by vehicular loads, reducing the load transmitted to the subgrade and volume changes caused by swelling of the subgrade soil. [12]. the findings show that the water permeability coefficients of the tested nonwoven geotextiles decrease significantly after artificial clogging and under cyclic water flow [16]. For four layers of geotextile pads, the CBR values of geotextile-reinforced soils have decreased by 70% [17]. The road's usable sub-grade soil is modify by adding geotextile content in various percentages, such as 1%, 2%, 2.5 percent, and 3 percent, respectively [21]. The use of woven and nonwoven Geotextiles improves the value of the reinforcing ratio calculated using the CBR strength test. [3], they discovered that adding a geotextile layer to reinforced granular soils raises the CBR values [22]. The experimental results show that the existence of geotextiles improves the soil's CBR value, implying that geotextiles can be used as a modernized method of improving road construction on weak soils and reducing pavement layer thickness [4]. Models reinforced with coir geotextiles increase kaolinite bearing capability, and the change starts beyond 10-12 mm deformation [6]. As a result, the addition of geotextiles improves the efficiency of the unpaved lane. It is obvious that the utilization of geotextiles increases more at greater depths of penetration as more layers of geotextiles are used [7]. The findings reveal that the strengthened specimen has a higher compression resistance than the unreinforced soil sample. By the subbase thickness, the impact of geosynthetics inclusion is reduced [8].The incorporation of NW geotextile materials into soils increases CBR and thereby soil strength. It means that geotextile-reinforced soils will outperform unreinforced soils in different earthen systems and will improve soil load carrying capability. [9] The main applications of geotextiles, as seen in (Figure 1) include road building, erosion control, and drainage systems [10].

![Figure 1](image1.png)

**Figure 1.** Market share of global geotextiles by application, 2019 (percentage).[10] (Figure 2) shows a comparison between the way that were used where geotextile and roads that were not used geotextile, roads used were effective geotextile not affected by weather factors and loads while not used where the failure appeared.
2. Function of Geotextiles

A geotextile has several functions among them:

2.1. Geotextiles Used in Separation

Geotextiles are used to separate or (isolate) two different materials, such as two soil layers with different properties, such as paving material and soil. The purpose of the separation process is to maintain or improve the safety and performance of the two layers and prevent them from mixing, since the geotextile can prevent soil components from migrating and mixing with the coarse stone layer, the geotextile can ensure that the coarse stone layer maintains its load-bearing capacity.

2.2. Geotextiles Used Reinforcement and Stabilization

Geotextiles are considered to have bearing capacity or with high tensile strength while soils in general are considered low stress materials but with high compressive strength at the same time. Therefore, geotextiles are the ideal material for use in increasing the efficiency of the soil and thus in increasing the stability of the structural composition. To protect the soil from collapse, it demonstrates the use of geotextiles in the areas of soil consolidation and stabilization.

2.3. Geotextiles Used Filtration

The balance between the geotextile and the soil system can maintain sufficient liquid flow and limited soil loss on the entire surface of the geotextile. Porosity and permeability are the main characteristics of geotextiles involved in permeability, the use of a geotextile in a sidewalk edge sewer, as shown in the figure below, is a popular application to demonstrate the filtration function.

2.4. Geotextiles Used Drainage

The function of draining geotextiles involves fluid passing through the flat surface of the fabric without losing soil. The geotextile used for the drain function must be thick for the fluid passage process to be adequately efficient.

![Figure 2. Comparison between the pavement with or without geotextile [10]](image)
2.5. Geotextiles Used Waterproofing

Geotextiles can act as waterproof when dipped in bitumen or polymeric sealing materials, and after this dipping process, the permeability of the fabric to water and steam decreases in both the horizontal and vertical direction of the fabric.

![Geotextile Function Diagram](image)

**Figure 3.** Function of geotextile [11]

3. Materials Used

3.1 Clay use

The use of a sample of clay obtained from Nergal area, which is situate on the city's eastern outskirts Mosul. The clay was brown, and they were groups as (A-2-6) According to AASHTO soil classification system, the soil is organic silty clay with low plasticity According to unified soil classification,

As a result, the soil's properties have been determined and are present (Table 1).

| Data                          | Value  | specifications                  |
|-------------------------------|--------|---------------------------------|
| Specific Gravity              | 2.6    | ASTM D 854                      |
| Liquid Limit (%)              | 39     | AASHTO T-90 & ASTM D - 4218     |
| Plastic Limit (%)             | 24     | AASHTO T-90 & ASTM D-4318       |
| Shrinkage limit (%)           | 5      | ASTM D- 4943                    |
| Plasticity Index (%)          | 15     | AASHTO T-90                     |
| Organic matte (%)             | 8      | B.S-EN1744/2009&ASTM-40         |
| Soluble salts Test (%)        | 1.3    | -                               |
| Amount of gypsum (%)          | 10.6   | -                               |
| Clay size (%)                 | 56     | ASTM D-422                      |
| Optimum Moisture Content (%)  | 15.9   | ASTM D1557-2004                 |
| Maximum Dry Density (g/cm3)   | 1.7    | AASHTO T-180                    |
| Un soaked CBR (%)             | 54     | AASHTO T-193, ASTM D 1883-05    |
3.2. Recycle concrete Aggregate

Recycle aggregate was obtained from the rubble of demolished buildings in the city of Mosul.

In addition, according to United Nations statistics, there are more than 10 million tons of rubble in the city of Mosul, the capital of Nineveh Governorate, and because of this for a large number, this research was conducted to find out the suitability of this rubble in the design of road layers after testing it (see Table 2).

Table 2. Test results for RCA and natural aggregate

| The data                                      | Value     | Specification             |
|-----------------------------------------------|-----------|---------------------------|
| Constant head permeability                    | 1.727*10^-3 | ASTM D -2434              |
| Plastic limit                                 | NON       | AASHTO T-90 & ASTM D – 4318. |
| Liquid limit                                  | NON       | AASHTO T-90 & ASTM D -4218 |
| Shrinkage limit                               | NON       | AASHTO T-90 & ASTM D -4943 |
| Specific gravity of fine aggregate (RCA)      | 2.55      | AASHTO T-84 & ASTM, C 127- C 128 |
| Specific gravity of coarse aggregate (RCA)    | 2.38      | AASHTO T-85 & ASTM, C 127- C 128 |
| Absorption of fine aggregate (RCA) %          | 6.39      | BS -EN -1097- 6:2000. &ASTM - C 127] |
| Absorption of coarse aggregate (RCA) %        | 1.68      | BS -EN -1097- 6:2000 & ASTM - C 128 |
| Specific gravity of natural fine aggregates   | 2.66      | AASHTO T- ASTM, C 12784 & - C 128 |
| Specific gravity of natural coarse aggregates | 2.67      | AASHTO T-84 & ASTM, C 127- C 128 |
| Absorption of natural fine aggregates %       | 2.06      | BS -EN -1097- 6:2000 & ASTM - C 127 |
| Absorption of natural coarse aggregates %     | 0.67      | BS -EN -1097- 6:2000 & ASTM - C 128 |
| Soundness of fine aggregate (RCA) in sodium sulphate % | 2.9 | ASTM C88/C88M – 18 - AASHTO T 104. |
| Soundness of coarse aggregate (RCA) in sodium sulphate % | 0.85 | ASTM C88/C88M – 18 - AASHTO T 104. |
| Soundness of fine aggregate (RCA) in magnesium sulphate % | 2.6 | ASTM C88/C88M – 18 - AASHTO T 104. |
Soundness of coarse aggregate (RCA) in magnesium sulphate % 0.68 ASTM C88/C88M – 18 - AASHTO T 104.

Soundness of natural fine aggregates in sodium sulphate % 3.6 ASTM C88/C88M – 18 - AASHTO T 104.

Soundness of natural coarse aggregates in sodium sulphate % 0.6 ASTM C88/C88M – 18 - AASHTO T 104.

Soundness of natural fine aggregates in magnesium sulphate % 2.7 ASTM C88/C88M – 18 - AASHTO T 104.

Soundness of natural coarse aggregate in magnesium sulphate % 0.64 ASTM C88/C88M – 18 - AASHTO T 104.

Los Angeles test (RCA) % 29.3 ASTM C 131- 06

### Table 3

| Properties                | Value | specification |
|---------------------------|-------|---------------|
| Weight                    | 48 gm./m² |               |
| Tensile Strength          | 50 N  | ASTM -D 4632  |
| Thickness                 | 0.58 mm |               |
| Puncture strength         | 275 N  | ASTM-D 751    |
| Roll Dimension            | 1.06X100m | _            |
| Dynamic puncture.         | 8mm   |               |
| Permeability              | 7.19 * 10⁶ | ASTM D 4491  |

**3.3. Geotextile material**

Geotextile material in this studied is a nonwoven made of staple fibers, mechanically bonded by a needle punching process to produce a dimensionally stable network. (See figure 4). The properties of the geotextile are given in (table 3).

![Figure 4](image-url)
4. Specimen Preparation and Test Procedure

Specimens with specify amounts of soil added to the crushed concrete waste aggregates samples were prepare by mixing. The percentage of clay added to type A is (5%, 6.4%, 7.3%, 8.7%) and type B (10%, 12.6%, 14.3%, 16.6%) this is the sub base layer (top layer) and used only clay. This is subgrade (bottom layer) with the use of geotextile in different layers and without use geotextile, this is indicating in the figure (5).

![Figure 5. Simple sketches of specimens with geotextile sheets placed between soil layers and without geotextile.](image)

5. Procedure for the CBR Test

As shown in Figure 6, the subgrade soil (clay) was compacted in the CBR mold to its full dry density at the optimum moisture content determined by the Standard Proctor test, and the remaining (50mm) with well graded RCA, CBR analyses were conducted separately for soil (clay)-nonwoven geotextile-aggregate (RCA) structures using (50mm) plunger.

![Figure 6. (a, b, c ) A diagram and illustration of the soil aggregate in the CBR mold.](image)

6. Result and discussion

6.1. Sieve analyses

Sieve analyses for the recycle concrete aggregate Gradation test (-particles size distribution) According to Iraqi specifications for roads and bridges and amendments for 1999 -2003- (SROP/R6)
Table 4. Gradation test type A

| Sieve No. | Specification limits | Mid specification | Partial Retained weight | Cumulative Retained weight | Retained % | Passing % |
|-----------|----------------------|-------------------|--------------------------|---------------------------|------------|-----------|
| 1"        | 75-95                | 85                | 0.75                     | 0.75                      | 15         | 85        |
| 3/8"      | 40-75                | 57.5              | 1.375                    | 2.125                     | 42.5       | 57.5      |
| No.4      | 30-60                | 45                | 0.625                    | 2.75                      | 55         | 45        |
| No.8      | 21-47                | 34                | 0.55                     | 3.3                       | 66         | 34        |
| No.50     | 14-28                | 21                | 0.65                     | 3.95                      | 79         | 21        |
| No.200    | 5-15                 | 10                | 0.55                     | 4.5                       | 90         | 10        |
| PAN       | –                    | –                 | 0.5                      | 5                         | 100        | 0         |

Table 5. Gradation test type B

| Sieve No. | Specification limits | Mid specification | Partial Retained weight | Cumulative Retained weight | Retained % | Passing % |
|-----------|----------------------|-------------------|--------------------------|---------------------------|------------|-----------|
| 1"        | –                    | –                 | 0                        | 0                         | 0          | 100       |
| 3/8"      | 30-65                | 47.5              | 5.25                     | 5.25                      | 52.5       | 47.5      |
| No.4      | 25-55                | 40                | 0.75                     | 6.0                       | 60         | 40        |
| No.8      | 16-42                | 29                | 1.1                      | 7.1                       | 71         | 29        |
| No.50     | 7-18                 | 12.5              | 1.65                     | 8.75                      | 87.5       | 12.5      |
| No.200    | 2-8                  | 5                 | 0.75                     | 9.5                       | 95.0       | 5         |
| PAN       | –                    | –                 | 0.5                      | 10                        | 100        | 0         |

Figure 7. Sieve analyses for A

![Particle Size Distribution A](image-url)
Figure 8. Sieve analyses for B

Table 6. Shows the resulting results from grading graphics (A) and (B).

| The data  | D10 | D30 | D60 | Cc  | Cu      |
|-----------|-----|-----|-----|-----|---------|
| Type A    | 0.14| 2.4 | 12.1| 3.40| 86.428  |
| Type B    | 0.085| 1.0 | 10.0| 1.176| 117.64 |

6.2. California Bearing Ratio (CBR) test:

The test was accordance with AASHTO T-193, ASTM D 1883-05. The Results (CBR) were for a type with use the geotextile and without geotextile (A) and type (B) shown in a table (6)

Table 7. The value of CBR without geotextiles

| The data                      | Added clay (10%) | Added clay (12.6%) | Added clay (14.3%) | Added clay (16.6%) |
|-------------------------------|------------------|--------------------|--------------------|--------------------|
| CBR test type B without geotextile | Soaking          | 53.9 %             | 111.7 %            | 156 %              | 97.4 %             |
|                               | Un soaking       | 50.0 %             | 115.8 %            | 120 %              | 134.6 %            |
| CBR test type A without geotextile | Soaking          | 56 %               | 52.4 %             | 58 %               | 57.5 %             |
|                               | Un soaking       | 45.8 %             | 56.5 %             | 56.6 %             | 55.5 %             |
Figure 9. CBR value for RCA type B

Figure 10. CBR value for RCA type A
Table 8. CBR value with use geotextile for different layer type B

| The data                      | % CBR (2.5mm) | % CBR (5.0mm) | The details |
|-------------------------------|---------------|---------------|-------------|
| 60 % clay + 40 % RCA Without geotextile | 134           | 104           | RCA clay    |
| 60 % clay + 40 % RCA With geotextile     | 155.2         | 118.2         | RCA clay    |
| 50 % clay + 50 % RCA      | 168.2         | 147.3         | RCA clay    |
| With geotextile               |               |               |             |
| 60 % clay +40 % RCA With geotextile | 96.7          | 95.6          | RCA clay clay clay |
| 60 % clay + 40 % RCA With geotextile | 126.8         | 121.6         | RCA clay clay clay |

Table 9. CBR value with use geotextile for different layer type A

| The data                      | CBR (2.5mm) % | CBR (5.0mm) % | The details |
|-------------------------------|---------------|---------------|-------------|
| 60 % clay + 40 % RCA Without geotextile | 43.7          | 36.6          | RCA clay    |
| 60 % clay + 40 % RCA With geotextile     | 62            | 57.2          | RCA clay    |
| 50 % clay + 50 % RCA      | 64.6          | 48.7          | RCA clay    |
| With geotextile               |               |               |             |
7. Conclusions

This study focused on the performance of geotextiles and their effect on the California Bering ratio (CBR) aggregates and soils used in this research and the following was conclude based on the findings of this study:

1. Clay soils with a liquid limit (39%), plastic limit (24%), shrinkage limit (5%), Plasticity Index (15%) specific weight (2.6) and CBR (54%), and these soils are consider of the type (A-2-6) According to AASHTO soil classification system, the soil is organic silty clay with low plasticity. This study is classify as a subgrade layer by the unified soil classification system.

2. Recycled aggregates were used after conducting the sieve analyses test for it according to the Iraqi standard for roads and bridges of the two types (A, B) for the sub base-layer.

3. The geotextiles used are of the non-woven type (50 pressed) where they were Tensile Strength (50N), Thickness (0.58mm), Puncture strength (275 N), and Permeability (7.19*10^-6).

4. The sub-base layer that contains a geotextile is stronger, stiffer, and gives more strength than the sub-base layer that does not contain a geotextile; Geotextiles improve recycle aggregate interlock in road infrastructure stabilization through subbase restraint and base reinforcement applications.

5. In this study, 40% recycled aggregate was used, which represents the sub base layer, and the clay used at 60%, which represents the subgrade layer, with geotextiles placed in different layers it was found that the CBR values are much greater than the standard specifications and thus the thickness of the sub-base layer can be reduced when designing.

6. CBR values that appeared for type B were greater than the CBR values for type (A), due to the difference in the size of the aggregate grains, which had a direct effect on the difference as type A did not contain aggregates of size (1") and contained more fine grains than type (B).

7. The geotextiles improved and increased the CBR value about (20%) of the road layers as well as the geotextiles worked on Reduce permeability about (50%).

8. Through all the tests that were conducted in this study, it was found that when placing a layer of geotextile between the sub-base layer and the sub-grade layer, at 50% for both layers, the highest CBR value was given for both types, A and B.
9. The use of geotextile material to reinforce road layers and position it between the sub-base and subgrade layers would carry the stresses induced by vehicle loads, reducing the loads transported to the sub-base layer and the volume increases caused by the swelling of the subgrade layer's soil.

10. Geotextiles also worked to separate or (isolate) two materials that are not alike, such as two soil layers with different properties, such as separating the subgrade layer from the subbase layer. The purpose of the separation process is to maintain or improve the safety and performance of both layers and prevent their mixing.

11. The load carrying capacity of the pavement system significantly increases for geotextile reinforced subbase stretch compared to unreinforced subbase layer on expansive subgrade soil. This is reflect in the values of failure load, which is greater in reinforced subbase layer model than in unreinforced model.

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