Prediction and performance of check-measurement systems

Prévisions et comportement des systèmes de mesures de contrôle

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SYNOPSIS: In the report have been presented a part of the results of a programme the begin of which has been set up already before twenty years. It has been made an analysis of predicated and performanced check-measurement systems of instruments for pore water pressure for eight big embankment dams with central clay cores and height from 50 to 100 meters, built in this period in Bulgaria. A comparement of measured instrument values of different firms in our country has been made for a long period of time. On this basis have been made suitable valuations as well as necessary recommendations to the engineers interested in soil mechanics.

1 INTRODUCTION

A considerable number of embankment dams with height from 55 to 100 meters have been constructed and introduced in regular operation on the territory of Bulgaria during the period 1965-1987 years. Some of them as Belmeken dam (97 m), Kamtchia dam (75 m), Asenovez dam (72 m), Yovkovtsy dam (64 m), Dospat dam (63 m), Ch. Smirnenski (53.1 m), Dushantsy (51 m) and others are the object of the present report. On principle as waterproof element in the embankment dams are constructed relatively narrow vertical clay corse, the width of the base is almost always smaller or equally the half of the height. The thickness of the layed layers in the clay cores in the mentioned examples from 25 to 30 cm for uncompacted layer. The water content of theused core materials during the laying varies from 1 to 2% over the optimum or by the optimum as approximately on principle the quarry materials are always been with water content over the optimum for the corresponding material. This is one of the based cause that forced already at the end of 1960 year to pay great attention as well to the experimental investigations for determination of the strength parameters in the triaxial stress state, to the coefficients for pore water pressure of Skempton-Bishop as to the choise of most suitable theoretical models for resolving the task for clay cores consolidation during the time with a view to obtain the most reliable prediction of the distribution and appearance of the pore water pressure isochrones.

Parallel to the development and resolve of simular tasks by designing of dams becomes necessity the problem decision for performance of the check-measurement systems of suitable instruments built in the clay cores during the construction.

It was gained a rich experience of laying for a long period of time-more than twenty years as a significant information from more than 300 devices for measurement of the pore water pressure in the cores of eight big embankment dams which are object of the presented report.

A difficult problem for desiding was the choise of the most suitable check-measurement system for the performance in the clay cores of the embankment dams in accordance with out specific conditions, materials sort, used in the embankment and his characteristics. Having in mind that in principle the utilized clay materials for the mentioned dams have coefficient of permeability of the order of 10^{-8} cm/s so that enforces by some dams like Belmeken dam and Kamtchia dam the accomplishment of instruments duplicating from the both based firms, which are used as instruments supplier in our country during for more than twenty years - the firms Maihak and Huggenberger by the performance of check-measurement systems.

A similar method of approach is successfully used from manly engineers by the design and performance of embankment dams in Europe which is with the purpose to use in the following project decisions the prefered trends of the best check-measurement systems, who engages the best possible coincidence of predicated and performanced ideas and decisions in situ.

2 EXPERIMENTAL INVESTIGATIONS

All materials, used for building of the clay cores of the examinating dams have been tested in the soil mechanics laboratory of Energoproect - Sofia according to the previously drown up programme it included the investigations of the experimental samples in the conditions of triaxial stress state by the usual for this type investigations in "unconsolidated-undrained", "consolidated-undrained" and "drained" experimental examination. With a view of examination the consolidation processes in the clay cores during the construction and after it the respectively values of the pore water pressure have been determined with the help of measured coefficients of Skempton-Bishop.

The size of the tested experimental samples in the triaxial cell are with diameter 55, 70 and 100 mm and height respectively 110, 140 and 200 mm. The density and the water content of the samples corresponded to these conditions under which the embankment material for the water-proof element will be layed.

Main characteristics of the soil material,

Table 1

Dams	γ_s kN/m³	γ_d kN/m³	w_{opt} %	I_p	k cm/sec	Grain size, mm 200-2	2-0.10	0.1-0.005	<0.005
1 Belmeken	26.6	18.2	15.0	10.0	10^{-7}-10^{-8}	8	41	33	18
2 Lakatiza	27.0	17.8	17.0	17.0	10^{-8}	-	-	-	18-30
3 Kamtchia	27.2	18.5	14.5	14.0	10^{-8}	2	47	38	13
4 Asenovez	27.1	17.3	18.0	17.0	10^{-8}	26	20	30	24
5 Yobkovtsy	27.6	17.2	21.0	18.0	10^{-8}	-	12-18	51-58	30-32
6 Dospat	27.1	18.8	13.0	16.0	10^{-7}-10^{-8}	10	14	30	19
7 Ch.Smirnensky	27.5	16.0	23.5	20.0	10^{-8}-10^{-9}	-	41	58	28
8 Dushantsy	27.5	18.1	16.0	13.0	10^{-8}	5	45	32	18

used for the cores examinated dams are shown in Table 1. The changing of the optimum water content varies from 13% to 23,5% and respectively the dry density from 16,0 kN/m³ to 18,8 kN/m³.

Proctor's curves and their distribution for the different soil materials as well as the form and geometrical sizes of the clay cores for the examinated dams are shown on Figure 1. In regard to the cores geometry this is a prefered structure for the conditions and available amounts of soil materials in Bulgaria.

All characteristics of soil materials received by taking into consideration the stress state for every layer of the examinated clay core are received by the examinator. The last is of utmost importance by utilizing of these characteristics in the chosen theoretical decisions for pore water pressure predicating in the waterproof elements of the embankment dams.

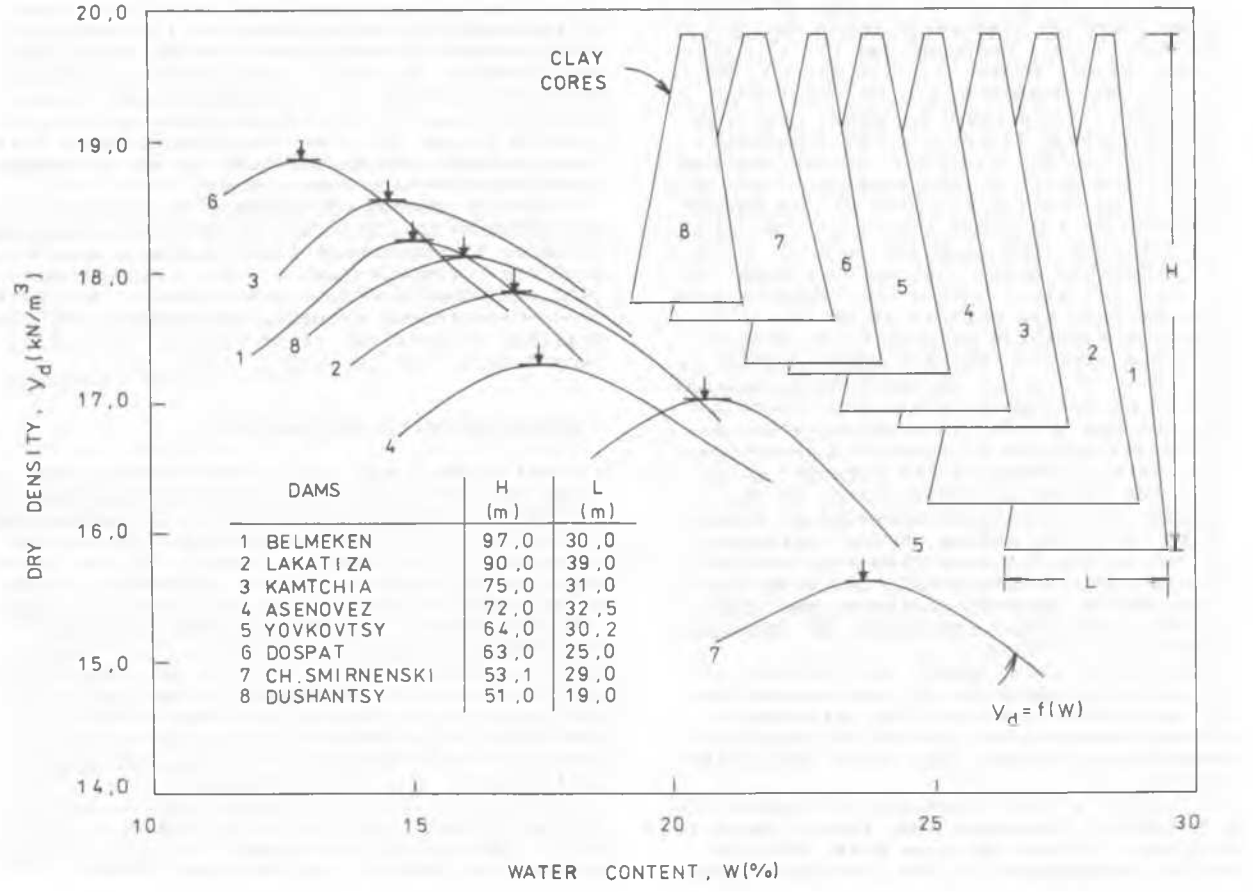

Figure 1. Proctor's curves for the different materials of the cores (left part) and geometrical sizes (right part).

3 THEORETICAL CONSIDERATIONS

The theoretical prediction of the consolidating processes in the water-proof elements of the embankment dams receives in the last twenty years a great development. The multiformity of existing theoretical decisions of different authors in Europe and America troubles sometimes hard their use from the engineers in practice.

Decisions have been offered which requires quite high knowledgements of mathematics but in the same time don't give an account for the influence of great number of parameters of the soil materials and vice versa comparatively more simplified decisions but taking into account a lot of the changing of the soil parameters in height of the core.

With the wish addition of many authors today to take into account the influence of the reological occurences in the soil massif the task for theoretical prediction of the isochrones sort and distribution of the pore water pressure in the clay cores is sometimes too hard for many designers.

Similar conditions were formed in our country in the period of the 60-years when these methods hadn't a great practical utilisation. Already of the time the author expressed preference for a method, who takes possibly into account the influence of the most soil characteristics in a function of the stress state of the examinated element.

All clay cores of the embankment dams in Bulgaria as well as these, who are object of the present report are examinated in advance with method of VNII, Vodgeo-Moscow. The fundamental theoretical equations of Prof. V.A.Florin are the base of this method.

The basic conditions of the used theoretical model are reported from the author on the 8th ICSMFE in Moscow-1973 and on the 9th ICSMFE in Tokyo-1977.

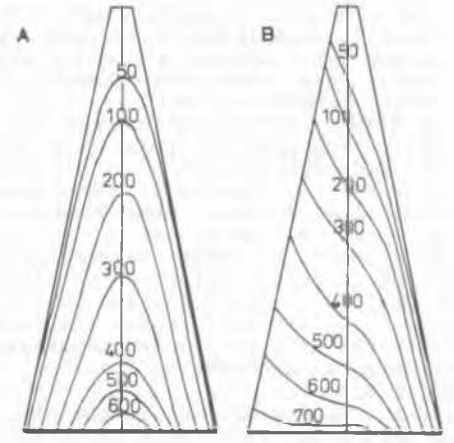

Figure 2. Distribution of the pore water pressure - isochrones in the clay core of Kamtchia dam in the construction period of time (A) and after filling up of the dam (B), obtained form the theoretical prediction.

In order to make the method more accessible for practical use for greater circle of engineers interested in this area still in 1967 a programme for computer has been composed and in 1987 year a new improved programme for personal computer IBM. With a help of a peripheral device-ploter the isochrones of the pore water pressure can be drowed up as well as this is shown on Figure 2 in the case of the clay core of Kamtchia dam.

The possibility to receive illimitably number of variant elaborations makes the programme desired and prefered from all establishment in our country. A reason for that preference was the fact, that the pore water pressure measured values in situ in the clay cores of many embankment dams for a period of time more than twenty years has shown comparatively the best coincidence of the predicted and measured values in situ. Dingosov,G., Markov,G.(1977), Markov,G., Damov,K.51985).

4 CHECK-MEASUREMENT SYSTEMS

Every check-measurement system includes exact number of instruments and has for a purpose to give the possible richest information about the measured values in situ in the examinated dam element. The description of the separate measurments as well as the range of the instruments set in the clay cores are determined in advance in the practice on the base of the theoretical prediction of the consolidating processes about which we have told in point 3.

Today when every country which occupies with similar sort of equipments has a rich information experience of measurement in situ will hardly call in question the benefit of similar activities, even so in the near past it created some troubles in the relationship between the builder and investor. Such measurement information can over and over again reward the project authors and will contribute to the better security insurance of the dam during the construction. Sherard,J.L.,Woodward,R.J.,Gizienski, S.T.,Clevenger,W.A.(1963),Sherard,J.L.(1981), O'Rurke,J.E.(1974),Hanna,T.H.(1985),Dingosov,G., Markov,G.(1985).

We have already mentioned that the reliability of the obtained information for measurement has an exceptionally importance for taking decisions which may bring to spend of significant means for example from stopping the embankment works on the clay core because of high pore water pressure. By the by such examples are shown from many authors as well as in Europe so in America.

Therefore today the choise of the most suitable instruments of firms-producer for performance of check-measurement systems set up in the dam during the period of construction is not an easy problem for deciding. Many project authors use the accomplishment of some instruments duplicating for resolving of such problems of least two prefered firms having in mind together the necessary information for the near future by the design and construction of similar equipments. Such method of approach is adopted in Bulgaria. By the construction of the indicated at the begin embankment dams we have restricted in suppling of instruments for measurement of pore water pressure mainly from the firms Maihak and Huggenberger.

Generally 347 instruments set up in the clay cores of Maihak-MDS 75 and Huggenberger-PZE type help in many cases to take the best decisions possible for every specific case. An instruments duplication has been accomplished in

the based central cross sections from the both above mentioned firms for some hard responsible equipments as Belmeken and Kamtchia dams. The measurement accomplished analysis during one moreprolonged period of the time over twenty years allowed to be done the following conclusion:the both instruments types show relatively near results for one and the same point of the examinated element. More stable results are obtained from the instruments of Maihak-MDS 75 firm from type Vibrating-Wire in continuous period of time.

The carefully discussion of the obtained results and the made conclusion for some preference of instruments from this firm is the fact, that the materials for the constructed waterproof elements of the embankment dams in Bulgaria have comparatively small permeability 10^{-8} cm/s and for that reason the instruments are better used and give sure information.Because of that it was prefered for the Dospat dam, Asenovez dam, Yovkovtsy dam, Ch.Smirnenski dam and other to construct check-measurement systems utilizing Maihak-MDS 75 instruments.

The information of the conducted measurements on eight big embankment dams in a continuous period of the time allowed to be seen the isochrones description and distribution of the pore water pressure as well as it is shown on Figure 3. Two types of isochrones distribution is chaped: normal, which has good coincidence with the theoretical prediction in advance, see Figure 2(A) and Figure 3(A).Such description forms are shown for Tooma dam-Australia, Asuan dam-Egypt, Serre-Poncon dam-France, Ch.Smirnenski dam-Bulgaria, Yovkovtsy dam-Bulgaria and others and form "core" type isochrones distribution as well as it is shown for Kamtchia dam in Figure 3(B) and distinguishes essential from the prediction in advance as well as it is shown in Figure 2(B).

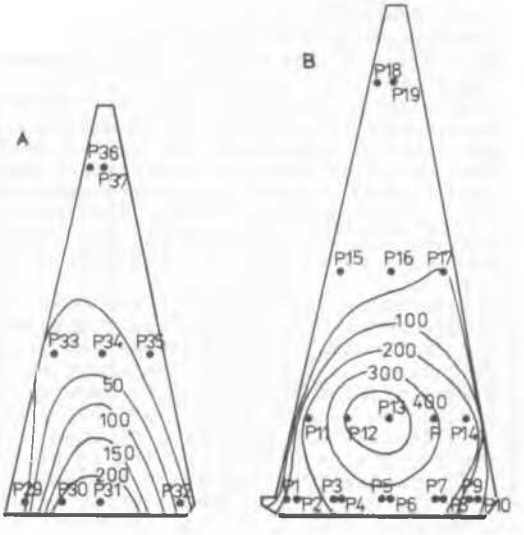

Figure 3. Measured values of the pore water pressure in the core of Kamtchia dam in situ.

For similar "core" isochrones distribution are indicated Mibiro dam-Japan, Castiletto dam-Switzerland, Kamtchia dam-Bulgaria, Green Mountain dam-U.S.A., Anderson Ranch dam-U.S.A. and others. Leastuise for Kamtchia dam the explanation for the "core" isochrones distribution is the presence of a material with velatively higher water content comparated with the project required in a zone of central part.

The observation shows a zone where the pore water pressure values haven't either been measured or they are minimal and negative.This zone takes usually for the examinated dams the upper 1/4 to 1/3 part of the height and that introduces always doubts for instruments set bing up in this part. The final removing of them is an extreme but the number decrease is probably more reasonable decision.

5 CONCLUSIONS

(1) The used theoretical method which allowes to take into account the soil characteristics changing in cores height during construction and exploitation cases sives many good prediction in advance for the isochrones distribution and description of the pose water pressure. This is confirmed with the made comparament with the measurements in situ.

(2) By the performance of check-measurement systems in the clay cores having water permeability at the rate of 10^{-7} 10^{-9} cm/s, as it is the case of the materials for the examinated dams is successful to utilize the instruments Vibrating-Wire Type Piezometer and they must be set up in future performanced projects.

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