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Investigation on Pore Water Pressure in Core of Karkheh Dam

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***Abstract*—**Pore water pressure is normally because of consolidation, compaction and water level fluctuation on reservoir. Measuring, controlling and analyzing of pore water pressure have significant importance in both of construction and operation period. Since end of 2002, (dam start up) nature of KARKHEH dam has been analyzed by using the gathered information from instrumentation system of dam. In this lecture dam condition after start up have been analyzed by using the gathered data from located piezometers in core of dam. According to TERZAGHI equation and records of piezometers, consolidation lasted around five years during early years of construction stage, and current pore water pressure in core of dam is caused by water level fluctuation in reservoir. Although there is time lag between water level fluctuation and results of piezometers. These time lags have been checked and the results clearly show that one of the most important causes of it is distance between piezometer and reservoir.

***Keywords*—**Earth dam, Reservoir, Piezometer, Terzaghi, Consolidation

I. Introduction

PORE water pressure refers to the pressure of groundwater held within a soil or rock, in gaps between particles (pores). Pore water pressures in below the phreatic level are measured in piezometers [7]. In Nowadays, piezometers are use in earth dam to monitoring different parts of earth dam [11].In worldwide, over 45,000 large dams have been built, and nearly half the world's rivers are obstructed by a large dam [3]. Earth dam has four main parts: 1) Shell 2) Core 3) Filter 4) Foundation. The main objective of core of earth dam is sealing the dam. For core construction, mixture of stuff with an optimum humidity have been used and compacted as construction is under programs [9], [4]. Pressure on lower layers of core has been increased and because of it, the pores of soil would be decreasing. In this term, soil would be saturated. Firstly, pore water pressure caused by water weight on soil would be made. This pressure is caused by consolidation after it, because of consolidation of soil, pore water pressure would have decreased and lastly because of infiltration extant water have been drained and consolidation would have been occurred [2]. Following parameters cause the water pore pressure:

1. Compaction 2. Consolidation 3.Water level fluctuation

Measuring, controlling and investigating of pore water pressure have significant importance in different stages of earth dam life (construction and operation) [6], [1].

Infiltration system and cutoff system performance, probability crack occurrence in core and even effects of earth quacks on dam stability can be realized by water pore pressure measurement. Efficiency of grouting system could be investigated by this way, too. After soil saturation, water pore pressure, which is caused by consolidation, would be occurred. Then any other extra load (caused by earth fill) causes more water pore pressure [5].

Pore water pressure (sometimes abbreviated to pwp) is vital in calculating the stress state in the ground soil mechanics, from Terzaghi's law for the effective stress of a soil (Terzaghi, 1936). Necessary time for compaction could be calculated by TERZAGHI equation (1), [8].

$$\frac{\partial u}{\partial t} = \left[\frac{k(1+e_0)}{a_v \gamma_w}\right]\frac{\partial^2 u}{\partial z^2} \qquad u = \frac{p_a \Delta}{v_a + .02 v_w - \Delta} \tag{1}$$

Increase the pore pressure water in soil, decrease effective stress. So soil shear stress that has direct relation with effective stress decrease by increase pore water pressure. Decreasing the soil shear stress might be cause of dam broke [12].

Compaction occurring when pore water under the soil stress (by soil compacting) out. Consolidation is a process which soils decrease in volume. According to Karl Terzaghi consolidation is any process which involves decrease in water content of a saturated soil without replacement of water by air. In general, it is the process in which reduction in volume takes place by expulsion of water under long-term static loads. It occurs when stress is applied to a soil that causes the soil particles to pack together more tightly, therefore reducing its bulk volume. When this occurs in a soil that is saturated with water, water will be squeezed out of the soil.

Exist pore water pressure potential in reservoir water is cause of water level fluctuation. During increase water level in reservoir exist gravity force caused flowing water in earth dam (core & bulwark).

Up to now all lecture and Investigation on Karkheh dam has been focused on pore water pressure due consolidation, actually pore water pressure due water level fluctuation never

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has be studied. Therefore, this paper investigates all reason of pore water pressure in core of Karkheh dam.

II. Materials and Methods

Karkheh dam with 7.4 billion-m^3 content is the largest dam in Iran. This dam is earth dam with clay core, height of dam is 127m. Totally 412 piezometers has been used in Karkheh dam [10]. In this investigation water level's data and three kinds of piezometers has been used. The piezometers are EP (Electrical Piezometers), RP (Rock Piezometers) and SP (Stand Pipe).

Study of water level fluctuation during eight years (2002-2010), illustrated eight maximum points. In fig (1) x-axis is time and y-axis is water level reservoir. As it apparent, there is one maximum point for each year. To procure more details, each group of piezometers has been study separately), Fig (2), (3), (4). Although all times that water level in piezometers and reservoir were in the maximum, point peaked and diagram of water level fluctuation's times has been draw. Difference of maximum points of water level in reservoir with water in piezometers gathered. In addition, this job has been done to calculate difference of peak time (the time that water level is in maximum point) in piezometers and reservoir.

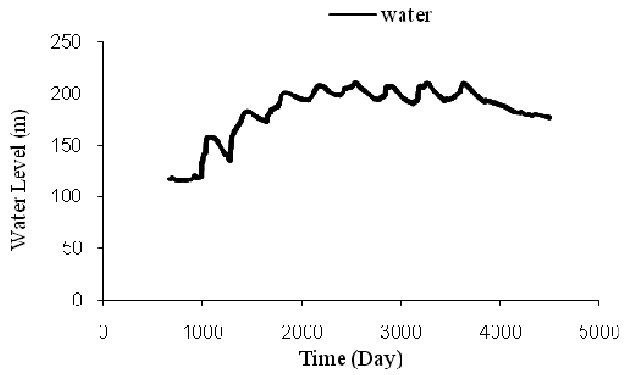

Fig. 1 Water level fluctuation in reservoir since 8 years

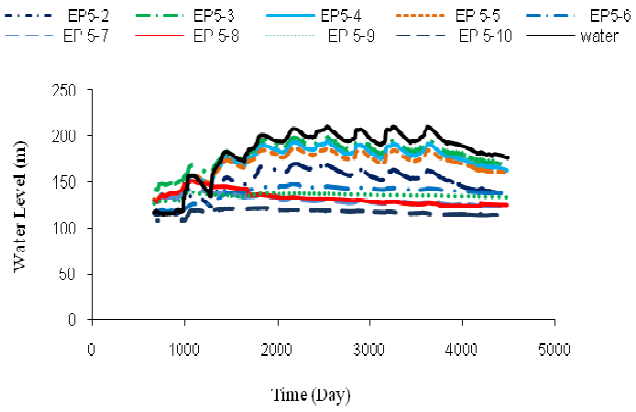

Fig. 2 Water level fluctuation in EP piezometers and reservoir since 8 years

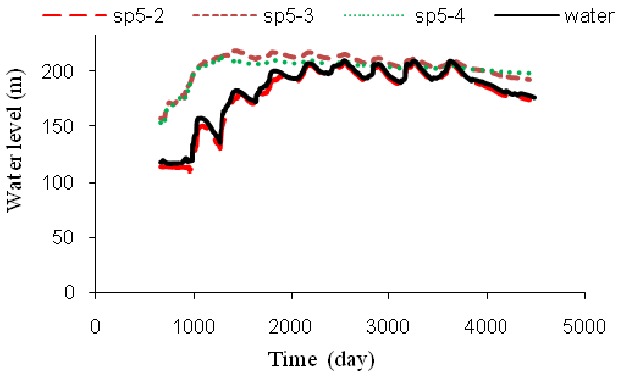

Fig. 3 Water level fluctuation in SP piezometers and reservoir since 8 years

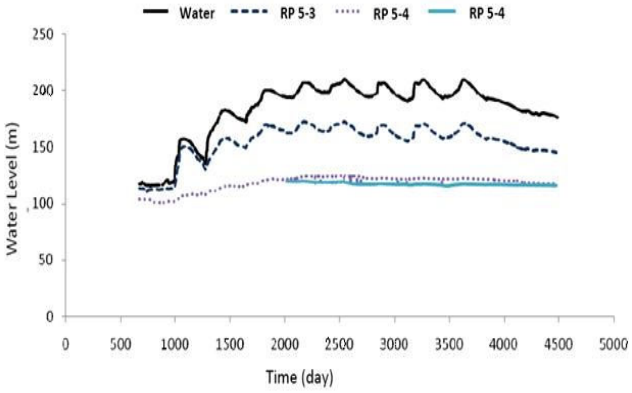

Fig. 4 Water level fluctuation in RP piezometers and reservoir since 8 years

III. Results and Discussion

Compaction occurs in construction period, so it would not be reason of existing water pore pressure during operation time, so this parameter would not be study in this investigation.

Necessary time for compaction calculate by TERZAGHI equation. Results show that consolidation lasted around five years during early years of construction stage, table (I).

TABLE I
TIME OF CONSOLIDATION , CALCULATED BY TERZAGHI EQUATION

piezometer	Consolidation time (year)
EP	2
EP	4
EP	4
SP	5

In the other hand curve of EP and SP piezometer's records shows that in the first five years water level in piezometers is upper than water level in reservoir,fig (5).The cause of this occurrence is existing pore water pressure in core of dam. Current pore water pressure in core of dam is cause by water

level fluctuation in reservoir. Also, because RP piezometers are installing in stone always shows their water level lower than level of water in reservoir. This demonstrated consolidation has no effect in stones.

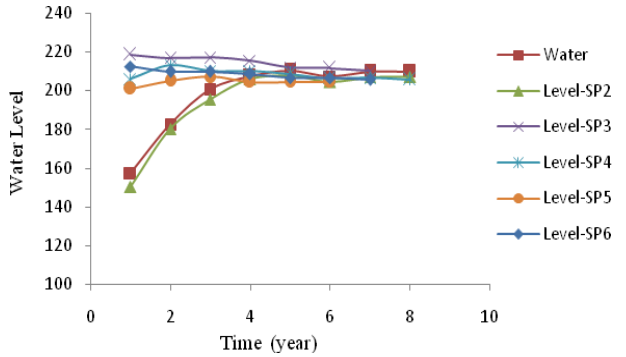

Fig. 5 maximum level of water in reservoir and SP piezometers since 8 years

It seems that velocity of water level fluctuation is different in reservoir and piezometers. In the other hand more study on carves and graphs of maximum points of water level in piezometers and reservoir illustrated that there is a delay between occurred changes of water level and results of EP and SP piezometers. This occurrence studied by drawing slope of water level fluctuation in reservoir and piezometers versus time. Inspection on these fluctuations appeared that water level fluctuation in reservoir always occurred with much more velocity into piezometers. Investigation appeared this might be cause of (1), low hydraulic conductivity in core (2), Distance of piezometers.

Thus, investigation has been done in this way: the velocity of water level fluctuation in reservoir ($\frac{\Delta l}{\Delta t}$) and all piezometers in core calculated. Figure (6) observe draw curve of velocity of water level fluctuation in reservoir (X-axes) and velocity of water level fluctuation in one piezometer (EP5-2 as an example) (Y-axes). In this figure, all points are located under Coefficient line. The line coefficient of fitted line to water level fluctuation data versus time in reservoir compare to water level fluctuation in piezometer is less than 1 (y=0.789). It prove existing time lag of water level fluctuation in piezometers versus water level fluctuation in reservoir that is because of low hydraulic conductivity in core. In addition, studies make it clear that the line coefficient has undirected relation with distance of piezometers. It means that whatever piezometer's distance to reservoir be further line coefficient will be less, in otherwise time lag would be more.

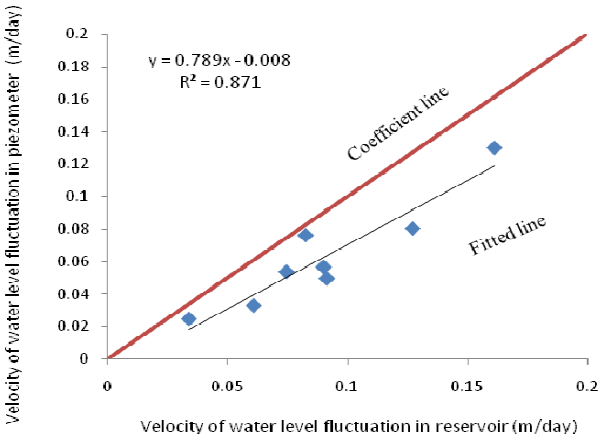

Fig. 6 Water level fluctuation versus time in reservoir and piezometer EP5-2

Table (II) shows some piezometers distance from reservoir and time lag of approaching water level to maximum point. These piezometers selected from three level of installation but piezometers of each column of table installed in the same level. Regarding to table (II) this is clear whenever distance of piezometers is further into reservoir time lag would be more.

TABLE II
PIEZOMETERS DISTANCE FROM RESERVOIR AND TIME LAG

Piezometer	DISTANCE FROM RESERVOIR(M)	Time lag(day)
EP5-4	171.6	6
EP5-5	179.26	8
EP5-6	183.05	45
EP5-11	156.3	6
EP5-12	165.2	17
EP5-16	209.97	45
SP5-2	138.77	3
SP5-4	158.81	30
SP5-5	166.26	54

IV. CONCLUSION

Based on the study, the following conclusions are drawn:

1. According to TERZAGHI equation and records of piezometers, consolidation lasted around five years during early years of construction stage, and current pore water pressure in core of dam is caused by water level fluctuation in reservoir.
2. In current time, some of piezometers record water level higher than water level in reservoir this occurrence is because of time lag due low hydraulic conductivity in core.
3. Whenever distance of piezometers is further into reservoir time lag would be more.
4. Time lag is correlative with distance of piezometer versus reservoir and hydraulic conductivity of core of dam.
5. Measuring, controlling and investigating of pore water pressure have significant importance in different stages of dam life (construction and operation). Although it seems

that in investigations, on pure water pressure attention to all possible reason is necessary.

6. Suitable equations for prediction these phenomena derivation should be using different dams characteristics and hydraulic properties.

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