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"Research Note"

INVESTIGATION OF CONSTRUCTION METHOD OF A WET CORE EARTH DAM IN THE NORTH OF IRAN *

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Abstract– In this research note, a procedure for finding the specifications for compaction of the core material of an earth dam in the humid climate of the north of Iran has been presented. Laboratory experiments on the soil itself together with studies on samples taken from a test-embankment constructed in the field indicates such a procedure can be followed in order to obtain the specifications for construction of wet cores of dams in other humid regions around the world as well.

Keywords– Wet compaction, wet core, moist material

1. INTRODUCTION

Northern parts of Iran frequently experience high annual rainfall spread over the entire year and only a short dry season. The natural moisture of the local impermeable soil is often more than the optimum water content. Handling and compaction of the material in such a state is rather difficult. The material is too wet and soft to be compacted by conventional heavy equipment regularly used in dam construction. Different methods have been employed in the past for treatment of the problem. A brief review of these methods will be presented in the next section. One of these methods has been to use the relatively wet material as it is, but in a proper way. The purpose of this research note is to explain the procedure followed for finding the proper methodology of construction in a dam project in the north of Iran. It is believed that the procedure presented here can be followed in other dam projects in regions of the same climate as well.

2. A REVIEW OF MAJOR GUIDELINES

There is an old precedent of embankment construction in high rainfall areas all over the world. As a brief note, only the major guide lines that have been followed successfully are mentioned herein. For more details readers are referred to references [1] and [2].

a) Rockfill dams with upstream concrete face

The coarser the size of material grains, the easier it is to handle it under rainy weather. If the dam foundation is reasonably good rock, a rockfill dam with upstream concrete or asphalt face should be considered as an alternative. This type of dam is at least subject to construction contingencies from weather conditions in humid climates. [3, 4]

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b) Proper materials

There are some sorts of impervious soils regularly located in wet weather regions which have a low natural water content and hardly absorb moisture during construction in rainy weather, like soft and weathered rocks or coarse granular soils with relatively small contents of cohesionless fines. The granular part of such soils remains stable enough to tolerate heavy equipment, and the fine portion-or crushed stones while handling-provides required impermeability. Some examples of dams which are constructed with such materials are Swift Creek [5], Santa Rita [6], La Honda and Taguaza [4].

c) Reduction of water content

Reducing the high moisture content of the soil to nearly its optimum limit would be a solution to construction difficulties that may be achieved by air drying, heating by kilns or mixing with dryer granular materials [7-11]. The effect of the amount and shape of the added grains on the cyclic behavior of the mixture is a matter of concern in this case [12, 13].

d) Using the moist material

A method of dealing with wet material is to use it at its natural water content, although it is much higher than the optimum limit. Using such wet materials in embankment cores has a long history around the world: Puddle clay cores in England, hydraulic fill dams, the wet compaction method of Scandinavian countries and some other interesting experiences of wet core construction of dams, all being successful in dealing with wet clayey materials. In such cases the main idea is to lower the compaction energy by using light weight compactors instead of conventional heavy rollers used in dam construction [3, 4, 8, 9, 14-18].

All the above-mentioned guide lines are useful to reduce contingencies from wet weather. A combination of different methods may also be used, depending on the situation at the dam site.
Considering all probable trends, there may still be a need for using the wet material in construction as it is, without the implementation of a drying process or the addition of other materials. The rest of this note is devoted to proposing a procedure to define the proper low compaction level for this case. Though the current study has focused on a wet soil used in the construction of an earth dam in the humid climate of the north of Iran, the proposed procedure could be followed in other similar situations as well.

3. LABORATORY EXPERIMENTS

a) Classification

Standard tests were performed to obtain the physical properties and classification of the soil selected for this study. The results of the tests are presented in Table 1.

Table 1. Result of index tests for soil classification

LL	PL	PI	Classification	Gs
50	28	22	CH	2.81

b) Compaction

The compaction characteristics of the soil were studied by performing a series of compaction tests on soil samples with a different number of blows, everything else being similar to ASTM D698.

As shown in Fig. 1, in the range of water contents above optimum, a decrease in the compaction level does not make a noticeable change in dry density.

In Fig.1, some scattering is obvious in the data points of 5-blows compaction, which is due to the difficulties in performing the test at this level of compaction.

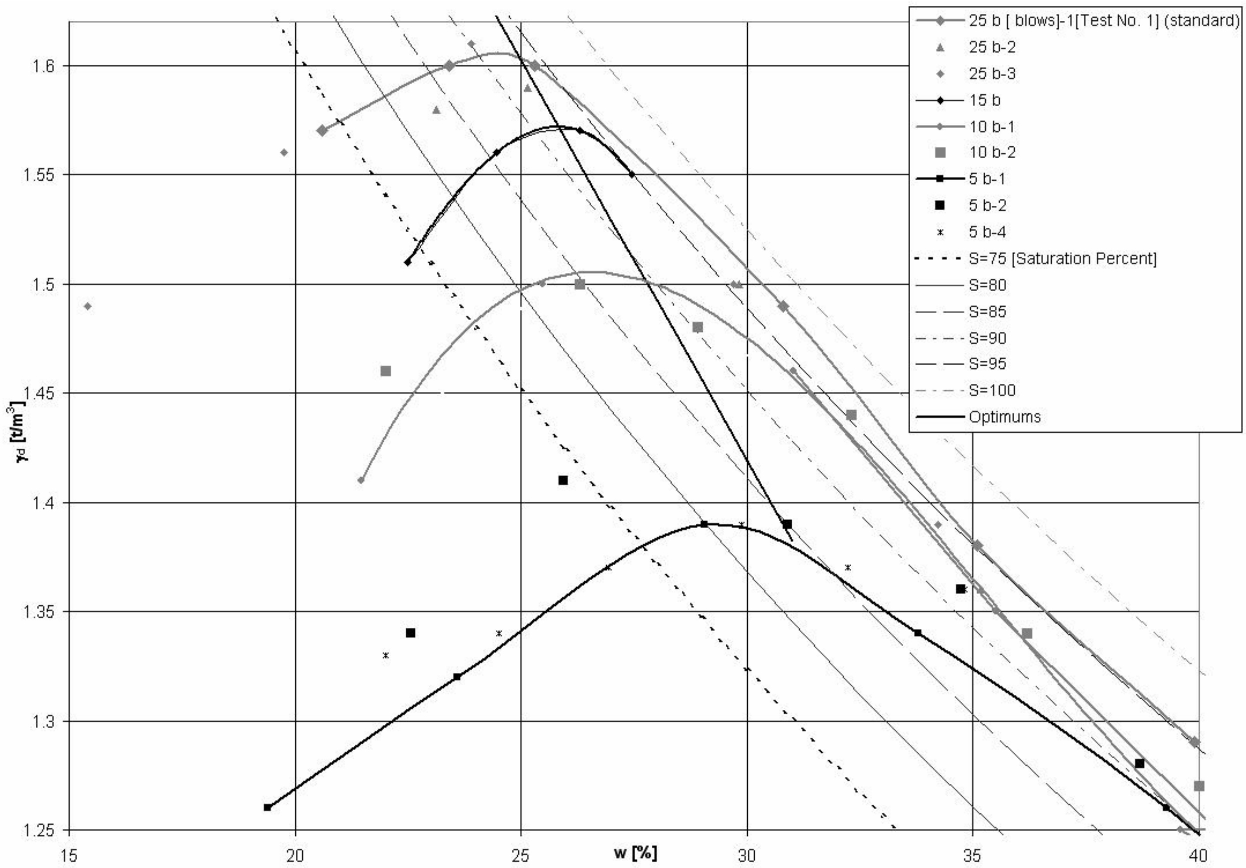

Fig. 1. Results of compaction tests performed with different compactive efforts

c) Shear strength

The next step was to determine the shear strength of the soil at different compaction levels. To capture this behavior, soil was compacted to the desired level in a standard compaction mold, trimmed to 35 mm diameter and 80 mm high samples, and tested in a triaxial apparatus.

To consider the soil situation in the wet core construction stage (which is usually managed to be as fast as possible to reduce contingencies from wet weather), UU triaxial tests were performed with a straining rate of 1 mm/min.

In accordance with the data available from the dam site, the water content of the soil in the laboratory was raised 5% above its optimum value (i.e. 5%+25%=30%, Fig. 1), to resemble the natural condition at the site. To study the behavior of the soil in this water content the samples were not saturated and the analysis was based on total stress.

Figure 2 shows the results of the 40 tests which were performed on samples of different compaction efforts at different confining pressures. Mohr circles appear as ellipses in this figure because of the difference between the horizontal and vertical scales. It is obvious from the results that an increase in the compaction effort does not increase the shear strength of the soil. The initial increase in strength with an increase in the confining pressure is due to the successive consolidation and subsequent saturation of the unsaturated samples.

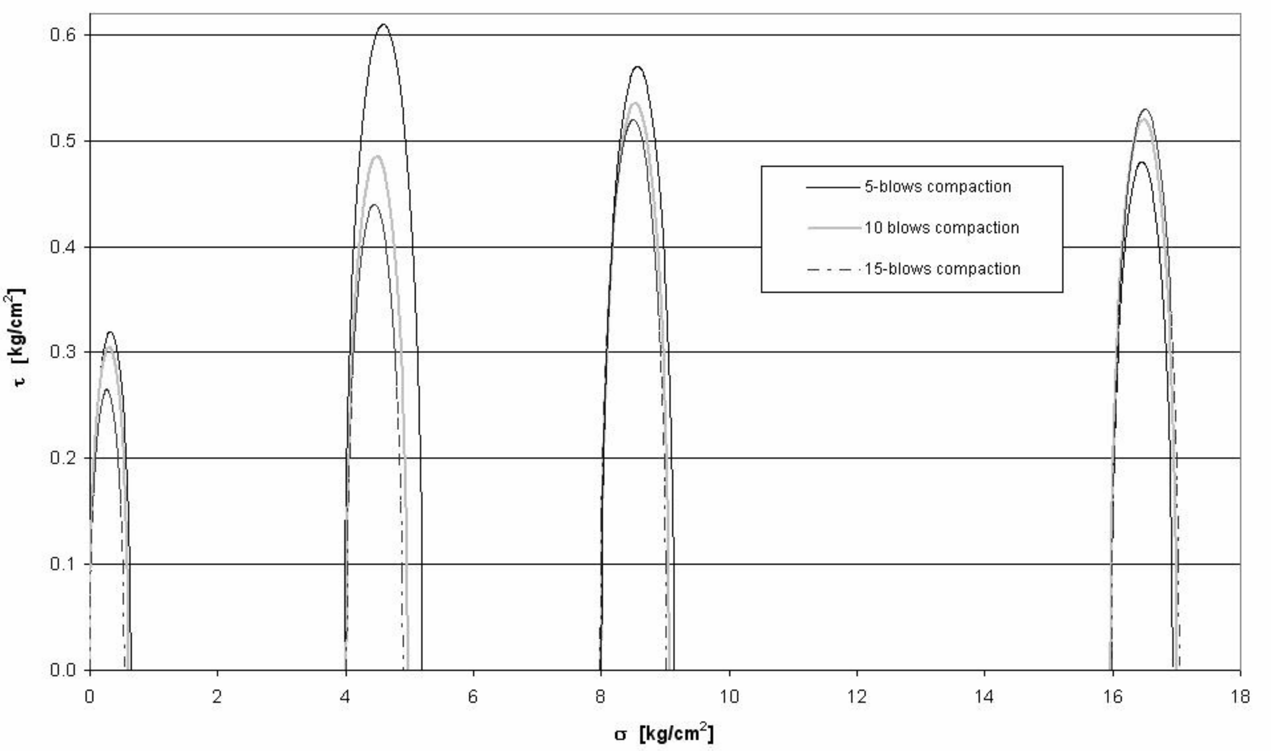

Fig. 2. Failure Mohr circles of unconsolidated undrained triaxial tests on samples prepared at different compactive efforts (w≈ 30%)

Results of compaction and shear strength tests show that an increase in the compactive effort does not result in a considerable change in the dry density and shear strength of the wet material. As a consequence, the 5-blows compaction seems to be the optimum compactive effort suitable for construction of the core because the optimum water content at this level of energy is the same as soil natural water content. As the standard compaction is gained by applying 25 blows, this means the required compaction level is gained by compactors which impose nearly 1/5 of the energy that the conventional compactors impose on the soil. This could be an initial estimate for the selection of a compactor for the field test.

4. FIELD TEST

To evaluate the experimental results in practice, a field test was performed on the same soil. The soil was wetted to 30% water content, i.e. 5% above the optimum value. A 5 ton tractor (John Deere 3140) was used to perform the compaction in the field (Fig. 3). The wetted soil was spread in a 3×10 meter area in four successive 30 cm thick layers.

After the first layer, it was detected that by 9 passages of the tractor, the maximum homogeneity would be obtained and more passes seemed useless. The average density obtained after 9 passes was $\gamma_{dry\ (w=30.4\%)} = 1.43$ t/m^3, which ideally fits data obtained from the 5-blows compaction test. (Fig. 1)

Soil samples from the field, contained a large amount of lumps which were not crushed due to weak manipulation and compaction made by the light tractor. To resemble the situation of the field in the laboratory tests, samples of soil passing from a ½ inch sieve which contained the same clumps as those in the field were prepared in the laboratory and sheared in a triaxial apparatus, which had the same results as those obtained from the field samples.


(a) (b)

Fig. 3. a) Soil was non-homogenous for initial passes, b) The desired density and homogeneity were achieved after 9 passes

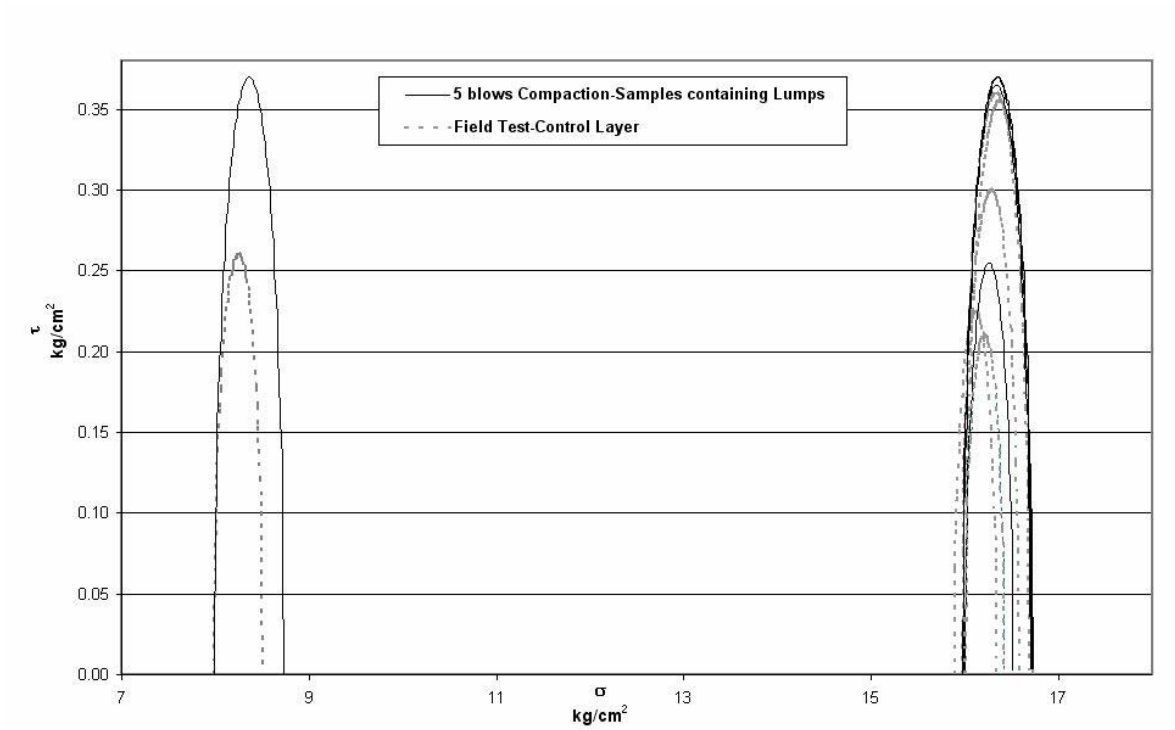

Fig. 4. Failure Mohr circles for unconsolidated undrained triaxial tests on samples prepared at 5-blows compaction effort (containing lumps) and samples of control layer in the field test

Finally, the control layer, i.e., the last layer, was made with 9 passes of the tractor. The similarity between the soil parameters in the control layer and the design layers confirmed the repeatability of the procedure. Fig. 4 shows the results of shear strength tests on samples of the control layer and those reconstituted in the lab which contained lumps. The effect of lumps in strength reduction is obvious comparing this figure with Fig. 2 which shows the shear strength of the lump-free samples.

5. CONCLUSION

Embankment dam construction in areas of high rainfall causes some problems, especially in compaction, due to the high natural water content of the soil. Major guidelines followed in such regions are as follows:

I) Considering rockfill or earth fill dam type with upstream concrete or asphalt face as an alternative
II) Use of proper materials easily handled under rainy weather
III) Reduction of soil water content by air drying, heating or mixing the soil with dryer materials
IV) Using the moist material at its natural water content, making use of light weight compactors together with proper specifications (wet compaction)

In order to perform wet compaction method (option IV), compactors lighter than conventional rollers should be used. To choose a proper low compaction level, these facts should be considered:

I) Wet soils only accept a limited amount of compaction, which is obtained by a level of compaction lower than that of proctor standard level. Using higher levels of compaction is practically difficult and almost ineffectual.
II) On the other hand, a high decrease in the level of compaction can result in a non-homogeneous compacted soil. There should be a minimum for this level which provides homogeneity in the soil under compaction.

Finding the least level of compaction energy that provides the desired values of dry density and shear strength for the wet material at its natural water content with enough homogeneity is easy in the laboratory, but requires trials in the field which are costly. As shown in this study, the first preference based on the laboratory results was the best one and there was no need for further trials in the field. This laboratory-based procedure can be followed in other sites with similar conditions to reduce probable costs of proper compaction level selection.

REFERENCES

1. Ghanooni Mahabadi, S. , Jahanandish, M. & Jalili, J. (2005). Investigation of construction methods of wet core earth dams in wet climates. *73rd Annual Meeting of ICOLD,* Tehran, Iran, Paper no.: 111-S5.
2. Jalili, J. (2005). Investigation of construction methods of wet core earth dams in North of Iran. *MSc Thesis,* Dept. of Civil Eng. Shiraz University, pp. 274, (in Persian).
3. Yamamura, T. (1988). New construction methods. State of the Art. *ICOLD, Bull 63,* pp. 135-137.
4. Sherard, J. L. (1981). Building embankment dams in areas of high rainfall. *Symposium on Hydro-electric Development in the Amazon Region*, Sao Paolo, Brazil, pp. 1-19.
5. De Luccia, R. E. (1958). Earth dam construction in a wet climate. *6th International Congress on Large Dams,* New York, Question No. 22, R. 128, Vol. III, pp. 385-407.
6. Villegas, E., Mejia, O. & Sanchez, G. (1976). Construction of an earth dam built of silt in colombia under extremely rainy weather. *12th International Congress on Large Dams,* Mexico, Report 13, Vol. III, pp. 931-947.
7. Dixon, H. H., M. A., M. I. C. E., M. ASCE. (1958). Moisture control and compaction methods used during construction of the Sasumua dam, Kenya. *6th International Congress on Large Dams*, New York, Question No. 22, R. 12, pp. 139-152.
8. Kawakami, F. (1958). Compaction methods and field moisture content of the earth core for earth dams using the moist materials. *6th International Congress on Large Dams,* New York, Question No. 22, R. 28, Vol. III, pp. 165-183.
9. Knight, D. J. (1986). Geotechnical properties and behaviour of the Monasavu Halloysite clay. Fiji. *Clay Minerals, The Mineralogical Sociaty*, Vol. 21, No.3, pp. 311-332.
10. Sherard, J. L., Woodward, R. J., Gizienski, S. F. & Clevenger, W. A. (1963). *Earth & earth-rock dams.* Wiley.
11. Takahashi, M. & Nakayama, K. (1973). The effect of regional conditions in Japan on design and construction of impervious elements of Rockfill dams. *11th International Congress on Large Dams,* Madrid, Report 29, Vol. III, pp. 501-524.

12. Jafari, M. K. & Shafiee, A. (2004). Mechanical behavior of compacted composite clays. *Canadian Geotechnical Journal*, Vol. 41, No. 6, pp. 1152-1167.
13. Meidani, M. , Shafiee, A. , Habibagahi, G. , Jafari, M. K. , Mohri, Y. , Ghahramani, A. & Chang, C. S. (2008). Granule shape effect on the shear modulus and damping ratio of mixed gravel and clay. *Iranian Journal of Science and Technology, Transaction B, Engineering*, Vol. 32, No. B5, PP. 501-518.
14. Bernell, L. (1982). Experiences of wet compacted dams in Sweden. *Proc.14th International Congress on Large Dams,* Rio de Janerio, Vol.4, Q55/R 24, pp. 421-431.
15. Kerkes, D. J. & Tarbox, G. S. (1988). Wet core construction (WCC) technology for embankment dams. *16th International Congress on Large Dams,* San Francisco, Report C 19, Vol. III, pp. 1237-1254.
16. Morpurgo, S. & Brezzi, A. (1976). Influence of climate conditions on Chivor dam construction. *12th International Congress on Large Dams,* Mexico, Report 31, Vol. III, pp. 1209-1221.
17. Penman, A. D. M. (1982). Materials and construction methods for embankment dams and cofferdams. *Proc.14th International Congress on Large Dams,* Rio de Janerio, Question 55, Vol. 4, pp. 1105-1228.
18. Penman, A. D. M. & Mitchell, P. B. (1970). Initial behaviour of scammonden dam. *10th International Congress on Large Dams,* Montreal, Report 42, Vol. I, pp. 723-747.