

EFFECT THE SHAPE OF GRAVEL ON IMPROVING CBR AND COMPACTION BEHAVIOUR OF CLAYEY SOIL

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ABSTRACT

Investigating the effect of adding various types and shapes of materials on the behaviour of engineering properties of clayey soil is very important. In this study, various shapes of gravels have been used with different ratios (from 0 to 50% with 10% intervals) to show their effect on improving the mechanical properties of clayey soil. Many tests have been conducted on clayey and clayey-gravel soil mixtures. Modified compaction tests showed that by increasing percentages of gravel, amount of maximum unit weight (MUW) increased and optimum moisture content (OMC) decreased especially when rounded gravel was added. The increasing in amount of MUW of the clayey soil was about 10.32% after adding 50% of rounded gravel and it was about 8.98% after increasing same amount of crushed one. Values of California Bearing Ratio (CBR) increased after adding more amounts of gravel with more extent during adding crushed gravel. The addition of 50% gravel by weight to clayey soil resulted in 101.47% increase in the maximum CBR value for rounded gravel and 198.53% for crushed gravel. The swelling ratio decreased from 4.5% for the clayey soil to 0.2% after adding 40% of rounded gravel while it decreased to 0.56% after adding same ratio of crushed one. After adding 50% of both shapes gravel, a slight change in swelling ratio was appeared by increasing from 0.2% to 0.45% for rounded gravel and from 0.56% to 0.87% for crushed one.

KEYWORDS: *Clayey Soil; Rounded Gravel; Crushed Gravel; Compaction; CBR; Swelling.*

1. INTRODUCTION

The behaviour of fine-grained soil changed when course grained particles are available. This change depends on the degree of interaction between clayey and gravel soil particles (Mitchell & Soga, 2005; Kuerbis et al. 1988; Troncoso & Verdugo, 1985; Lupini et al., 1981 and Kenny, 1977).

Previous researchers (Kakou et al. 2001; Petley 1966) explained that the execution and interpretation of laboratory test results will be easier if there is an understanding of the effect of soil particle shapes. The influence of particle shape on the behaviour of granular soil was also investigated by a group of researchers like Dyskin et al. 2001; Miura et al, 1998; Shimobe & Moroto 1995. Particle shape descriptions which are commonly used by researchers (Cho et al., 2006;

Santamrina & Cho, 2004) include sphericity, roundness, roughness and texture. According to the observations of several studies, each type of particle shape has its individual effect on the engineering properties of soil materials. For example, Cho et al., 2006; de Graff-Johnson et al., 1969 and Santamrina & Cho, 2004 indicated that by increasing the angular particles or decreasing the rounded or spherical particles, the amount of void ratio increased. Moreover, the availability of irregular particles in soil mixtures lead to elevation in stiffness, unit weight and strength while the opposite may occur if platy particles have been increased (Cho et al., 2006; Cubrinovski & Ishihara, 2002; Guimaraes, 2002 Hight et al., 1998).

During constructing subgrade course of highway projects, used materials may contain gravels with different sizes and shapes that get

their strength from particle interlock and internal friction whenever no clay content between gravel grains. While, this contact mechanism of the soil matrix is determined by the amount of clay content.

Clayey soil is utilized in highway construction as filler material provided that it has required engineering properties. Rounded or crushed stone are only used to enhance the strength and stability of subgrade layer although they cost more than natural materials. Adding certain amounts of gravel to clayey soil is important to improve soil admixture materials through providing more strength and durability. Furthermore, Duhok City where the present study was conducted is close to Khazir River which is a good gravel reservoir. This paper investigates the effect of gravel shape, rounded and crushed, as an alternative and beneficial way to improve the mechanical properties, CBR and compaction, of clayey soil. A series of modified compaction and (CBR) tests have been conducted on clayey and clayey- gravel samples. The samples were obtained from Duhok

City and neighboring areas, where geotechnical engineering works have been significantly increased over the last years. To show the influence of both shapes of gravel on the mechanical behaviour of clayey soil, a wide range of additive gravel was used (10 to 50 % with 10% interval).

2. EXPERIMENTAL STUDY

2.1 MATERIALS

The materials used in the tests to form mixtures were Rounded Gravel (RG), Crushed Gravel (CG), clayey soil, and de-aired water. Rounded Gravel was quarried from the banks of Khazir River in Duhok province, Kurdistan Region of Iraq. Crushed Gravel was obtained after crushing big rounded river stone using a special machine. A gradation of the gravel (between 20 and 4.75 mm) is selected to assess its effect on the behaviour of clayey soil and to get relatively uniform specimens for visual classification purposes (Plate 1 and Figure 1).

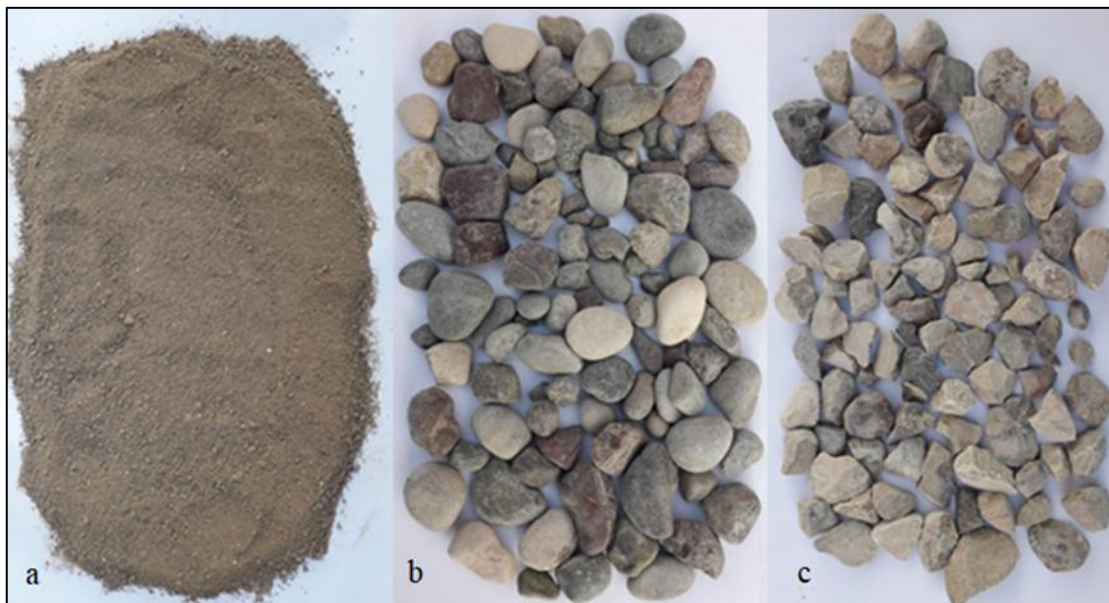


Plate 1: Used clayey and gravel soils, (a) Clayey soil, (b) Rounded gravel, (c) Crushed gravel.

The gravel (rounded and crushed) was classified as GP (Poorly graded Gravel) according to the Unified Soil Classification System. The specific gravity of the gravel was 2.68 for rounded, and was 2.64 for crushed one. The sizes of D₁₀, D₃₀ and D₆₀ are around 8.0, 12.4 and 15.8. Thus, the coefficient of uniformity (C_u) and the coefficient of curvature (C_c) have been

calculated as 1.98 and 1.22, respectively. The internal friction angle (ϕ) of the rounded and crushed gravel was 36° and 38°, respectively. Clay used in the experiment was obtained from Bardarash District, Duhok Province, Kurdistan Region of Iraq. Its plastic limit and liquid limit values were 19% and 38%, respectively. The specific gravity of the clay grains was 2.61. The

internal friction angle (ϕ) and cohesion (c) of the clay were 27° and 21 kPa, respectively.

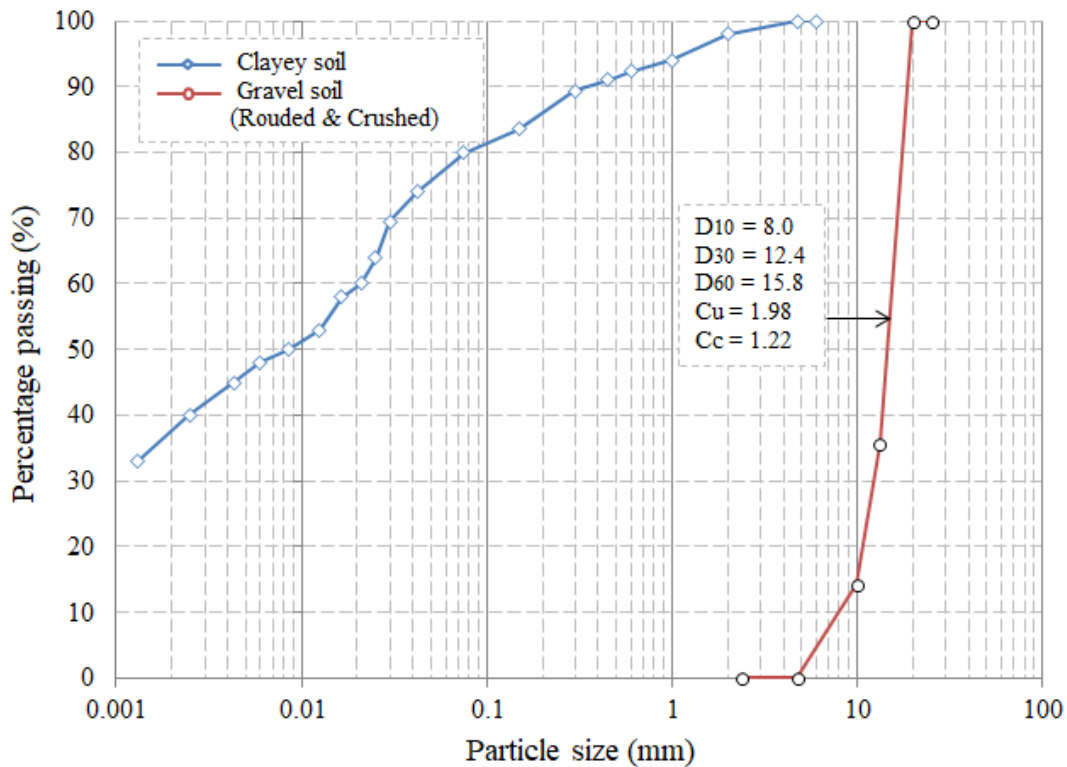


Fig.(1): Particle size distributions for clay and gravels (rounded and crushed) used in the experiment.

2.2 SPECIMEN PREPARATION AND TESTING APPARATUS

To show the relationship between moisture content and unit weight of clayey and clayey-gravel mixtures, laboratory compaction tests were conducted.

A required amount of specimens was prepared for both clayey and clayey-gravel mixtures at modified proctor compaction energy levels to represent field compaction process. The required amount of clayey, gravel of both shapes and water were weighed and then mixed properly to homogenize mixtures. Then the mixtures stored in plastic bags for about 24 hours to get homogenous moisture content. After that, the mixtures were compacted into the metal cylindrical compaction molds in five layers applying modified compaction effort (2700 kN-m/m^3) and then the surfaces of all molds were trimmed out for leveling purpose. Standard molds with a diameter of 152mm and a height of 178mm have been used. Standard specifications of ASTM D1557 were used to show the compaction characteristics of the samples.

The CBR testing apparatus exploited in the study had a 30 kN capacity of proving ring and 0.01mm sensitivity of a dial gauge to read the displacement. After that, CBR results were contrasted against standard test results according to ASTM D1883. Five different ratios of gravel of both shapes at the mixture ratios of 10, 20, 30, 40, and 50% by dry weight of the samples were added to clayey soil. To illustrate CBR variation of clayey and clayey-gravel soils at different amounts of water contents, four to five percentages of water contents were selected by the weight of specimens and then mixed until a uniform mixture obtained.

By applying modifying compaction effort (2700 kN-m/m^3), the mixtures were compacted to the CBR standard metal molds in five layers and then all of the mold surfaces trimmed out for leveling. To prevent losing fine particles during soaking process, filter papers were placed at bottom and top of each sample. A standard surcharge load of 4.5 kg was put over each sample. To determine the amount of swelling of each sample, a dial gauge was put over the samples during the soaking time. Then, the

samples were put into the water tank for 96 hours until being fully saturated and initial measurements of swelling were performed. A final dial gauges readings were observed at the end of soaking period. Later, the samples were taken out from the water tank. Finally, CBR testing apparatus was employed to observe the behaviour of the samples put in the device. CBR values of the specimens were evaluated at penetrations of 2.54mm and 5.08mm using readings taken at every 0.25mm penetration depth.

3 RESULTS AND DISCUSSIONS

3.1 COMPACTION PROPERTIES

Depending on ASTM D1557 standards procedures, the relationship between dry unit weight and water content is drawn for all soil mixtures by applying modify compaction effort. Both shapes of gravel (rounded and crushed) were added to clayey soil. Clayey and gravel materials are widely used during construction road projects. Therefore, it is important to study the compaction behaviour of such materials. The relations of water content and dry unit weight are illustrated in Figures 2 and 3. The amount of maximum dry unit weight of all samples after adding both shapes of gravels to clayey soil was proportionate with gravel contents due to higher specific gravity of gravel particles.

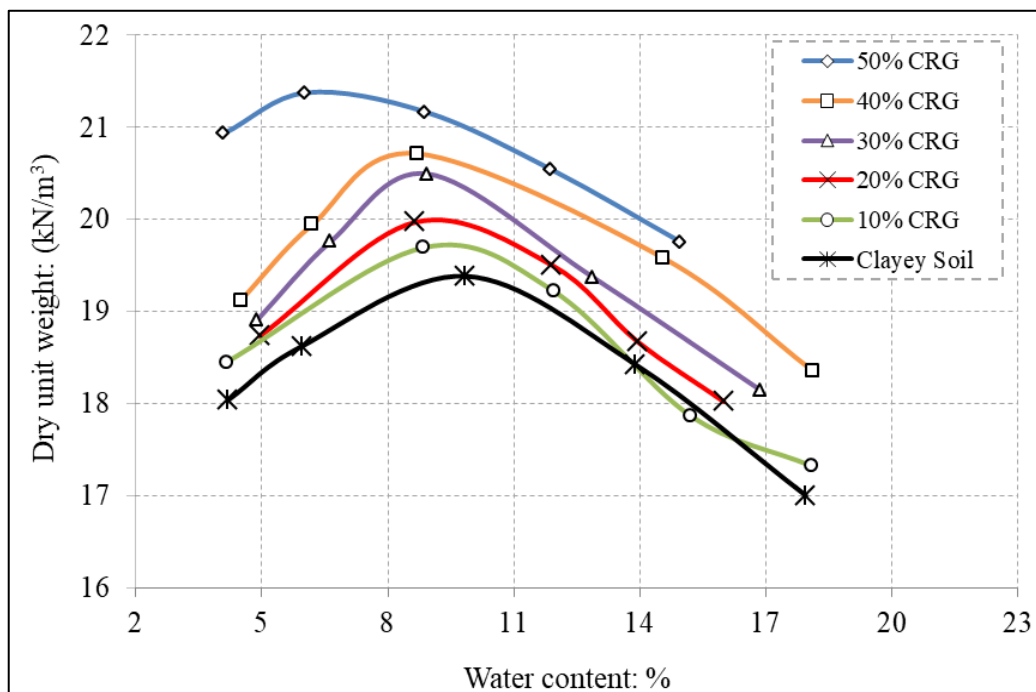


Fig.(2): Compaction curves of the specimens at different mix ratios after adding rounded gravel.

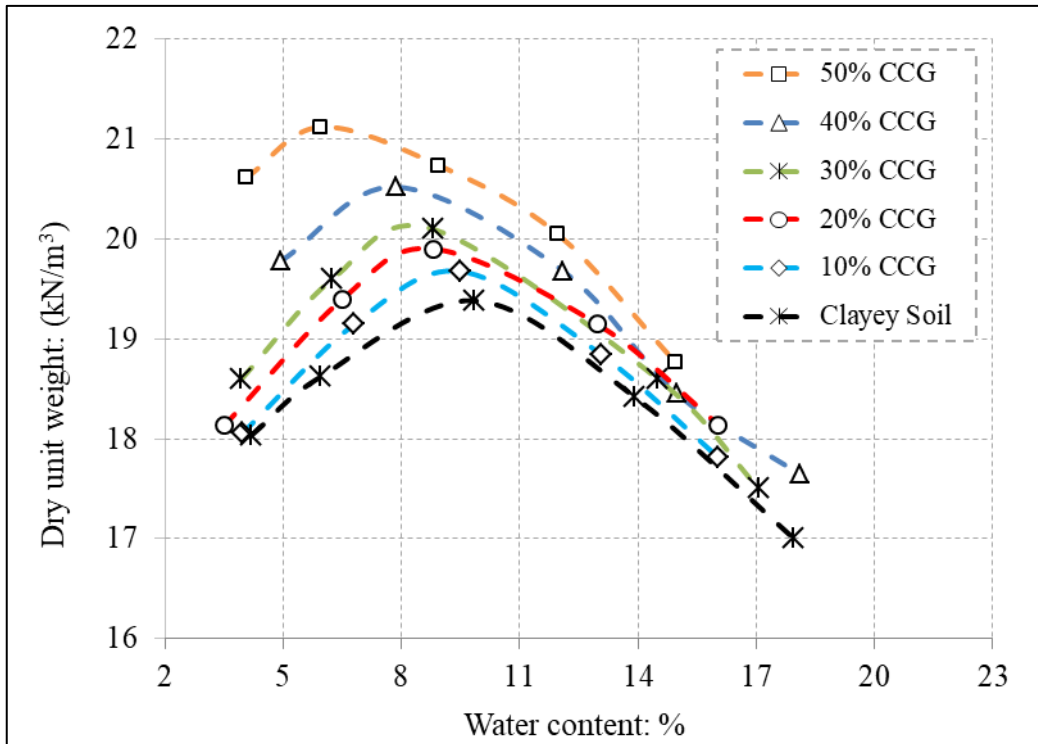


Fig.(3): Compaction curves of the specimens at different mix ratios after adding crushed gravel.

However, the optimum moisture content (OMC) was disproportionate with gravel content. The variations in the maximum dry unit weight

and optimum water content values with gravel contents of both shapes are presented in Figures 4 and 5.

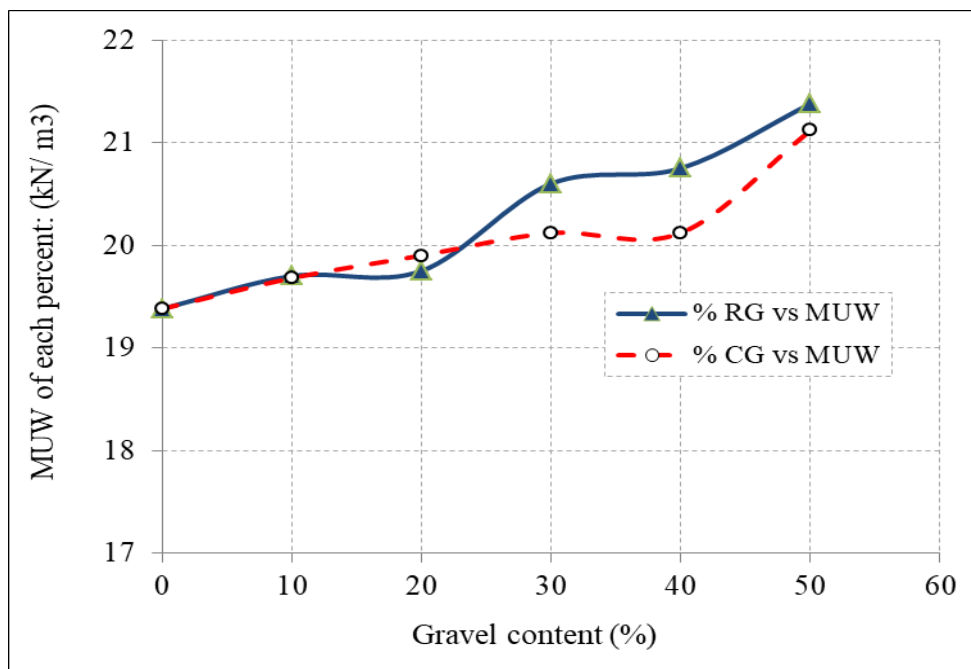


Fig.(4): Variation in the maximum dry unit weight and gravel content of both shapes.

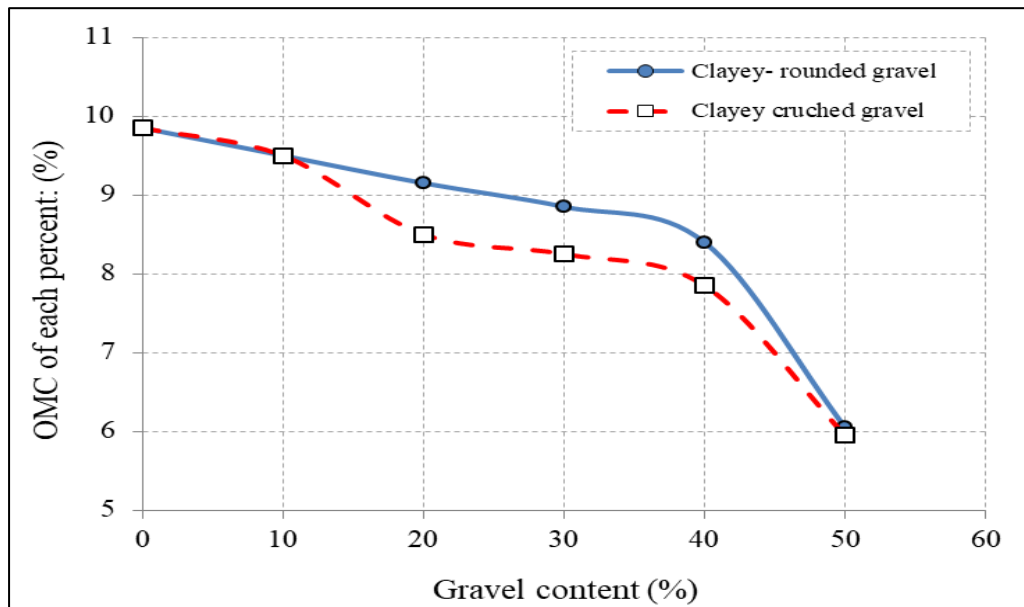


Fig.(5): Variation in the optimum moisture content and gravel content of both shapes.

A change in amount of maximum unit weight (MUW) of clayey soil was observed after adding 10% of gravel which lead to increase by about 1.65% at rounded gravel and by about 1.55% at crushed one. Simple increase in (MUW) was seen during adding (0 to 40) % of both shapes of gravel. While after adding 50% of both rounded and crushed gravel, amount of increasing in (MUW) value reached 10.32% and 8.98% respectively. Similar behaviour of clayey soil was observed in many previous studies (e.g., Chinkulkijniwat et al., 2010; Donaghe & Torrey, 1994) after adding various amounts of gravel and rock soils to fine grained soil.

On the other hand, it was noticed that the variation in MUW after adding 50% of both

shapes of gravel soil was insignificant due to the small difference between specific gravity of both shapes of gravel as illustrated in the above-mentioned material properties.

3.2 CBR PROPERTIES

It can be depend on CBR value to indicate the stability of clayey and clayey-gravel mixtures used to construct pavement projects. Therefore, a great care was taken during determining CBR values of all soil mixtures at various amounts of water contents. Figures 6 and 7 illustrate the variation of CBR values of the tested samples at variable amounts of water contents.

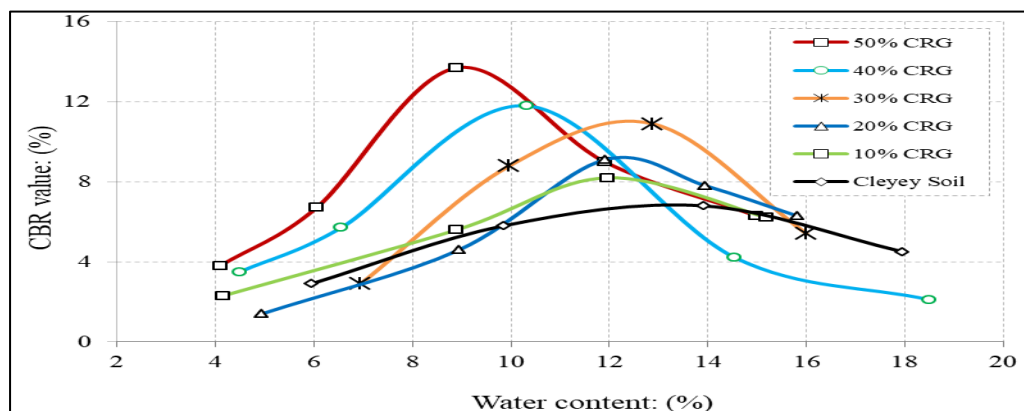


Fig.(6): Variation of CBR value with water content after adding rounded gravel.

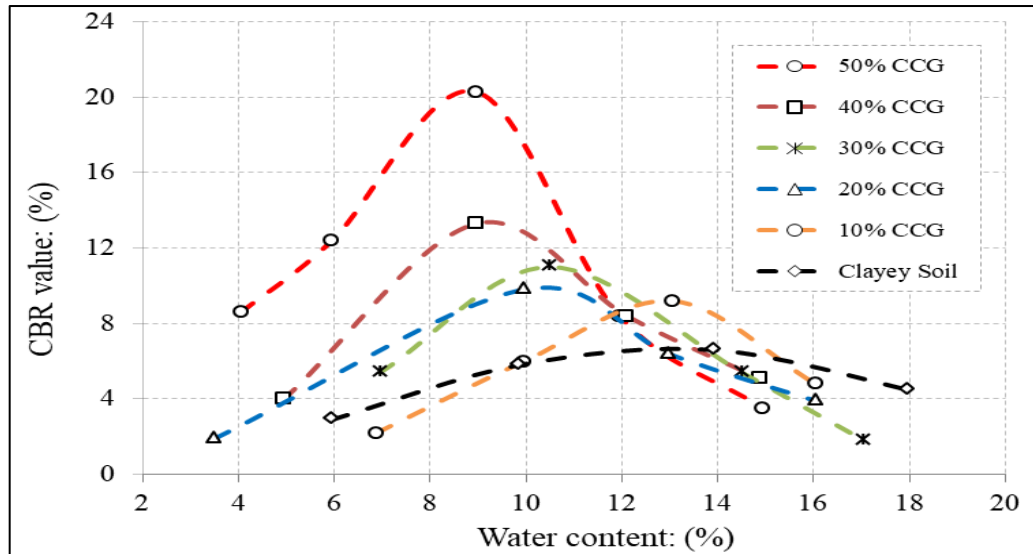


Fig.(7): Variation of CBR value with water content after adding crushed gravel.

It can be seen that adding gravels of both shapes to clayey soil increases CBR values. As indicated by many previous studies (Thevanayagam, 2007; Xenaki & Athanasopoulos, 2003; Vallejo & Mawby, 2000) that the amount of fine contents have a great effect on the behaviour of the mixed soils. This means that the strength which adapted by compacted clayey- gravel mixtures is related to frictional strength between whole material particles. Hence, the amount of gravel content significantly influences CBR values by filling the soil mixture with stronger materials. When amounts of fine (clay) grains surpass gravel soil, the gravel grains will have no

grain-to-grain contact and float in the fines. Therefore, the behaviour of the samples becomes to clay like. While increasing gravel grains will elevate the contact between gravel particles and the behaviour of the samples is controlled by gravel grains.

It is observed that adding 10% gravel by weight to clayey soil resulted in 20.59% increase in the maximum CBR value in case of rounded gravel and 35.29% for crushed gravel, and adding 50% gravel by weight to clayey soil resulted in 101.47% increase in the maximum CBR value for rounded gravel and 198.53% for crushed gravel (Figure 8).

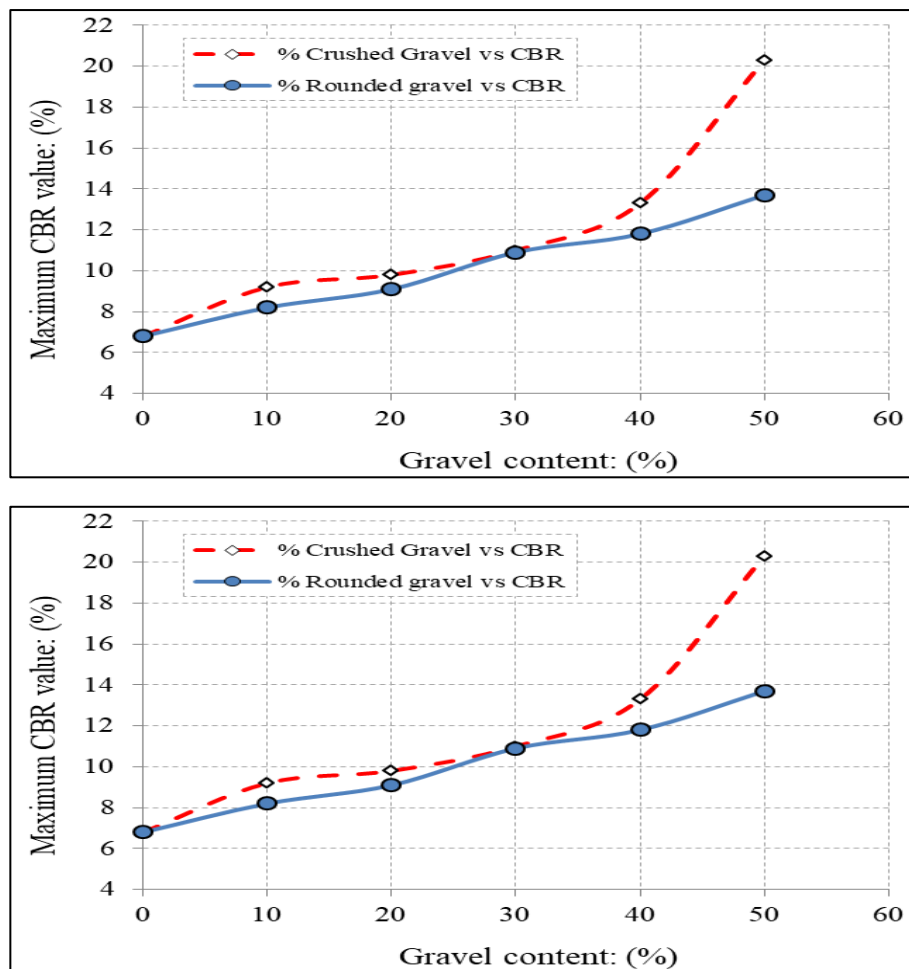


Fig.(8): Effect of gravel content on the maximum CBR values.

It can be seen from Figure 8, that the variation in maximum CBR value after adding crushed gravel was more than that of the rounded one. This may be because of surface roughness of crushed gravel that offers more strength to the soil mixture and results in needing bigger applying force to reach the required amount of penetration. In the light of this observation, it is important to study the impact of the shape of coarse-grained soil on the behaviour of fine-grained soil is as recommended also by many previous research (Lees, 1964; Gilboy, 1928).

3.3 SWELLING PERCENTAGES

Swelling potential was also measured during soaking CBR molds in water bath for all samples of clayey and clayey- gravel mixtures. The amount of expansion ratio which happens for each sample is considered as swelling potential and it can be defined as the ratio between final heights of sample at the end of soaking process to the beginning height of sample before soaking process. It is seen that the amount of swelling

potential of clayey soils records maximum value when the sample contain higher amount of clayey soil due to the high ability of clay particles to absorb water particles. Figures 9 and 10 illustrate the variation of swelling potential with water content for all samples and at various mixture ratios after adding both shapes of gravel (rounded and crushed). The figure shows that by adding gravel to clayey soil the amount of swelling potential dropped significantly. The swelling ratio decreased from 4.5% for the clayey soil to 0.2% after adding 40% of rounded gravel. While it decreased to 0.56% after adding same ratio of crushed one, as shown in Figure 11. Depending the observation made earlier by Gray et al. (1984), gravel particles behave as an inert material and swelling potential is controlled by mass of clay soil only which work to combine volume of clay and voids that are available in each sample. On the other hand, it can be seen that by adding rounded gravel to clayey soil, the amount of decreasing in swelling potential was bigger that when crushed one added. This may be attributed to the surface

roughness of crushed gravel particles that help to store more amounts of voids surrounding each particle and leads to absorbing more water.

Another behaviour of clayey soil was manifested by adding 50% of gravel to clayey soil which presented by increasing swelling potential again from 0.2% to 0.45% for rounded gravel and from 0.56% to 0.87% for crushed one. The reason behind this change in the swelling potential behaviour is may be related to the high gravel content in the sample, which helps in dissipating the water particles inside the soil media easily, and helps the clay particles to absorb water particles

easily and led to push out the gravel particles, which finally increases sample height.

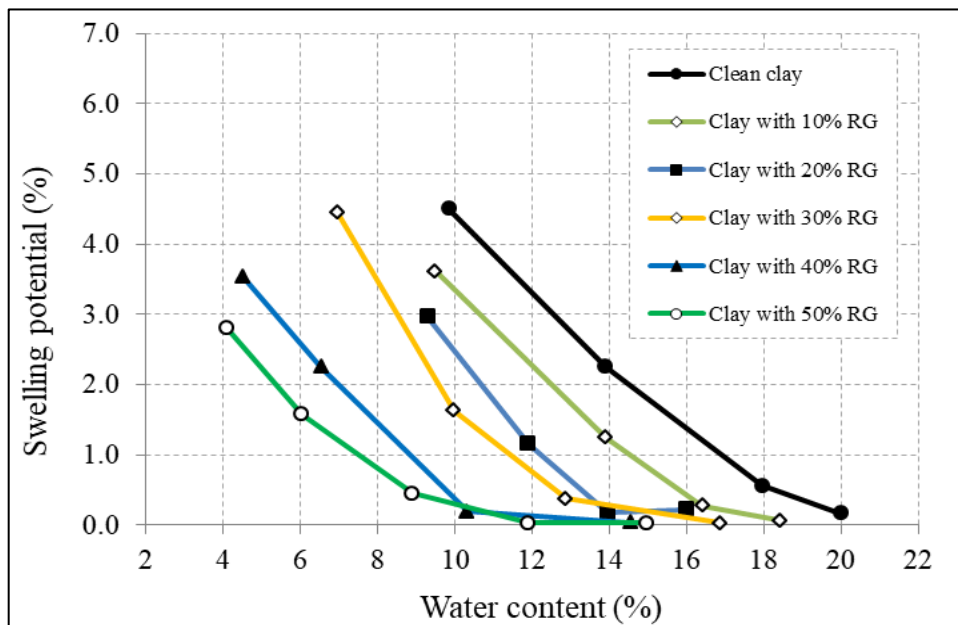


Fig. (9): Variation of swelling potential vs. water content for the specimens with different rounded gravel contents.

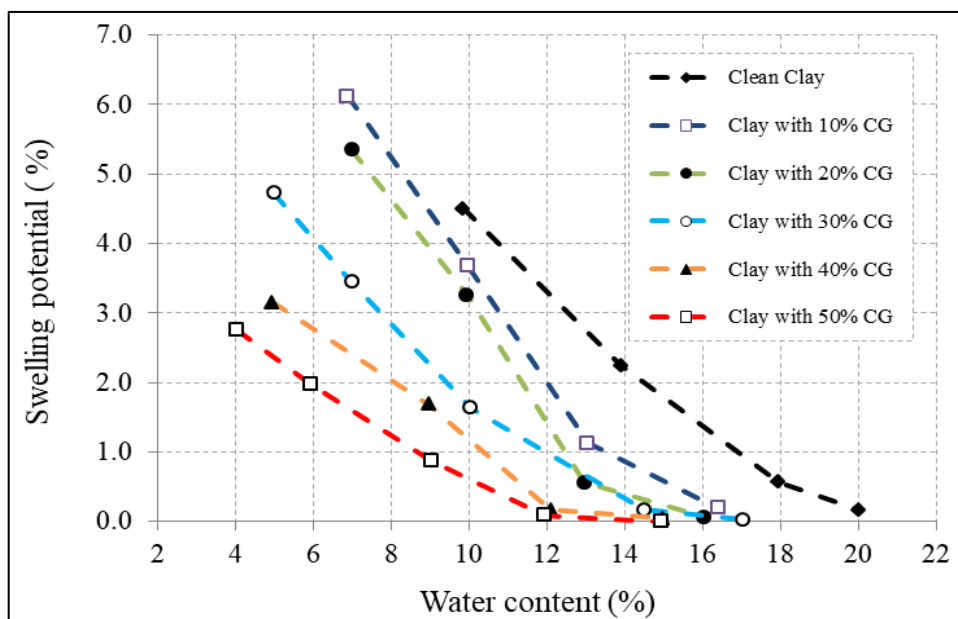


Fig.(10): Variation of swelling potential vs. water content for the specimens with different rounded gravel contents.

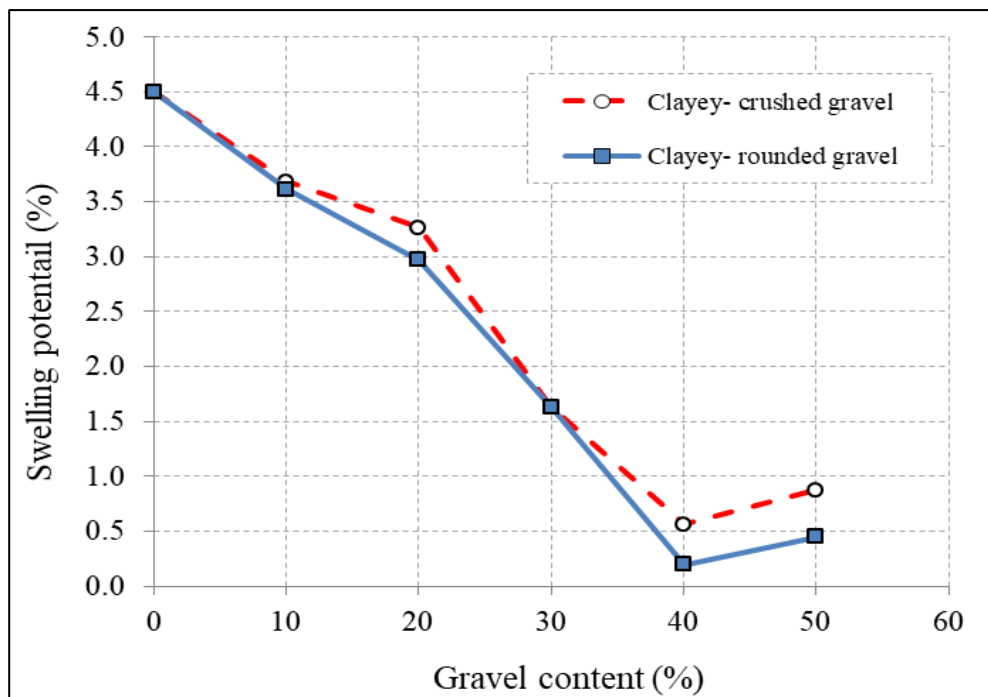


Fig.(11): Variation of swelling potential vs. gravel content (rounded and crushed).

4 CONCLUSIONS

In this study examined the effect of adding various shapes of gravel soil (rounded and crushed), which are widely used in earthwork projects in Duhok Province, on improving the mechanical behaviour of clayey soil depending on a series of modified and CBR tests. The following points are concluded:

1- The amount of maximum dry unit weight (MUW) of all samples after adding both shapes of gravels to clayey soil are proportionate to gravel content, and disproportionate to optimum moisture content (OMC) under the same conditions.

2- A change in amount of maximum unit weight (MUW) of clayey soil was observed after adding 10% of gravel that led to increase by 1.65% at rounded gravel and by 1.55% at crushed one. Moderate increase in (MUW) was seen during intervals from 0 to 40 % of both shapes gravel. By adding 50% of rounded and crushed gravels, amount of increasing in (MUW) value reached 10.32% and 8.98% respectively. This means that the variation in MUW levels after adding 50% of both shapes gravel soil was insignificant.

3- The addition of 10% gravel by weight to clayey soil resulted in 20.59% increase in the maximum CBR value for rounded gravel and

35.29% for crushed gravel. Also, the addition of 50% gravel by weight to clayey soil resulted in 101.47% increase in the maximum CBR value for rounded gravel and 198.53% for crushed gravel. Namely, adding crushed gravel resulted in variation in maximum CBR more than resulted from rounded one.

4- Maximum value of swelling potential was obtained when the sample contain highest amount of clay soil due to the high ability for absorbing water particles. After adding gravel soil, swelling ratio was decreased from 4.5% for the clayey soil to 0.2% after adding 40% of rounded gravel while it decreased to 0.56% after adding same ratio of crushed one. By adding 50% of gravel to clayey soil, the amount of swelling potential increased from 0.2% to 0.45% for rounded gravel and from 0.56% to 0.87% for crushed one.

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