INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

SIMSG   ISSMGE

Determination of compaction curves by utilizing the gyratory compactor

Détermination des courbes de compactage à l'aide du compacteur giratoire

Natalia Perez
Infrastructure Laboratories, Mexican Transportation Institute, Mexico, nperez@imt.mx

Paul Garnica
Consultant, cii.com.mx, Mexico

ABSTRACT: Different compaction methods exist to obtain the standard Proctor test. However, advances in technology have made more sophisticated equipment available to engineers for the evaluation of laboratory properties. One such piece of equipment is the gyratory compactor. This is mainly used for compacting asphalt mixtures, however, in recent years it has also been used for compacting soils and granular materials. This paper documents a recommendation of a procedure for obtaining the compaction curve of soils passing sieve No. 4 using the gyratory compactor. The recommendation is based on results of several soils with different classifications.

RÉSUMÉ : Il existe différentes méthodes de compactage pour obtenir l'essai Proctor standard. Cependant, les progrès technologiques ont permis aux ingénieurs de disposer d'équipements plus sophistiqués pour l'évaluation des propriétés en laboratoire. L'une de ces pièces d'équipement est le compacteur giratoire. Il est principalement utilisé pour le compactage des mélanges d'asphalte, mais ces dernières années, il a également été utilisé pour compacter les sols et les matériaux granulaires. Ce document documente une recommandation d'une procédure pour obtenir la courbe de compactage des sols passant la maille n°4 en utilisant le compacteur giratoire. Cette recommandation est basée sur les résultats des courbes de compactage de divers sols compactés dans l'équipement giratoire.   .

KEYWORDS: gyratory compactor, Proctor standard curve, draining soils, maximum dry unit weight, optimum water content.

1 INTRODUCTION

To date, in several countries the quality control of compacted materials is still carried out by means of the degree of compaction. Accordingly, parameters such as the maximum dry density of the material obtained in the laboratory and the dry density evaluated in the field are required. With respect to the former, the way to determine it is by means of the standard Proctor or modified Proctor test. According to the procedure of these tests, the material is compacted in a mold by means of impacts. Some authors have documented that the impact method is not the way that best simulates the compaction processes of field equipment. For this reason, other compaction methods have been studied to obtain soils with structures more similar to those provided by field compaction equipment. Thus, several researchers propose the gyratory compactor as the most suitable equipment for compacting soils and granular materials. However, it is clear that, if this equipment is to be proposed to determine compaction curves, the procedure must be provided. This paper proposes a procedure to obtain standard Proctor compaction curves for soils passing sieve No. 4. It should be noted that this is the first proposal since other variables involved in the compaction process have yet to be studied.

2 BACKGROUND ON EVALUATION OF COMPACTION CURVES WITH GYRATORY COMPACTOR

Several author have determined compaction curves using the gyratory compactor (Camacho et al,2007; Browne, 2006; Perez et al., 2006; Khaled et al., 2017), however each of the researchers has determined the compaction curve by controlling or fixing a certain number of variables. But to date there is no procedure indicating how the compaction curve should be determined using gyratory compactor. This paper sets out a procedure for determining the standard Proctor compaction curve of soils passing sieve No. 4.

3 SOILS AND PROCEDURES

3.1 *Soils and Preparation*

In this research soils sampled at different locations of Mexico were utilized. These soils were dried for several days and then sieved through sieve No. 4. After the sieving, they were mixed thoroughly and then stored in bags.

Before evaluating the standard compaction curves; ASTM procedures were utilized to evaluate index properties.

3.2 *Determination of Proctor compaction curve*

To evaluate the standard compaction curve the ASTM D698-12 was followed. Method A was utilized as all soil was finer than No. 4 sieve.

3.3 *Determination of Proctor compaction curve with gyratory compactor*

To determine the compaction curve with gyratory equipment, the following steps were followed:
- At least five soils samples of 1 kg were prepared for each soil.
- Water was added to each test specimen in different amounts, so that the optimum water content is obtained from them.
- Each specimen is mixed throughly to ensure adequate water distribution. After mixing the soil with water, it was placed in a polyethylene bag and allowed to stand for 16 to 18 hours.
- Prior to compaction, the gyratory equipment is prepared. The valve that feeds the compressed air gyratory compactor is opened (Figure 1).
- The gyratory equipment is turned on and the compaction variables are set (Figure 1).
- The lid of the machine is removed to grease the mold. A circular rigid plastic is placed at the bottom of the mold to facilitate the extraction of the specimen at the end.

The entire soil sample is then placed in the compaction mold (Figure 2). With the help of a spatula, the material is spread until a flat surface is observed, on which another circular rigid plastic sheet is placed.

- The compactor lid is placed and the start button is pressed to initiate the compaction process.

Figure 1. Turn on of the equipment and setting of the variables

Figure 2. Placement of the soil inside the mold

- At the end of the compaction process, the specimen is removed from the equipment and its weight and dimensions are determined (Figure 3).

Figure 3. Register dimensions and weight of compacted specimen

- To finalize the process, the sample is disintegrated and three soil samples are taken to determine the water content.
- Once the data is obtained, the compaction curves are plotted.

4 RESULTS

4.1 *Index Properties*

Index properties and soil classification according to USCS is summarized in Table 1.

4.2 *Compaction Curves evaluated in gyratory compactor by varying vertical pressure*

After obtaining the compaction curves with the traditional method, the objective was to find the compaction curve with gyratory compactor. For this, the speed, the gyration angle, and the number of gyrations were set at values of 30 gyrations per minute, 1.25 degrees, and 200 gyrations. The vertical pressure was increased until the compaction curve agreed with the curve obtained with the traditional method (Proctor standard). Figures 4 and 5 are two examples of the curves obtained by varying the vertical pressure. In the same plot, the Proctor compaction curve is shown. It should be noted that the first compaction curve was

determined with a vertical pressure of 400 kPa; the result showed whether to increase or decrease the vertical pressure for the next trial curve. The procedure was repeated as many times as necessary to find the correct vertical pressure.

Table 1. Index properties and soils classification.

Soil ID	Atterberg Limits		Passing 200 sieve (%)	Gs	USCS Class
	LL (%)	LP (%)			
Clay IMT	66	41	86.0	2.61	CH
Clay Gasera,	91	32	96.0	2.53	CH
Clay, Lago La Venta	69	45	87.0	2.56	CH
Soil CL	33	22	78.86	2.56	CL
Soil all in one	38	15	57.24	2.62	CL
Soil Galera	59	26	89.60	2.68	MH
Soil Guadalajara	64	30	63.7	2.4	MH
Soil 2. Mexico City	61	38	72.84	2.51	MH
Soil 3. Mexico City	87	58	84.68	2.50	MH
Soil Misha	44	11	87.0	2.74	ML
Soil 1. Mexico City	36	26	63.90	2.25	ML
Soil Veracruz	23	8	31.0	2.85	SC
Soil ciclovia	NP	NP	28.52	2.57	SM
Soil San José	NP	NP	13.30	2.43	SM
Soil HVS	51	30	43.70	2.62	SM
Soil Conin 08	NP	NP	32.90	2.37	SM
Soil Conin 09	NP	NP	32.20	2.48	SM
Soil Los Cues	NP	NP	37.0	2.52	SM

Note: NP=Non plastic; CH= High compressibility clay; MH= Silt of high compressibility; ML= Silt of low compressibility; SM= Sil ty sand; SC= Clayey sand; LL= Liquid limit; LP= Plastic limit; Gs = Specific gravity of soils.
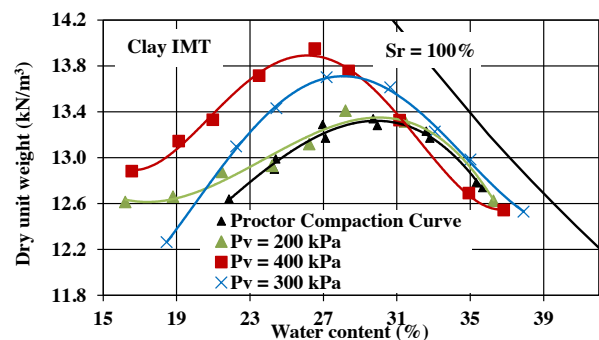

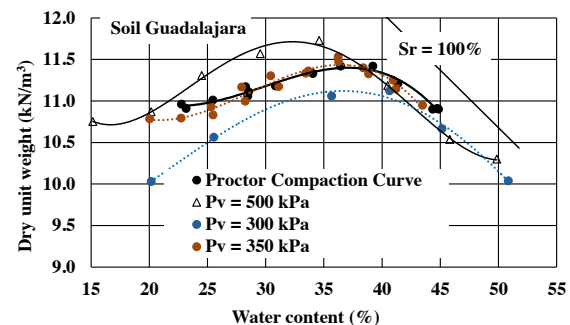Figure 4. Trials of compaction curves obtained with gyratory compactor for soil Clay IMT .

Figure 5. Trials of compaction curves obtained with gyratory compactor for soil Guadalajara.

4.3 *Comparison of traditional and gyratory compaction curves*

The above procedure was followed for all tested soils. Figures 6 to 22 show the comparison of traditional and gyratory compaction curves.
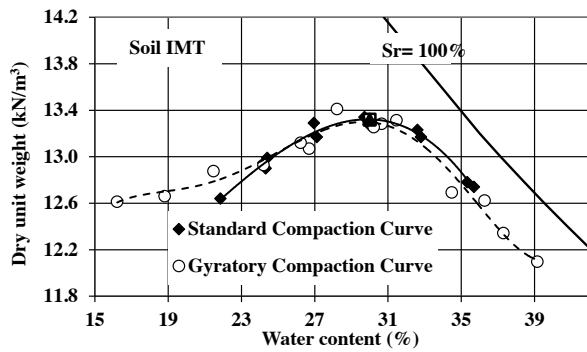
Figure 6. Compaction curves obtained with gyratory compactor and Proctor compaction curve for Clay IMT.
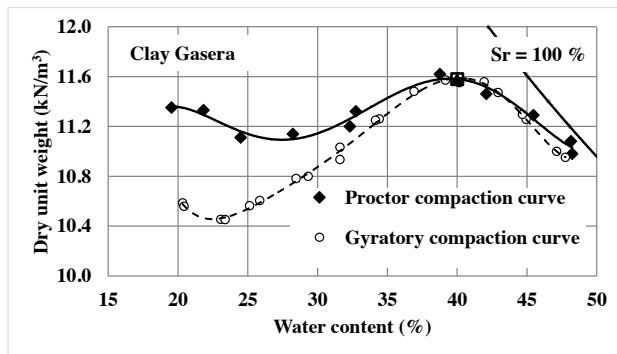

Figure 7. Compaction curves obtained with gyratory compactor and Proctor compaction curve for Clay Gasera.
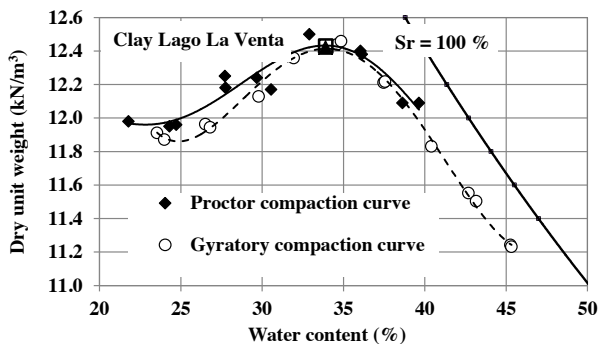

Figure 8. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil CL.
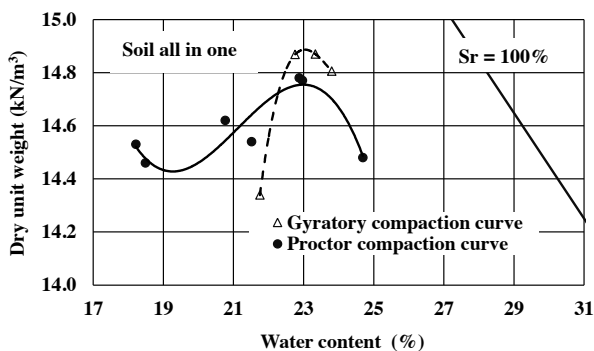

Figure 9. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil all in one.
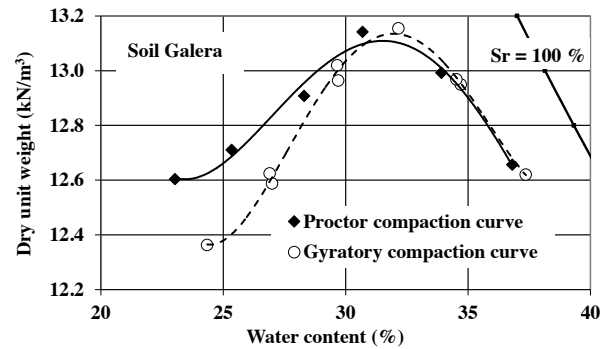

Figure 10. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Galera.
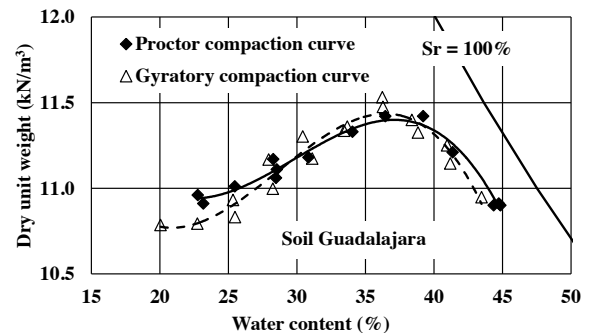

Figure 11. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Guadalajara.
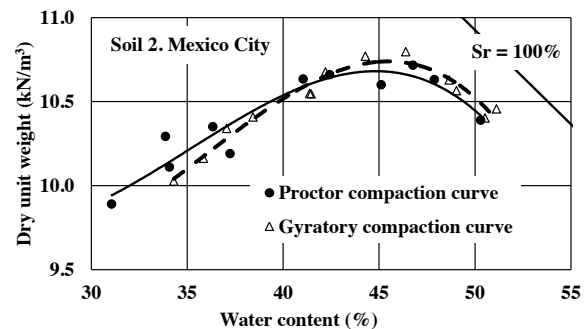

Figure 12. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil 2. Mexico City.
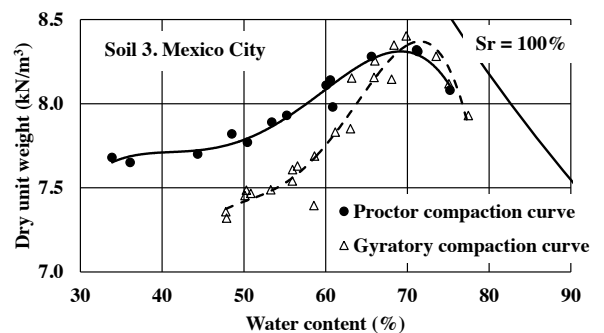

Figure 13. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil 3. Mexico City.
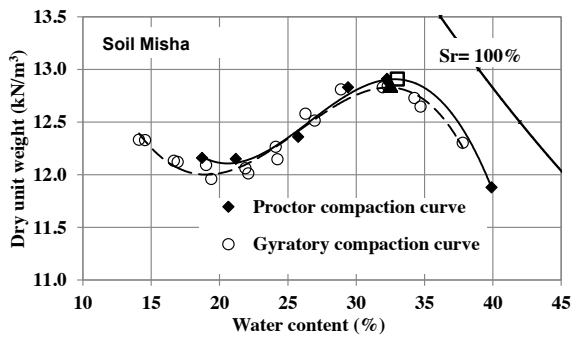
3063

Figure 14. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Misha.
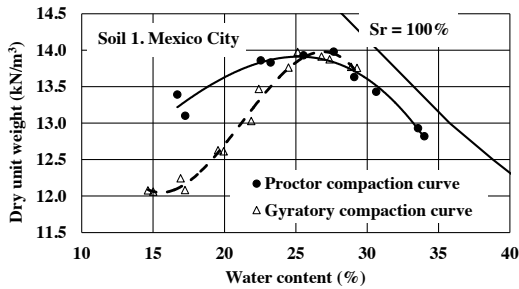

Figure 15. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil 1. Mexico City.
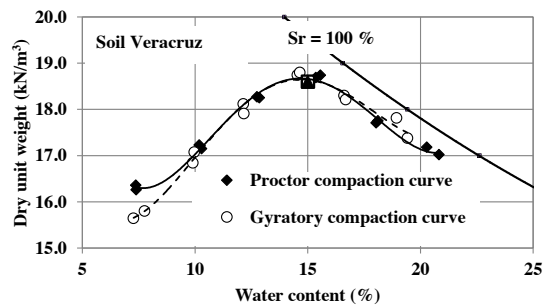

Figure 16. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Veracruz.
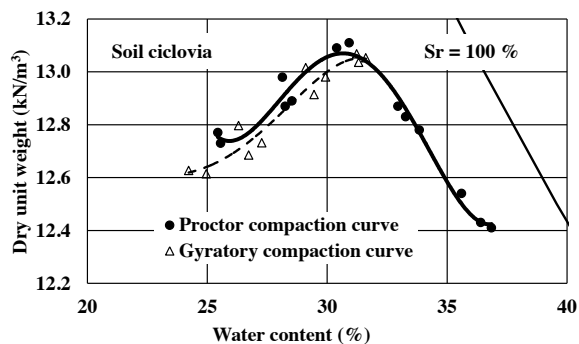

Figure 17. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil ciclovia.
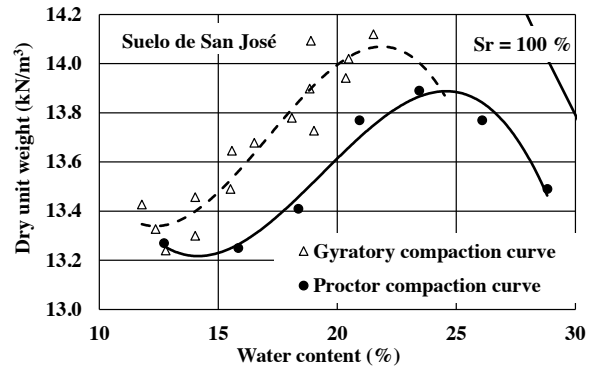

Figure 18. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil San Jose.
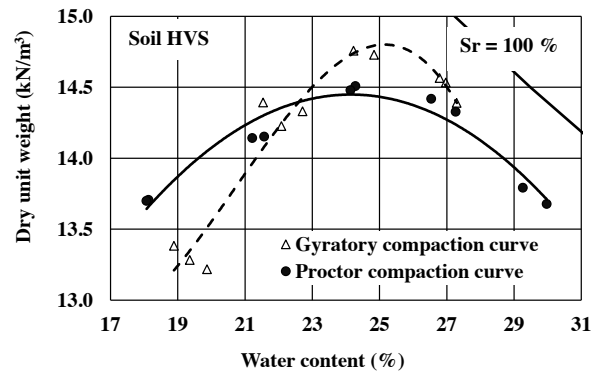

Figure 19. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil HVS.
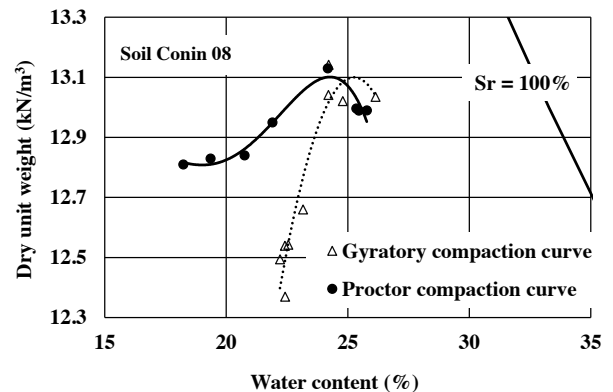

Figure 20. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Conin 08.
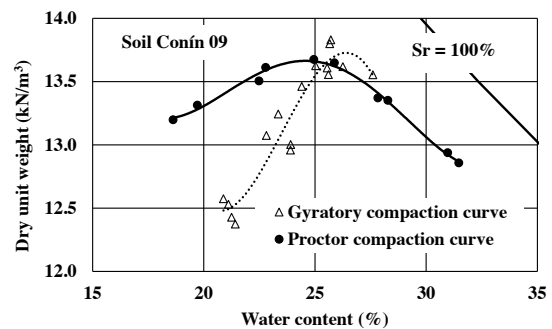

Figure 21. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Conin 09.
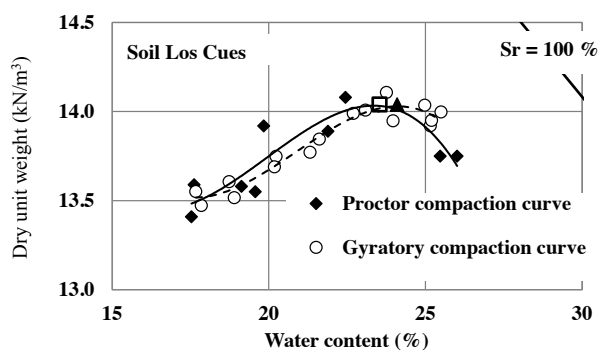
Figure 22. Compaction curves obtained with gyratory compactor and Proctor compaction curve for soil Los Cues.

To obtain the gyratory compaction curves different vertical pressures were required as shown in Table 2.

Table 2. Index properties and soils classification.

Soil ID	Atterberg Limits		Passing 200 sieve (%)	USCS	VP (kPa)
	LL (%)	LP (%)			
Clay IMT	66	41	86.0	CH	200
Clay Gasera,	91	32	96.0	CH	200
Clay, Lago La Venta	69	45	87.0	CH	400
Soil CL	33	22	78.86	CL	150
Soil all in one	38	15	57.24	CL	150
Soil Galera	59	26	89.60	MH	350
Soil Guadalajara	64	30	63.7	MH	350
Soil 2. Mexico City	61	38	72.84	MH	310
Soil 3. Mexico City	87	58	84.68	MH	400
Soil Misha	44	11	87.0	ML	400
Soil 1. Mexico City	36	26	63.90	ML	150
Soil Veracruz	23	8	31.0	SC	200
Soil ciclovia	NP	NP	28.52	SM	250
Soil San José	NP	NP	13.30	SM	100
Soil HVS	51	30	43.70	SM	50
Soil Conin 08	NP	NP	32.90	SM	50
Soil Conin 09	NP	NP	32.20	SM	80
Soil Los Cues	NP	NP	37.0	SM	550

Note: VP = Vertical Pressure.

The resulting compaction curves indicate that, for some soils, the curve obtained with the gyratory equipment is similar to the curve obtained with the traditional method. However, for non-plastic soils, the compaction curves obtained with gyratory equipment differs in the dry side. Both methods provide similar results for water contents above the optimum.

With draining soils (non-plastic soils), care must be taken when determining the compaction curve with gyratory equipment, since it is precisely at the optimum point where water begins to drain and the dry unit weight tends to increase due to the decrease in water content. For this reason, it is difficult to compact samples above the optimum water content, which makes it difficult to define the wet side of the compaction curve.

In draining soils, the compaction curve obtained in gyratory equipment differs from the Proctor compaction curve obtained with the traditional method. Examples of these soils were Conin 08, Conin 09, San Jose, all-in-one material, etc.

In general, according to the above results, for CH and CL type soils, the standard Proctor compaction curve could be determined with a vertical pressure between 150 and 200 kPa. For SM type soils, is approximately 100 kPa. For MH soils, 350 and 400 kPa. It should be noted that the vertical pressures would be the above mentioned, however, the other variables should be kept constant as shown in section 4.2.

5 CONCLUSIONS

At the beginning of the investigation it was thought that soils with similar classifications might result in the same vertical pressures to obtain the curve with the gyratory compactor, however, this was not the case, as the results indicate that similar soils cannot necessarily be compacted with the same vertical pressure. On the other hand, the results clearly show that for draining soils, the dry side of the curve shows lower volumetric weights with respect to those obtained with the traditional method, in addition, the slope of the same side of the curve is steep, indicating that a small increase in water content causes an important change in dry volumetric weight.

In order to arrive at a more definitive procedure, it is necessary to consider the effect of other variables, for example, the amount of soil to be prepared, since in this case 1000 grams of soil were utilized.

6 ACKNOWLEDGEMENTS

7 REFERENCES

Browne, M. J. (2006). Feasibility of using a gyratory compactor t o determine compaction characteristics of soil. Tesis de maestr ía. Universidad Estatal de Montan. Noviembre 2006.

Camacho, T. J. F., Reyes, O. O. J. y Méndez, G. D. F. (2007). E nsayo de compactación giratoria en suelos como una alternativ a al ensayo de compactación Próctor. Ciencia e Ingeniería Ne ogranadina, vol. 17-2. Pp. 61-81. Diciembre de 2007.

Khaled, Z. S. M., Abed, A. H., Nsayif, T. S. (2017). Significance of using superpave gyratory compactor to simulate field com paction of fine grained soil. Al-Nahrain Journal for Engineerin g Sciences (NJES). Vol. 20, No. 3, 2017. Pp. 641-646.

Perez, G. N., Garnica, A. P., Fredlund, D., Reyes, M.A., García, C. M., and Pérez, L. R. (2016). Compaction and mechanical properties of soils compacted in the gyratory compactor. Revis ta Infraestructura Vial. Vol. 18. Número. 31, Julio 2016. Pp. 2 0-29.