STUDYING APPLICATIONS OF EXPLOSION ENERGY TO ENHANCE SOIL DENSITY IN FOUNDATION

Van Thuy Do[1,*], Tung Lam Vu[1]

[1]*Le Quy Don Technical University, Hanoi, Vietnam*

Abstract

This article applies experimental methods in the laboratory to determine the increase of soil density with explosive energy. The results show that soil moisture, explosive mass, and the distance between compacted soil and the explosion centre have influenced the compaction of the studying soil significantly. In addition, these results illustrate that the research problem is feasible and can be applied to compact the foundation with explosion energy.

Keywords: *Foundation; soil density; moisture; explosion energy*.

1. Introduction

Nowadays, with the remarkable development of the road and air transport system to meet the needs of goods and people's transportation, it is required that the road surface system ensures the safe transportation of goods and services vehicles. In particular, the foundation is an indispensable part, having to satisfy the technical requirements during the construction process is always an important and worthy issue [1].

In the world, there are many methods of treating soft soil in embankment construction to change the physical and mechanical properties of the foundation such as: replacing the soil, using reinforcing piles, lowering the groundwater level, using binders, compacting the ground by mechanical means, using chemicals or explosion energy and the like, widely applied in the fields of the national economy [1-6].

In fact, the research and application of explosion energy to treat the soft soil of countries around the world is still their secret. Therefore, the application of explosion energy to enhance soft soil density in embankment construction should be studied in Vietnam, especially suitable for military conditions with the advantages of ensuring fast processing, simple construction, and use of available explosives of the National Defense.

Thus, through the experimental study of explosion in the laboratory (change in soil moisture, change in explosion mass, post-explosion soil sampling at different locations from the explosion center) to determine the density of the soil increased under the effect of explosion energy, thereby confirming the applicability of this method in reinforcing soft soil. The scope of the author's research on soil is gravel soil, taken from Hoa Lac - Son Tay - Hanoi [7].

* Email: dovanthuyhvktqs@gmail.com
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2. Analyzing the theoretical basis of explosion in infinite solid surroundings

According to explosion theory, soil with acoustic stiffness of $\rho.c \leq 5 \cdot 10^5$ g/cm^3.s include sub sand, clay, sub clay, dirt, etc. These types have very small compressive intensity and shear intensity (negligible destruction energy) which are destroyed mainly by the expansion kinetic energy of the explosive products in the explosion chamber. When detonating the spherical concentrated explosive in an infinite solid surrounding, under the effect of high pressure of the explosive product of about 10.5 MPa, the ground around the explosive is strongly compressed, and the compression spreads from the layer to others as a compressed wave. The compressive wave strength decreases as it moves away from the explosion center. The result is the formation of a hollow chamber around the explosive charge, along with compacted soil around the cavity. The degree of compaction decreases gradually as it moves away from the explosion center. At a limited distance away from the explosion center, the energy in the compression wave decreases, so it is not enough to compress the ground and then converts into a shaken wave.

Depending on the soil characteristics and explosion conditions, the degree of soil compaction around the explosion chamber is achieved to different degrees. If the explosion is close to the ground, an explosion funnel will be formed, then the soil is destroyed and the explosion will not have the effect of compressing the soil.

According to explosion theory, the radius of the void formed around the explosive concentration when an underground explosion has the following form [2, 3]:

- With the amount of spherical explosion:

$$r_b = m \cdot r_o \tag{1}$$

- With a long cylindrical explosion:

$$r_{by} = m_y \cdot r_{oy} \tag{2}$$

where m and m_y are coefficients that depend on the type of soil (see Appendix 7-2 document [2]), r_0 and r_{0y} are the radii of spherical and long cylindrical explosives, m.

At present, the explosion theory has not provided a theoretical formula for the dependence of the soil compaction around the explosion chamber on the explosive quantity and soil characteristics [2-6]. Therefore, it is necessary to study this issue experimentally, within the scope of the article's research, the authors go into researching this content by experimenting in the laboratory with gravel soil taken from Hoa Lac - Hanoi [7].

3. Experimental study in the laboratory

3.1. Experimental model and types of equipment

The experimental soil is gravel soil collected from Hoa Lac - Son Tay - Hanoi, with sufficient sample volume for testing and representative of the sampling area [7].

a) Experimental model

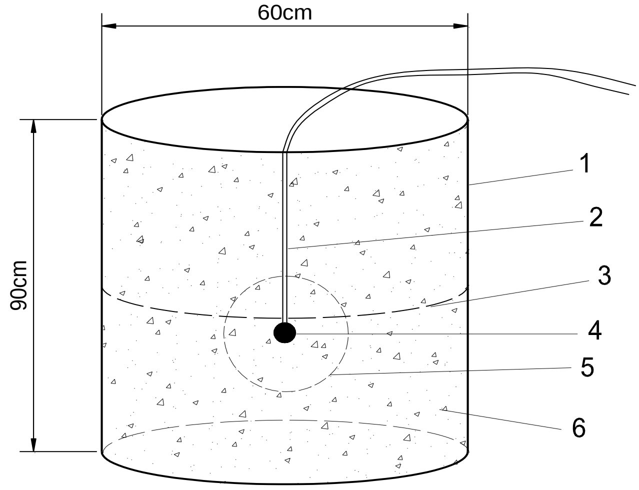

Fig. 1. Experimental model

1 - Non-iron barrel, size d × h = (60 × 90) cm; 2 - Wire detonator;

3 - Location of drum cutting; 4 - The amount of detonation placed at the center;

5 - Explosion hopper; 6 - Experimental soil.

b) Experimental equipment

The types of equipment used to conduct explosion experiments to determine the increased density of the experimental soil under the effect of explosion energy, including compaction, technical balance with an accuracy of 0.01 g, explosion quantity (1 g and 2 g detonators), sampler, detonator, fire point equipment, ignition wire, shovel, oven, sample container.

3.2. Experimental steps

• *Step 1: Preparing the soil, explosion test equipment*

The soil is pre-ground and uses a water sprayer to create moisture for the soil (the author's team creates moisture and leaves for a while to have a uniform relative humidity of the whole soil sample, then conducts the next step experiment).

Fig. 2. Prepare soil for testing.

• ***Step 2: Putting the soil into the mold, and compacting it as required*** [8, 9]

- Put the test sample into the pre-prepared model divided into 3 layers, each layer occupies about a third of the volume of the model.

- Use a free-falling compactor at a height of 30 cm for each layer, allowing the hammer to fall freely and evenly distributed on the ground.

- The number of hammers per layer is 25 times.

Fig. 3. Compact the soil.

• ***Step 3: Carrying out the arrangement of explosive*** [3]

- When pouring soil into the mold to about 1/2 of the mold body, proceed to place a guide pipe to arrange the detonator later, then proceed to put the soil into the mold and compact it to the end of the mold volume.

Fig. 4. Place the guide pipe to arrange the explosive charge.

- After completing the compaction work, proceed to withdraw the pipe to create a detonator hole, install the detonator and fill the detonator hole with soil to make the detonator firmly fixed.

- Connect the detonator wire to the ignition device through an electrical conductor, the ignition device is located away from the test sample to keep it safe when detonating.

Fig. 5. Deployment of explosive.

• ***Step 4: Carrying out an explosion*** [3, 4]

After arranging the explosive quantity, and re-checking the wiring, re-checking the safety, proceed to the point of fire to cause the explosion.

Fig. 6. Explode by fire point equipment.

• ***Step 5: Sampling and sample testing*** [8, 9]

- After the explosion, dig out the soil from the mold, dig to the location of the explosion chamber and measure the parameters of the explosion chamber (1/2 part of the lower explosion chamber).

- Sampling to determine the increase in density: Samples are taken at different distances from the explosion center and numbered for ease of assessment.

Fig. 7. Measurement of explosion chamber parameters.

Fig. 8. Sampling to determine post-explosion tightness.

3.3. Analyzing experimental results

Test results were carried out on the same soil, with two different moisture levels, and using two different types of explosives. The obtained results are presented below.

a) Comparison of the change of explosive mass to the dry density value of soil with the same moisture

Tab. 1. Compare the dry density value of the soil sample with moisture w_1 (w_1= 10.38%), when using 1 g and 2 g explosives

Numerical order	**Sampling location away from the explosion center (Sampling Radius) (cm)**	**Dry unit weight at w_1 with explosive 1 g (g/cm^3)**	**Dry unit weight at w_1 with explosive 2 g (g/cm^3)**
1	4	1.45	1.58
2	5	1.41	1.51
3	6	1.33	1.45
4	7	1.24	1.40
5	8	1.21	1.37
6	9	-	1.35
Dry density of soil before an explosion		**1.20**	**1.34**

From there, we build a graph to compare the effect of changing the explosive volume on increasing the soil compaction (through the value of dry density), by the linear regression method, we get the following graph:

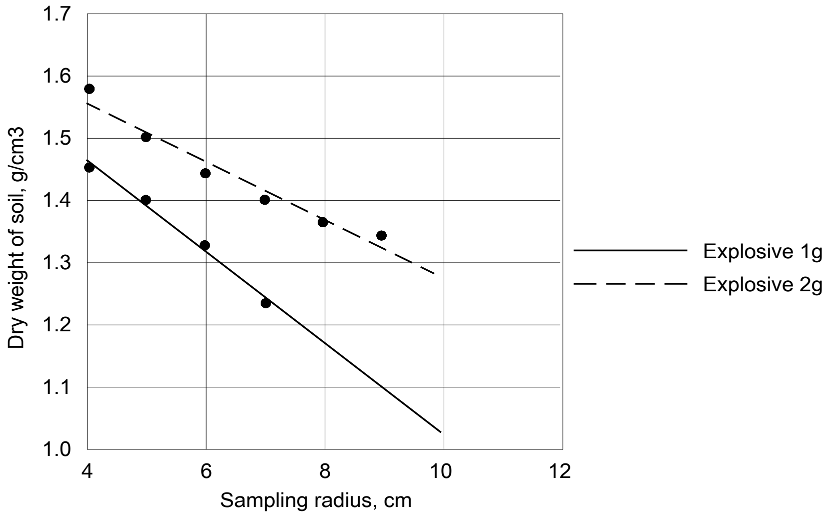

Fig. 9. Comparison chart of the effect of explosive mass change on the dry density value of soil at moisture w_1.

Comment: Through Fig. 9 and experimental results, it is found that for moisture w_1 when the explosive mass increases, the effective range of 2 g explosive is larger than using 1 g explosive. Since then, the soil density increases when using explosive 2 g compared to using explosive 1 g.

Tab. 2. Compare the dry density value of the soil sample with the moisture w_2 (w_2 = 17.15%), when using 1 g and 2 g explosives

Numerical order	**Sampling location away from the explosion center (Sampling Radius) (cm)**	**Dry unit weight at w_2 with explosive 1 g (g/cm^3)**	**Dry unit weight at w_2 with explosive 2 g (g/cm^3)**
1	4	1.61	1.72
2	5	1.56	1.66
3	6	1.53	1.60
4	7	1.47	1.54
5	8	1.44	1.50
6	9	1.39	1.45
7	10	1.34	1.41
8	11	1.32	1.37
9	12	-	1.34
10	13	-	1.31
Dry density of soil before an explosion		**1.31**	**1.30**

Similarly, we can also build a graph comparing the change of dry density of soil with moisture w_2 when changing explosive mass.

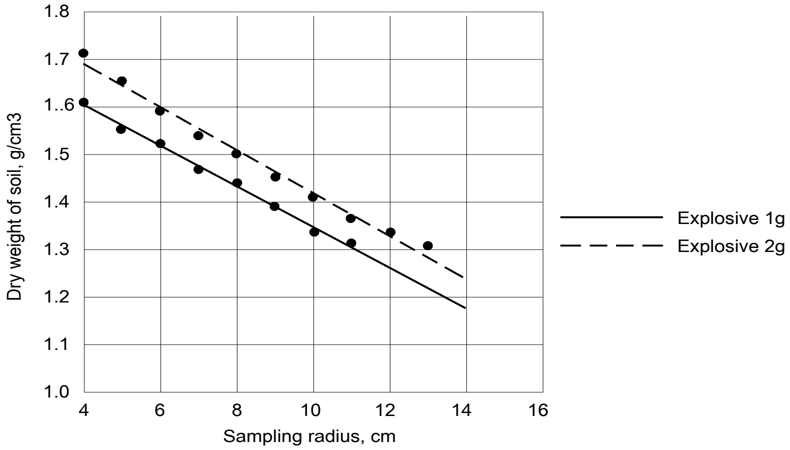

Fig. 10. Comparison chart of the effect of explosive mass change on the dry density value of soil at moisture w_2.

Comment: Through Fig. 10 and experimental results, it is found that for moisture w_2 when the explosive mass increases, the effective range of 2 g explosive is larger than using 1 g explosive. Since then, the soil density increases when using 2 g explosives compared to using 1 g.

From the above results, we can see that the dry density value of the soil sample increases with the growth of explosive mass, so to rise the soil compaction, it is necessary to choose a reasonable amount of explosives to increase the compaction efficiency.

b) Comparison of the change in moisture to the dry density value of the soil using the same type of explosive

Tab. 3. Compare the value of dry density of soil samples when using explosive 1 g, in 2 cases moisture w_1 and moisture w_2

Numerical order	**Sampling location away from the explosion center (Sampling Radius) (cm)**	**Dry unit weight at w_1 with explosive 1 g (g/cm^3)**	**Dry unit weight at w_2 with explosive 1 g (g/cm^3)**
1	4	1.45	1.61
2	5	1.41	1.56
3	6	1.33	1.53
4	7	1.24	1.47
5	8	1.21	1.44
6	9	-	1.39
7	10	-	1.34
8	11	-	1.32
Dry density of soil before an explosion		**1.20**	**1.31**

We can build a graph comparing the change of dry density value of soil when using explosive 1 g, in 2 cases of moisture w_1 and moisture w_2.

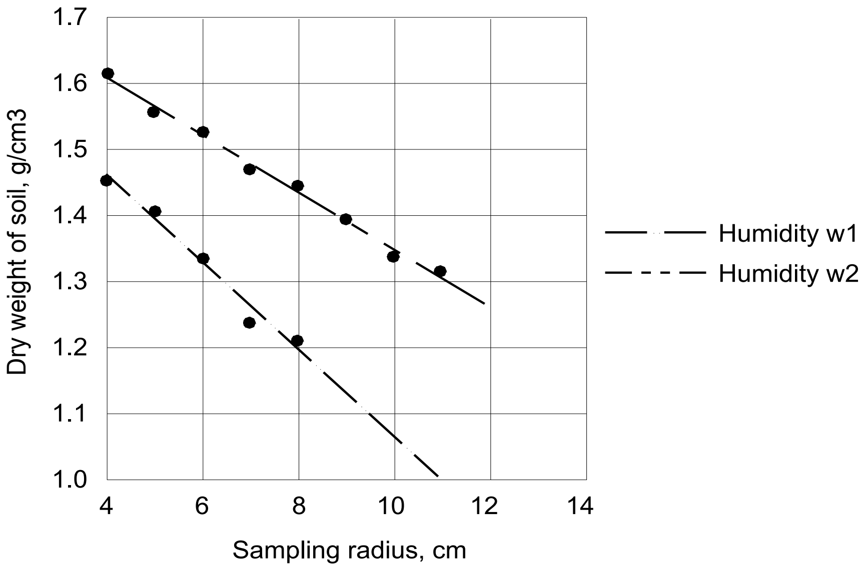

Fig. 11. The graph compares the effect of changing the moisture of the experimental soil on the dry density value of the soil when using explosive 1 g.

Tab. 4. Compare the value of dry density of soil samples when using explosive 2 g, in 2 cases moisture w_1 and moisture w_2

Numerical order	Sampling location away from the explosion center (Sampling Radius) (cm)	Dry unit weight at w_1 with explosive 2 g (g/cm^3)	Dry unit weight at w_2 with explosive 2 g (g/cm^3)
1	4	1.58	1.72
2	5	1.51	1.66
3	6	1.45	1.60
4	7	1.40	1.54
5	8	1.37	1.50
6	9	1.35	1.45
7	10	-	1.41
8	11	-	1.37
9	12	-	1.34
10	13	-	1.31
Dry density of soil before an explosion		**1.34**	**1.31**

Similarly, we can also build a graph comparing the change of dry density value of soil when using explosive 2 g, in 2 cases of moisture w_1 and moisture w_2.

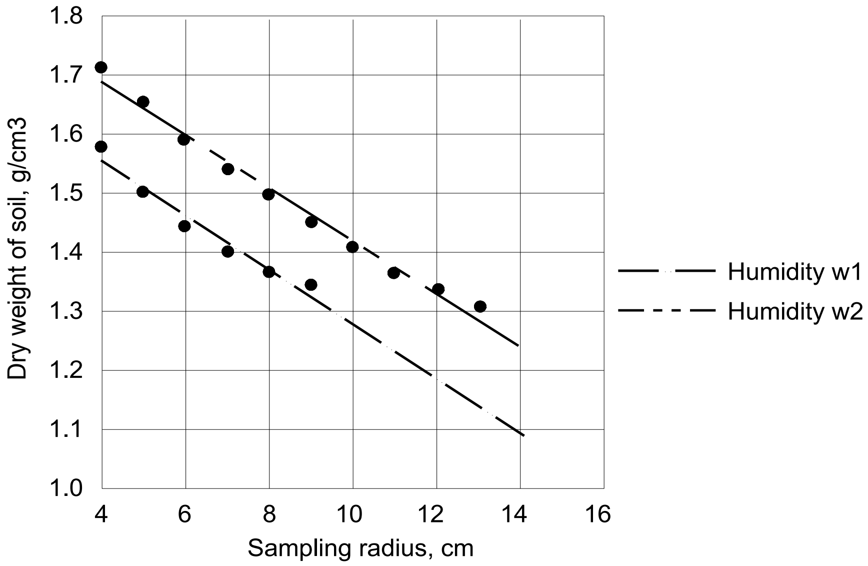

Fig. 12. The graph compares the effect of changing the moisture of the experimental soil on the dry density value of the soil when using explosive 2 g.

Comment: Through Fig. 11 and Fig. 12, it can be seen that, with the same explosive mass, when changing the experimental soil moisture value, the efficiency of explosive energy to increase the density of the foundation also changes. Specifically, when the soil humidity is close to reaching the optimal moisture value according to [7], the value of the dry density of the soil is larger, which is consistent with the theory of optimal soil moisture efficiency when using the same compaction.

From comparing four tables and four figures above, it illustrates that to achieve the effect of explosion energy to increase the soft soil density, not only use the type of explosion suitable for specific conditions but also achieve the optimal moisture of the soil for ensuring both technical requirements and economic requirements.

4. Discussion and conclusion

The application of explosion energy to enhance soil density of the foundation is a content that needs to be studied more deeply and widely because it is highly feasible.

For the type of soil studied, the experimental results show that:

- Soil moisture has a significant influence on the work of increasing the compaction of the foundation. With the same type of explosive volume, detonating at the moisture value w_2 = 17.15% will give the value of compaction and the distance of compaction from the center of the explosion higher than the moisture value w_1 = 10.38%. This is completely consistent with the study on the optimal moisture of each type of soil for the compaction of the ground in the construction of the road foundation (moisture of 17.15% is close to the optimal moisture value of the studied soil 18.5% [7]).

- Explosive mass also has a noticeable effect on increasing the compaction of the foundation. Together with fixed soil moisture, a 2 g explosive mass will give a higher value of compaction and distance from the center of the explosion than with a 1 g. However, it is necessary to study specifically the number of explosives used, because it is possible that when the amount of explosives is too large, it will not be able not only to compact the soil, but also to cause damage to the intact structure of the soil, and at the same time can not be controlled the density of the upper soil layers. Therefore, it is necessary to use a reasonable explosive volume to have both economically efficient and the highest compacting effect.

- The degree of soil compaction around the explosion chamber is different, which is shown by the distance of soil sampling after detonating from the explosion center. The closer to the explosion center is, the higher the density of the soil is, the further away from the explosion center is, the less compaction of the soil is, and depending on the case study, with a limited distance from the explosion center the soil is no longer compressed.

In summary, the application of explosion energy to increase soil density is feasible and required to study. The use of appropriate explosive mass, as well as optimum soil moisture during construction, is very important to the effectiveness of this method.

References

[1] Pierre Laréal, Nguyễn Thành Long, Nguyễn Quang Chiêu, Vũ Đức Lục, *Công trình trên nền đất yếu trong điều kiện Việt Nam*. Nxb Giao thông vận tải, 2001.

[2] Nguyễn Quang Trung, Lê Hồng Đức, Võ Thanh Tùng, *Giáo trình công tác nổ - Tập 1*. Học viện Kỹ thuật Quân sự, Hà Nội, 1998.

[3] Nguyễn Văn Tính, Đàm Trọng Thắng, Nguyễn Hoài Nam, *Công tác nổ mìn*. Nxb Quân đội Nhân dân, Hà Nội, 2012.

[4] Trần Anh Vinh, *Khoan - nổ mìn*. Nxb Khoa học và Kỹ thuật, Hà Nội, 1972.

[5] Dam Trong Thang, Nguyen Tri Ta, Vu Xuan Bang, "Study on the velocity potential field of the group of parallel long cylindrical charges," *Section on Special Construction Engineering/Journal of Science and Technique*, No. 04, pp. 70-80, 2020.

[6] Trong Thang Dam, Tri Ta Nguyen, Xuan Bang Vu, "Study on the reasonable spacing of flat charge in the form of long and parallel cylindrical charges for breaking rock," *Section on Special Construction Engineering/Journal of Science and Technique*, Vol. 04 No. 02, pp. 57-71, 2021.

[7] Đỗ Văn Thuỳ, Nguyễn Văn Hiếu, "Nghiên cứu độ ẩm tối ưu của đất sỏi sạn đối với công tác đầm nén đất khi thi công xây dựng nền đường," *Tạp chí Cầu đường Việt Nam*, ISSN 1859-459X, 2021.

[8] *Đất xây dựng - Phương pháp xác định độ chặt tiêu chuẩn trong phòng thí nghiệm*, Tiêu chuẩn Quốc gia TCVN 4201:2012.

[9] *Phương pháp xác định độ chặt của đất sau đầm nén tại hiện trường*, Tiêu chuẩn Quốc gia TCVN 8730:2012.

NGHIÊN CỨU ỨNG DỤNG NĂNG LƯỢNG NỔ LÀM TĂNG ĐỘ CHẶT NỀN ĐẤT

Đỗ Văn Thùy[1], Vũ Tùng Lâm[1]

[1]*Đại học Kỹ thuật Lê Quý Đôn, Hà Nội, Việt Nam*

Tóm tắt: *Bài báo áp dụng phương pháp thực nghiệm trong phòng thí nghiệm để xác định việc làm tăng độ chặt của nền đất bằng năng lượng nổ. Kết quả nghiên cứu cho thấy, độ ẩm của đất, khối lượng lượng nổ và khoảng cách nén ép của đất từ tâm nổ có ảnh hưởng quan trọng tới độ chặt của loại đất nghiên cứu. Ngoài ra, kết quả này cho thấy vấn đề nghiên cứu là khả thi và có thể áp dụng để đầm nén nền đất bằng năng lượng nổ.*

Từ khoá: Nền đất; độ chặt của đất; độ ẩm; năng lượng nổ.

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