Influence of the Use of Additives on the Properties of Compacted Gypseous Soils

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ABSTRACT

In this paper, an experimental study is carried out on the effect of three different additives to gypseous soils in order to improve the compaction properties of the gypsum soil. The additives used in this study are Recycled Asphalt Pavement passing from sieve No.4 (RP), Recycled Asphalt Pavement passing from sieve 3/8 and remaining on sieve No.4 (RR) and Rice Husk Ash (RHA). The percentages of (RP) and (RR) are varied between (3-9)% by weight in the first and second series; whereas the percentage of Rice Husk Ash was between (3-9)% by weight in the third series. In the fourth and fifth series, the percentage of (RHA) was kept constant (6%) by weight, while the percentage of (RP) and (RR) varied from (3-9)% by weight. The results showed that the best improvement in compaction characteristics is achieved when the sample is tested by adding a mix of (RR) and (RHA), the maximum dry density increases with the increase in the mixing content, while the opposite is true for the optimum water content.

KEYWORDS: Soil, Gypsum, Compaction, Rice husk ash, Recycled asphalt pavement.

INTRODUCTION

Many studies have been conducted on gypseous soils in Iraq because they are covering a wide area of nearly (31.7%) of the surface sediments of Iraq with gypsum content ranging between (10-70)% (Ismail, 1994) and (0.6%) of the world area (Alphen and Romero, 1971).

When salt bearing soils are subjected to soaking, an increase in moisture content can take place causing dissolution of some gypsum. In practice, soaking can take place in different ways such as local shallow wetting, deep local wetting, as well as slow and uniform rise of ground water level. The magnitude and character of such development depend on the type of soil, initial gypsum content, relative amount of leached salts, soil properties and acting load (Petrukhin and Boldyrev, 1978).

In the construction of highway embankments, earth dams and other engineering structures, loose soil must be compacted to increase its unit weight. Compaction is the improvement of the engineering properties of the soil mass which occurs by increasing strength, reducing compressibility, volume change and permeability and improving the stability of structures (Das, 1990).

Rice husks which are an agricultural waste, constitute about one-fifth of the 500 million tons of rice produced annually worldwide (Mahmud et al., 2004). The primary work on RHA was started at the Asian Institute of Technology by (Columana, 1974), who found out that when a village burnt, the husks were converted to ash at temperatures less than 300°C.

(Ahmed, 1985) reported that increasing gypsum

Accepted for Publication on 4/7/2013.

content increases maximum dry unit weight and decreases the optimum water content.

(Al-Ani et al., 1988) found that the maximum dry unit weight and optimum water content increase with the increase in gypsum content.

(Dabbagh et al., 1990) noticed that the maximum dry unit weight decreases and the optimum water content increases with the increase in gypsum content.

(Al-Abdullah, 1996) found for compacted soil that the maximum dry unit weight decreases, then increases with increasing the gypsum content, while the optimum water content decreases with the increase in gypsum content.

(Al-Shalhomi, 2000) compacted a clayey soil after adding gypsum at different percentages (1.45% to 60%). He found that increasing gypsum content decreases the maximum dry unit weight, while the optimum water content increases or decreases according to the size of the added gypsum grains.

(Al-Morshedy, 2001) reported that the maximum dry unit weight increases with the increase in gypsum content, while the optimum water content decreases with the increase in gypsum content.

(Al-Hadithy, 2001) studied the effects of gypsum content on the compaction properties for four types of soils. He showed that the optimum water content increases and then decreases with increasing the gypsum content, while the maximum dry unit weight increases with the increase in gypsum content.

(Al-Shakayree, 2003) showed that the maximum dry unit weight decreases and the optimum water content increases with the increase in gypsum content.

The contradiction in the results and different behaviors stated above may be explained by the role of gypsum in the compaction results. Of course, the type of the soil, the shape and size of the particles may also affect the compaction behavior.

EXPERIMENTAL PROGRAM

Materials

Soil: The soil samples used in this study were taken from one location at Al-Najaf-Karbalaa highway of Al-Najaf city. The soil samples were obtained from a depth of (1.5) m below the natural ground surface. The results of physical and chemical tests of natural soil are summarized in Table (1).

Rice Husk Ash (RHA): Burning of rice husks according to (Habeeb, 2000; Hana, 1996) was carried out in a furnace under controlled temperature in order to establish the optimum burning temperature and burning time. The produced ash was burnt at a temperature of 500°C for two hours, to minimize its carbon content to about 3.03 percent. The burning was made in Al-Zahraa- Women Organization/Al-Najaf City/Ministry of Youth. The chemical composition and physical properties of the (RHA) are given in Table (1), the test was carried out in the laboratory of New Cement Plant of Kufa.

Recycled Asphalt Pavement (RAP): The samples of Recycled Asphalt Pavement used in this study were taken from the residues of re-establishing roads. RAP has been broken into different sizes, and then added to the soil as follows:

- Recycled Asphalt Pavement passing from sieve No. 4 (RP).
- Recycled Asphalt Pavement passing from sieve 3/8 and remaining on sieve No. 4 (RR).

The physical and chemical properties of the Recycled Asphalt Pavement can be seen in Table (1). The test was conducted in the laboratories of Engineering Consulting Bureau at Kufa University.

TESTING PROGRAM

The testing program in this study can be summarized in the following groups:

Classification tests were performed firstly including physical and chemical tests. The physical tests include grain size distribution, Atterberg limits, specific gravity and water content.

Standard Proctor compaction tests were carried out to determine the moisture-density relationship for the natural soil and for treated soil by three additives (RP, RR and RHA) as follows:

- **Group one:** The soil was tested in the natural case.
- **Group two:** The soil was tested in treated case with:

1- Recycled Asphalt Pavement (RP), three percentages were used (3, 6 and 9)% by weight of soil.
2- Recycled Asphalt Pavement (RR), three percentages were used (3, 6 and 9)% by weight of soil.
3- Rice Husk Ash (RHA), three various percentages were used (3, 6 and 9)% by weight of soil.
4- Mix of (RHA) and (RP), (the percentage of (RHA) was kept constant at 6% by weight; while the percentage of (RP) was varied from 3 to 9% by weight).
5- Mix of (RHA) and (RR), (the percentage of (RHA) was kept constant at 6% by weight; while the percentage of (RR) was varied from 3 to 9% by weight).

List of Abbreviations and Notations

Abbreviations	Meaning
ASTM	American Society for Testing and Materials
BS	British Standard
SP	Poorly graded sand
X	Gypsum content (%)
RP	Recycled Asphalt Pavement Passing from Sieve No.4 by Weight (%)
RR	Recycled Asphalt Pavement Remaining on Sieve No.4 by Weight (%)
RHA	Rice Husk Ash by Weight (%)
USCS	Unified Soil Classification System

Table 1. Summary of Physical and Chemical Tests for Soil and Additives

Soil		Recycled Asphalt Pavement		Rice Husk Ash			
Gypsum Content (%)	36.4%	Asphalt Ratio (%)	5	Chemical Analysis Oxide (%)		Physical Properties	
Maximum Dry Unit Weight (kN/m^3)	16.5			SiO_2	87.2	Specific Gravity	2.06
Optimum Water Content (%)	19.512			Al_2O_3	0.43		
Specific Gravity (Gs)	2.54			FeO_3	0.28		
Initial Water Content (%)	0.91			CaO	1.51		
Liquid Limit (LL) %	25.63	Dry Unit Weight (kN/m^3)	2.315	MgO	0.37		
Plastic Limit (PL) %	-			Na_2O	1.25		
SO_3 (%)	16.901			K_2O	3.84		
Total Soluble Salts (%)	7.3			SO_3	1.8		
Soil Classification According to (USCS)	SP			Carbon	3.03		

Table 2. Results of Compaction Tests after Treatment

Soil Property	Optimum Water Content, %			Maximum Dry Unit Weight, kN/m^3		
Percentage	**3%**	**6%**	**9%**	**3%**	**6%**	**9%**
RP	17.6	16.41	15.5	17.5	18.2	18.84
RR	17	15.83	14.85	17.9	18.65	19.57
RHA	20.78	22.13	23.76	20.09	21.44	22.23
RP + (RHA = 6%)	19.1	17.66	15.8	19.33	20.1	20.93
RR + (RHA = 6%)	18.5	16.61	14.87	20.52	21.6	22.33

CLASSIFICATION TESTS

Physical Tests

- Grain Size Distribution

The grain size distribution was determined according to (ASTM D922-72) with dry sieving.

- Atterberg Limits

Liquid and plastic limits tests were carried out on soil passing sieve No. 4 and the temperature used for drying was maintained at (45-50°C) due to the significant amount in the soil (ASTM 2216-80). The liquid limit was determined according to (BS 1377:1972, Test No. 3).

- Specific Gravity

The specific gravity was determined according to (BS 1377: 1975, Test No.6 (B)). Kerosene was used instead of distilled water because of dissolving action of gypsum by water (Head, 1980).

- Water Content

This was determined in accordance with (BS 1377: 1975, Test (A), Head, 1980). The oven dry temperature was kept at 45°C due to dehydration of gypsum.

Chemical Tests

Chemical tests were carried out on the natural soil, including:

- Total soluble salts (TSS) % determined according to (BS 1377: 1975, Test (9)).
- The gypsum content found according to the method presented by Nashat and Al-Mufty (2000).

This method consists of oven drying the soil at (45°C) until the weight of the sample becomes constant. The weight of the sample at (45°C) is recorded. Then, the same sample is dried at (110°C) for (24 hrs) and the weight is recorded again. The gypsum content is then calculated according to the following equation:

$$X\,(\%) = \frac{W_{45^{o}C} - W_{110^{o}C}}{W_{45^{o}C}} \times 4.778 \times 100$$

where: X = Gypsum content (%).

$W_{45^{o}C}$ = Weight of the sample at (45°C).

$W_{110^{o}C}$ = Weight of the sample at (110°C).

Compaction Test

Standard Proctor compaction tests were carried out for the untreated and treated soil to determine the moisture-unit weight relationship according to (ASTM D 698, Method A, 2003). A mold of (101.6) mm in diameter and with a height of (115.5) mm was used. Samples were compacted in three equal layers each hammered by (25) blows using a (2.5) kg hammer dropped from (305.5) mm height.

The compaction control of gypseous soils also requires slow heating in temperatures ranging between (60-80)°C for (48 hrs), instead of (24 hrs) for non-gypseous soils, which causes delays in the process of field compaction (Al-Khafaji, 1997).

RESULTS AND DISCUSSION

According to the Unified Soil Classification System

(USCS), the soil can be classified as poorly graded sand (SP).

The relationship between dry density and water content for the tested soil is shown in Figure (1), while Figures (2) to (6) show the relationship for samples tested after treatment with the additives.

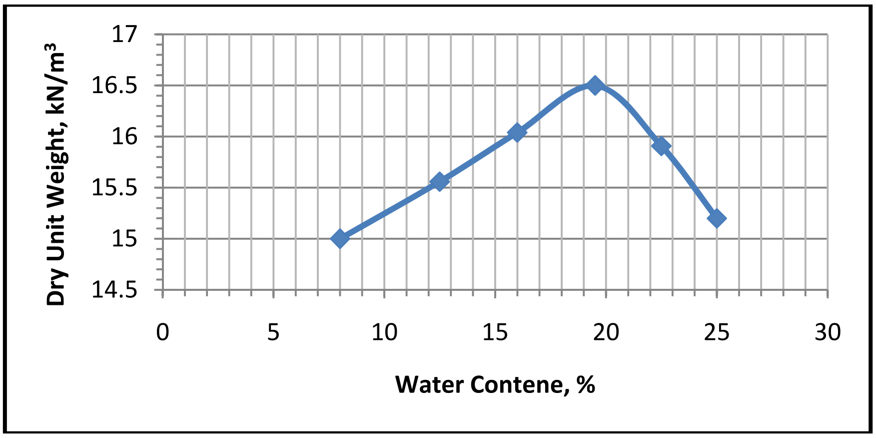

Figure 1: Standard Compaction Curve for Natural Soil

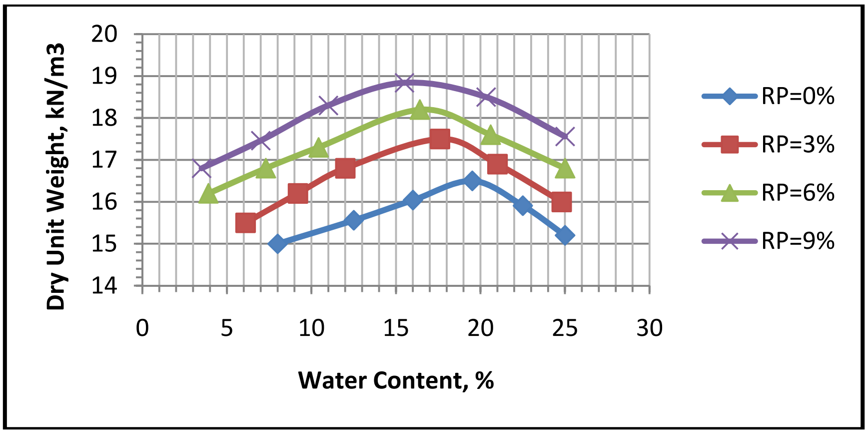

Figure 2: Standard Compaction Curve for Soil Treated with (RP)

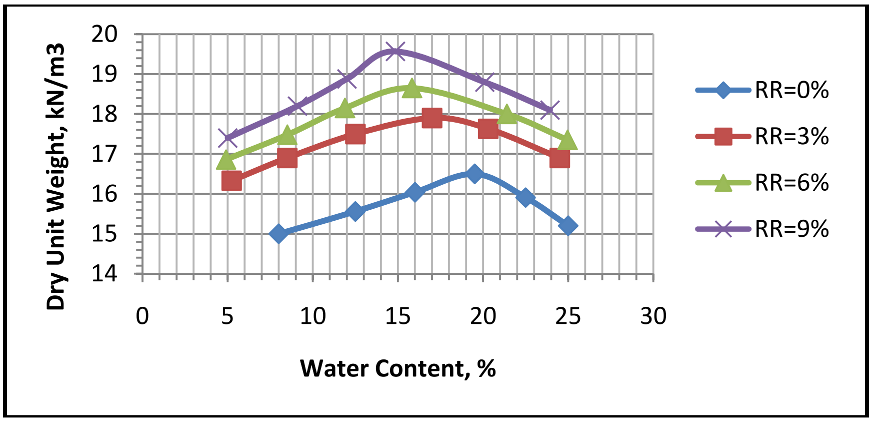

Figure 3: Standard Compaction Curve for Soil Treated with (RR)

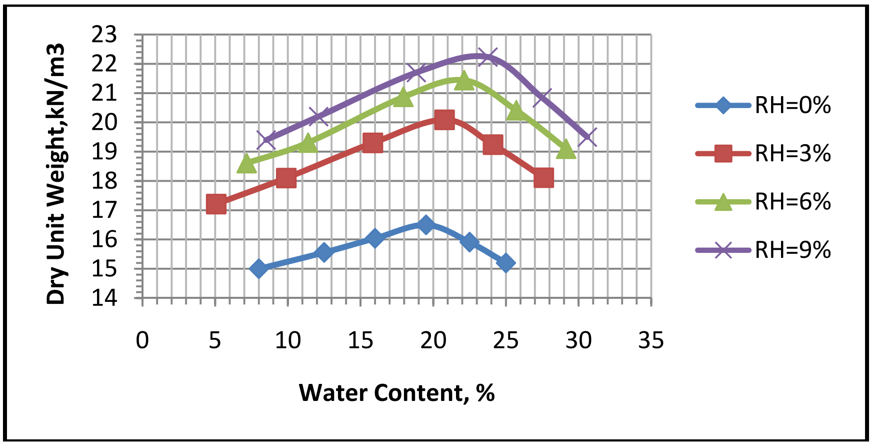

Figure 4: Standard Compaction Curve for Soil Treated with (RHA)

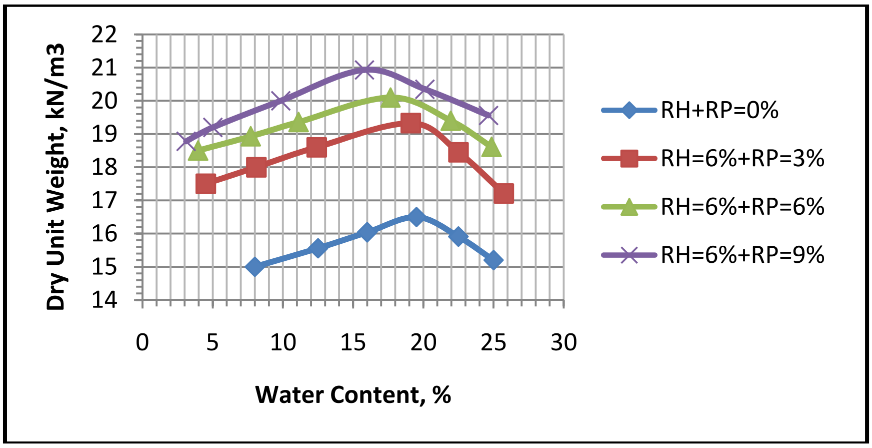

Figure 5: Standard Compaction Curve for Soil Treated with (RHA and RP)

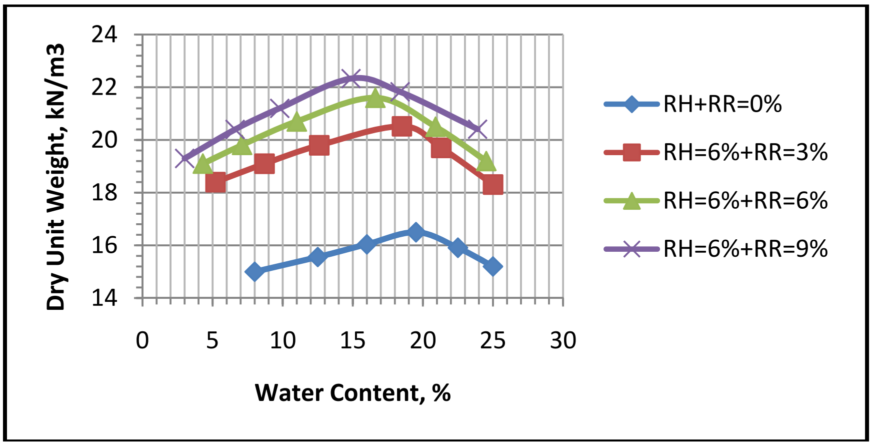

Figure 6: Standard Compaction Curve for Soil Treated with (RHA and RR)

In Figure (7), the additives content is plotted *versus* maximum dry unit weight in normal scale. It is noticed that the maximum dry unit weight increases with increasing the additives content (Recycled Asphalt Pavement (RP), Recycled Asphalt Pavement (RR) and Rice Husk Ash (RHA)). This is attributed to the low value of specific gravity of gypsum which equals (2.3) as compared with the specific gravity of soil and additives. A summary of data is given in Table (2). In Figure (8), the optimum water content is plotted *versus* the additives contents. This Figure shows that the optimum water content decreases with increasing Recycled Asphalt Pavement (RP) and Recycled Asphalt Pavement (RR) content which is probably due to reduction of the voids ratio because of that the required amount of water to fill the voids between soil particles will be less. On the other hands, the optimum water content increases with increasing Rice Husk Ash (RHA) content, this is due to the role of Rice Husk Ash which causes cementation to soil particles that helps the resistance to compaction effort and increases the required water content in order to reach the maximum unit weight.

In Figure (9) and Figure (10), the change in optimum water content and maximum dry unit weight are plotted *versus* the additives content. It can be noticed that the maximum dry density is increased about (35.33)% at (RR=9% and RHA=6%) content, while the decrease in optimum water content is about (23.9)% at RR=9%.

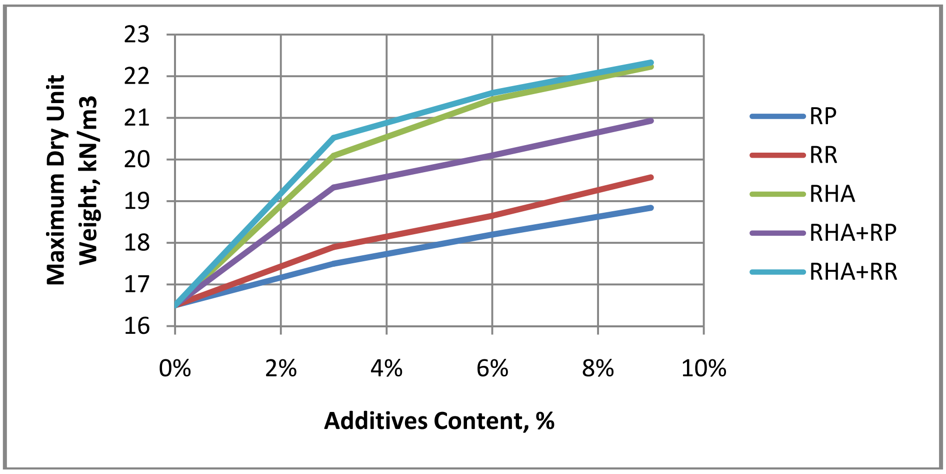

Figure 7: Effect of Additives on Maximum Dry Unit Weight

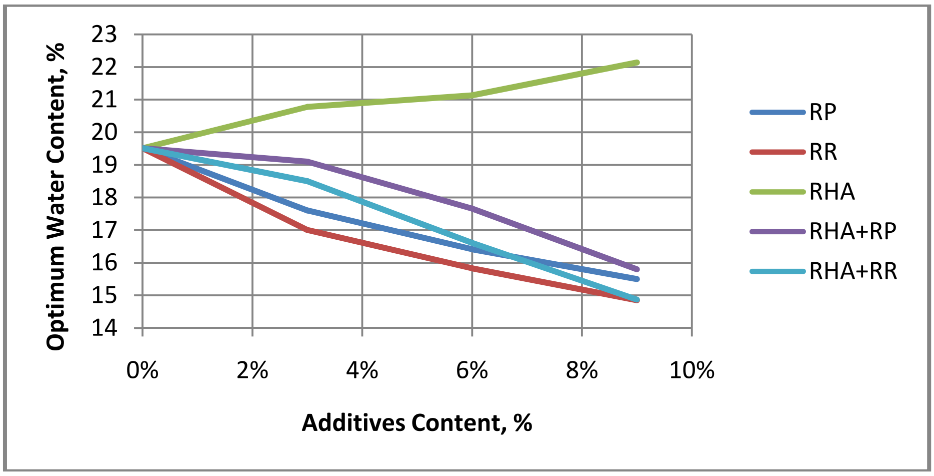

Figure 8: Effect of Additives on Optimum Water Content

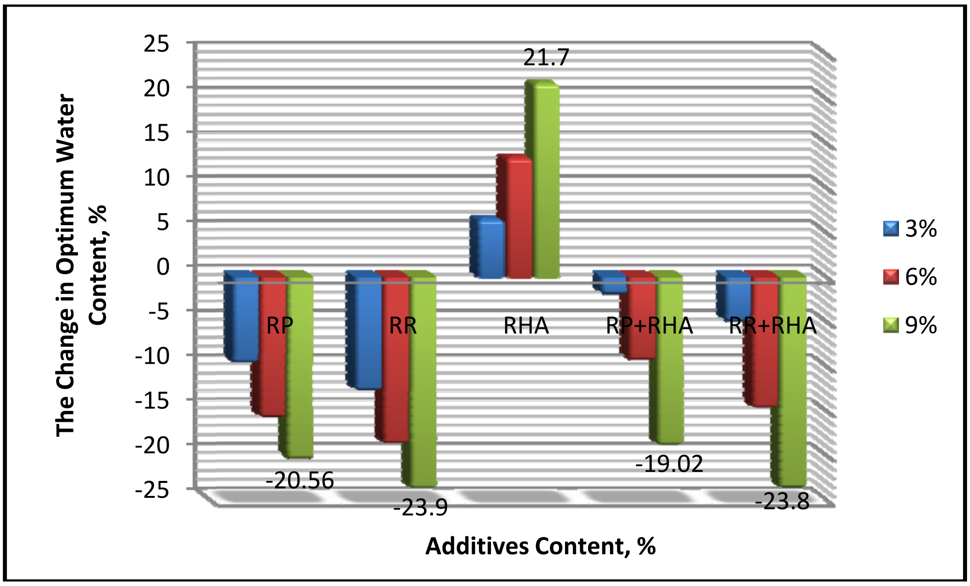

Figure 9: The Change in Optimum Water Content *Vs.* the Additives Content

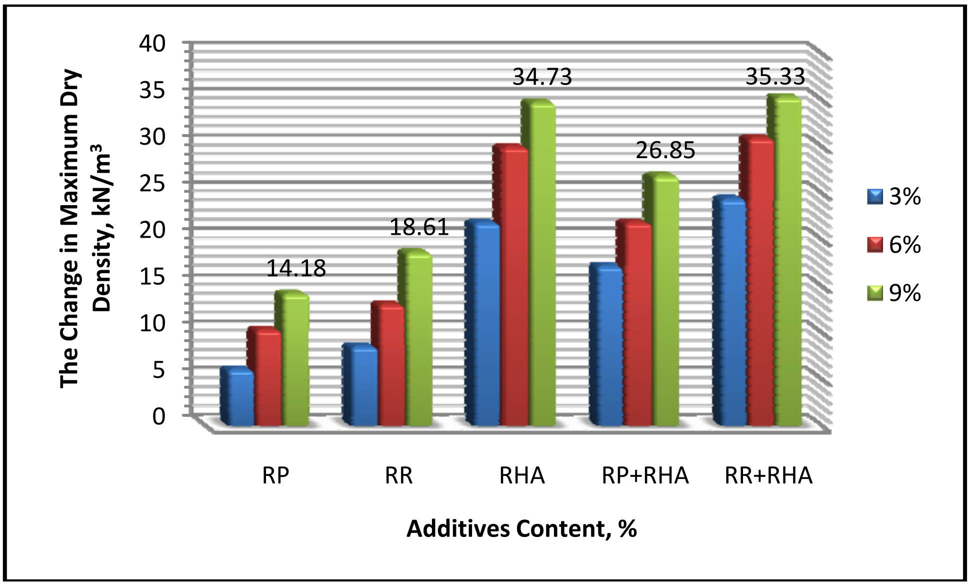

Figure 10: The Change in Maximum Dry Density *Vs.* the Additives Content

CONCLUSIONS

1. The best improvement in the maximum dry unit weight is achieved when the samples are treated with a mix of Recycled Asphalt Pavement (RR=9% by weight) and Rice Husk Ash (RHA=6% by weight).
2. The optimum water content decreases with increasing (RP and RR) content, while the optimum water content increases with increasing (RHA) content.
3. The maximum dry unit weight resulting from the samples after being treated with (RR) is greater than the maximum dry unit weight resulting from the samples after being treated with (RP).
4. Adding Rice Husk Ash (RHA) may add extra cost

but the overall cost of the mix may become economical. However, further researches are needed to study the mix economically.

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