# Influence of Compaction Factor on the mechanical behavior of the soils used for the earth dams in the North Central region, Vietnam

Van Toan TRAN[1] and Van Hien TRAN[2]

[1] Thuy Loi University, 175 Tay Son, Dong Da, Ha Noi, Vietnam
[2] Hydraulic Engineering Consultants Corporation No.II, 169 Tran Quoc Thao, District 3, Ho Chi Minh, Vietnam
tranvantoan@tlu.edu.vn and hienhecii@gmail.com

**Abstract.** Almost all the earth dams constructed in the North Central region of Vietnam usually encounter problems related to the use of cohesive soils during dam construction under humid climate conditions with long and heavy rain periods. Therefore, it is very difficult to compact the soil to achieve the compaction factor of $K \geq 0.97$ required by the designer. In this paper, the authors present experimental results to determine the correlation between the compaction factor ($K$) with the mechanical behavior of the soils used for the earth dams in the North Central region of Vietnam. The research results are applied to select the reasonable value of compaction factor for the soils used in dam construction, which is suitable with the requirements of the design standard.

**Keywords:** Earth dam, compaction factor, mechanical behavior, permeability coefficient, soil moisture content.

## 1 Introduction

In recent years, most of the earth dams constructed in the North Central region of Vietnam usually encounter problems related to the use of cohesive soils in dam construction under humid climate conditions with long and heavy rain period. There are usually two main types of soil used for waterproofing blocks and bearing blocks of earth dams which are sediment and ruin soil. The key constructions in provinces from Thanh Hoa to Thua Thien Hue such as: Truoi, Ta Trach, Ngan Truoi, Cam Thuy, Thuy Yen – Thuy Cam, Da Han, Ban Mong, ... are in regions that always experience high moisture content in the air and long rainy time [1]. The air moisture content in many months is greater than 80%. Therefore, it is very difficult to compact the soil to achieve the compaction factor of $K \geq 0.97$ corresponding to the soil moisture $W = W_{opt} \pm 3\%$ ($W_{opt}$ - Optimal moisture content) required by the design standard [2], [3], [4]. As a result, the construction time lasts longer and it does not meet the construction progress or economic and social development requirements. This reduces the effectiveness of the investment and leads to a long time of capital recovery.



C. Ha-Minh et al. (eds.), *CIGOS 2019, Innovation for Sustainable Infrastructure*,
Lecture Notes in Civil Engineering 54,
https://doi.org/10.1007/978-981-15-0802-8_115

In this paper, the authors present the experimental results to determine the correlation between the compaction factor (*K*) with mechanical properties of soils in the North Central region of Vietnam: friction angle ($\varphi$), cohesion (*c*) and permeability coefficient (*k*): ($\varphi$, *c*, *k*) ~ *K* [5]. The research results will help designers select the reasonable value of soils compaction factor during earth dam construction [4].

## 2 Methodology

This work is a combination of experimental tests in the laboratory and in the execute construction work for two types of soil: sediment and ruin rock. Laboratory experiments determine the soil moisture content at the material storage at several periods of the year, *17* mechanical properties, swelling, shrinkage and wet disintegration. Field experiments determine the particle components, permeability coefficient *k*, cohesion *c*, and friction angle $\varphi$ after the soil covered in the dam to reach the requirements of the design. Experimental results in the field will be compared and be verified with laboratory experimental results.

**Table 1.** Statistical table of laboratory test number [5].

| No | Earth dam | Experimental content | No. of tests |
|---|---|---|---|
| 1 | Ta Trach | 17 mechanical properties | 17 |
| | | *K, k, φ, c, W* curve | 22 |
| 2 | Ngan Truoi | *17* mechanical properties | 17 |
| | | *K, k, φ, c, W* curve | 11 |
| 3 | Thuy Yen | *17* mechanical properties | 17 |
| | | *K, k, φ, c, W* curve | 22 |

The experiments were carried out from August 2010 to February 2016 for soil sediment and ruins soil types in the works Ta Trach dam, Thuy Yen dam and Ngan Truoi dam. The number of experimental sample group is summarized in Table 1.

## 3 Experimental results in the laboratory

### 3.1 Sediment soil

Experimental results in Table 2 show characteristics of sediment soil in the study region. The results of the proctor experiment showed that the natural moisture content of the sediment soil is usually 3% higher than the optimal moisture content.

Through laboratory studies, the author built relations between [compaction factor (*K*) and moisture content of soil (*W*)] with [friction angle ($\varphi$), cohesion (*c*), permeability coefficient (k) and dry density] as shown in Fig. 1, Fig. 2 and Fig. 3.

**Table 2.** Characteristics of sediment soil

| No | Characteristics | Earth dam | | | |
|---|---|---|---|---|---|
| | | Ta Trach | Ta Trach 1 | Ngan Truoi | Thuy Yen |
| 1 | Maximum dry density $\gamma_{cmax}$(T/m$^3$) | 1.55 | 1.62 | 1.47 | 1.78 |
| 2 | Natural density $\gamma_w$(T/m$^3$) | 1.94 | 1.99 | 1.86 | 2.08 |
| 3 | Optimum moisture content $W_{opt}$(%) | 22.1 | 21.9 | 23.5 | 16.7 |
| 4 | Natural moisture content W(%) | 25.2 | 23.1 | 26.2 | 19.7 |
| 5 | Density Δ | 2.66 | 2.72 | 2.71 | 2.70 |
| 6 | Porosity n(%) | 48.2 | 48.4 | 40.9 | 38.6 |
| 7 | Saturation G(%) | 92.0 | 94.5 | 91.8 | 89.5 |
| 8 | Permeability coefficient k(cm/s) | $1.10^{-4}$ | $7.10^{-5}$ | $1.10^{-4}$ | $9.10^{-5}$ |
| 9 | Cohesion c(kG/cm$^2$) | 0.19 | 0.24 | 0.19 | 0.21 |
| 10 | Friction angle φ(°) | 17°46' | 15°26' | 17°59' | 22°31' |

Fig. 1 shows that the permeability coefficient decreases when compaction factor increases. When $K \geq 0.94$, the permeability coefficient is $k \approx 3 \times 10^{-5}$(cm/s) and stability when $K$ increase.

Fig. 2 showed that the friction angle $\varphi$ covariates with the compaction factor $K$ and rise slightly to reach the largest value when $K \geq 0.93$. This is suitable with the general rule. If we increase $K$, the effect of $\varphi$ will not increase much.

Fig. 3 shows that the cohesion $c$ covariates with the compaction factor $K$. When $K \geq 0.98$, c reaches the maximum value, in agreement with the general rule TCVN 8216 [1] and TCVN 8297 [4]. When the compaction factor $K=0.98$, $c$ increases *3.4%* compares to the case of $K=0.97$. After that, it did not increase significantly.

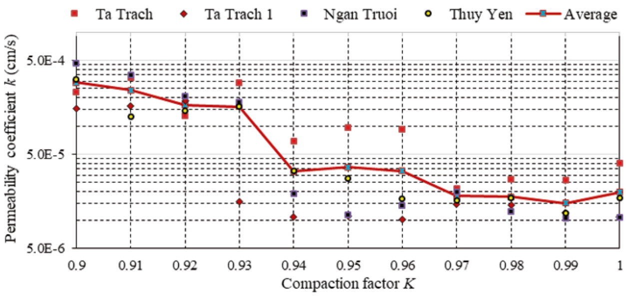


**Fig. 1.** Influence of compaction factor on the permeability coefficient ($k$ ~ $K$) of sediment soil

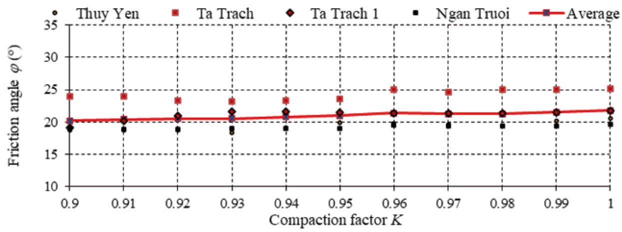


**Fig. 2.** Influence of compaction factor on the friction angle ($\varphi$ ~ $K$) of sediment soil

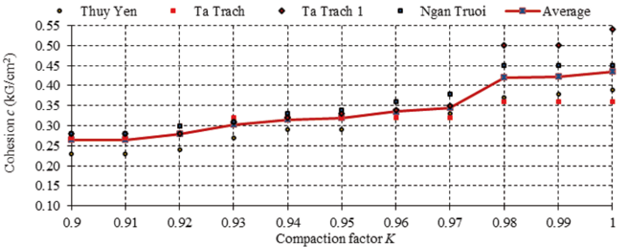


**Fig. 3.** Influence of compaction factor on the cohesion (c ~ K) of sediment soil

## 3.2 Ruin soil

Experimental results in Table 3 also show natural characteristics of ruin soil in the study region. The results of the proctor experiment also showed that the natural moisture content of the ruin soil is usually 3% higher than the optimal moisture content.

Through laboratory studies, the authors also built relations between [compaction factor (*K*) and moisture content of ruins soil (*W*)] with [friction angle ($\varphi$), cohesion (*c*), permeability coefficient (*k*) and dry density] as shown in Fig. 4, Fig. 5 and Fig. 6.

**Table 3.** Characteristics of ruin soil

| No | Characteristics | Earth dam | | | |
|---|---|---|---|---|---|
| | | Ta Trach | Ta Trach 1 | Thuy Yen | Thuy Yen 1 |
| 1 | Maximum dry density $\gamma_{cmax}$(T/m$^3$) | 1.80 | 1.75 | 1.74 | 1.68 |
| 2 | Natural density $\gamma_w$(T/m$^3$) | 2.15 | 2.08 | 2.09 | 2.06 |
| 3 | Optimum moisture content $W_{opt}$(%) | 16.5 | 17.1 | 16.8 | 20.1 |
| 4 | Natural moisture content W(%) | 19.3 | 19.1 | 20.1 | 22.8 |
| 5 | Density Δ | 2.72 | 2.67 | 2.68 | 2.69 |
| 6 | Porosity n(%) | 42.8 | 43.7 | 42.4 | 40.6 |
| 7 | Saturation G(%) | 68.4 | 65.7 | 89.5 | 90.8 |
| 8 | Permeability coefficient k(cm/s) | $2.10^{-4}$ | $1.10^{-4}$ | $6.10^{-5}$ | $3.10^{-4}$ |
| 9 | Cohesion c(kG/cm$^2$) | 0.20 | 0.18 | 0.16 | 0.17 |
| 10 | Friction angle φ(°) | 16°19’ | 17°40’ | 22°06’ | 20°00’ |

Fig. 4 shows that the compaction factor increases from $K=0.90$ to $K=0.96$, the permeability coefficient obtains from $k=10^{-4}$ (cm/s) to $k=5\times10^{-5}$ (cm/s). Then, when *K* increases, *k* is almost decreases.

Fig. 5 shows that the friction angle φ correlates to the compaction factor K and rise slightly to reach the largest value when $K\geq0.96$.

Fig. 6 shows that the cohesion *c* covariates with the compaction factor *K* and when $K\geq0.98$, *c* reaches the maximum value.

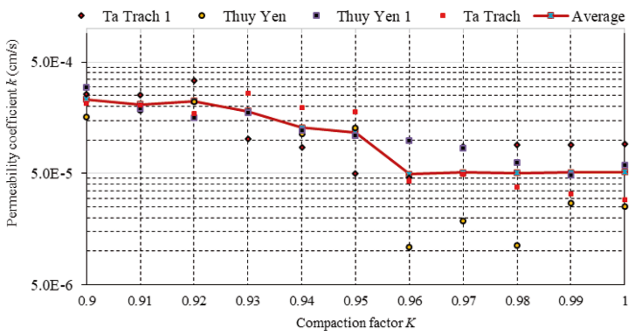


**Fig. 4.** Influence of compaction factor on the permeability coefficient ($k \sim K$) of ruin soil

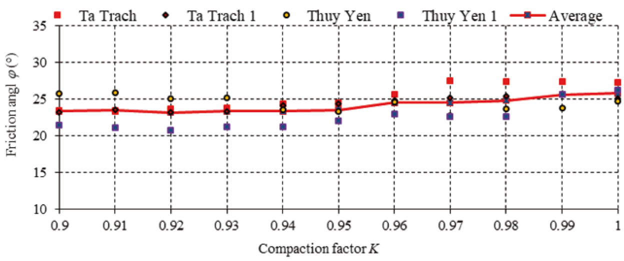


**Fig. 5.** Influence of compaction factor on the friction angle ($\varphi \sim K$) of ruin soil

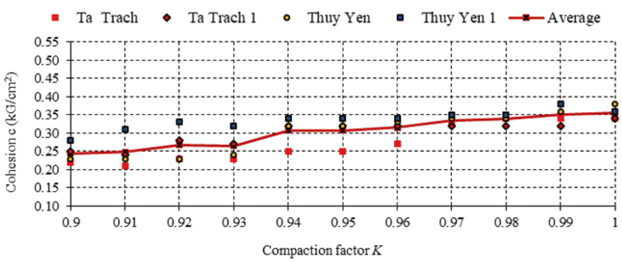


**Fig. 6.** Influence of compaction factor on the cohesion ($c \sim K$) of ruin soil

Comparing the experimental results in the field and the experimental results in the laboratory (in Table 4), the authors noticed that:

- For the permeability coefficient $k$ obtained from the experimental results in the field there is no difference in the sediment soil in the earth dam when compaction factor rises up to $K=0.97$ and $K=0.95$. This result is consistent with the experimental results in the laboratory;
- For the friction angle $\varphi$ and the cohesion $c$ of samples from drill holes in the earth dam is higher than samples from the quarry soil, but the difference is insignificant.

**Table 4.** Experimental results of sediment soil characteristics on the actual site

| No | Year | W (%) | $\gamma_w$ (T/m$^3$) | $\gamma_k$ (T/m$^3$) | k (cm/s) | φ (°) | c (kG/cm$^2$) | K |
|---|---|---|---|---|---|---|---|---|
| 1 | 2010 | 17.42 | 2.02 | 1.72 | $6.91\times10^{-6}$ | 21.12 | 0.22 | ≥0.97 |
| 2 | 2011 | 20.00 | 2.02 | 1.68 | $4.89\times10^{-6}$ | 22.73 | 0.24 | ≥0.95 |
| 3 | 2012 | 16.98 | 1.99 | 1.70 | $2.87\times10^{-6}$ | 21.51 | 0.22 | ≥0.95 |
| 4 | 2013 | 19.53 | 1.98 | 1.66 | $4.50\times10^{-6}$ | 19.22 | 0.22 | ≥0.95 |

## 4 Conclusion

The permeability coefficient *k* decreases when the compaction factor *K* increases. When the compaction factor *K* equals to $K\geq0.94$ corresponding to the soil moisture content $W=W_{opt}+3\%$, then *k* reaches the minimum value of $k\leq2.10^{-5}$ cm/s. When the compaction factor *K* is equal to $K=0.95$, the permeability coefficient in the field respectively is $k=3.63\times10^{-6}$ cm/s.

The friction angle $\varphi$ and the cohesion *c* covariates with the compaction factor *K* and these factors reach maximum values when $K\geq0.94$ for $\varphi$ and $K\geq0.98$ for *c*. The results show that the friction angle values $\varphi$ and the cohesion values *c* from holes drills samples of the earth dam are higher than from the samples of the quarry soil, but the difference is insignificant.

Thus, through the results of this experimental study, some knowledge is shown as follows:

- For the sediment soil used for the waterproofing blocks in the earth dam, the compaction factor should be chosen the value of $K\geq0.94$ corresponding the soil moisture content $W=W_{opt}+3\%$ instead of K≥0.97 in TCVN 8216, which is optimal in terms of waterproofing.
- For the ruin soil used for the bearing blocks in the earth dam, the compaction factor should be chosen the value $K=0.97$ same as in TCVN 8216, which will provide the highest stability for the earth dam.
- To ensure soil embankment on the earth dam is stabilized, it is necessary to control reasonable dam speed during construction process.

## References


1. Ministry of Agriculture & Rural Development, Profile of survey and design of the earth dams: Ban Mong, Ngan Truoi, Đa Han, Ta Trach and Thuy Yen, Hanoi (2008-2010).
2. Ministry of Construction, TCVN 8216:2009 "Design standard for compacted earth dam", Hanoi (2009).
3. Ministry of Agriculture & Rural Development, QCVN04-05:2012 "National technical regulation on hydraulic structures - The basic stipulation for design", Hanoi (2012).
4. Ministry of Construction, TCVN 8297:2009 "Hydraulics structurers – Earth dam: Technical requirements for construction by compaction method", Hanoi (2009).
5. Donald P.C., Geotechnical Engineering – Principles and Practices, Prentice Hall, Upper Saddle, NJ07458 (1999).