Long-term behavior of kinevars embankment dam using numerical model and compare it with the instrumentation results

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Abstract

During the construction and operation of an embankment dam, various parameters, such as total stress, settlement, and most importantly pore pressure in the core affect the dam stability. To study these parameters, numerical modeling of dam behavior in drained or undrained loading and unloading is essential. In this study, the result of instruments in the construction and operation of the Kinevars dam, which include the actual values of stress and settlement is compared with the values obtained from the analysis of stress-settlement achieved from numerical modeling. According to the results, it was found that Geostudio software and Duncan nonlinear elastic model are suitable for analyzing the behavior of an embankment dam. Additionally, our results revealed that the use of simplified common methods for stress-settlement-leakage modeling in dams is reliable. Also, in the construction filling time, the results of numerical modeling and instrumentation for the parameters of pore water pressure and total stress in core are close. Considering the results of this study, it was concluded that the behavior of an embankment dam during construction and operation with acceptable accuracy is predictable by using Geostudio software.

Keywords: Long-Term Behavior, Embankment Dam, Numerical Modeling, Instrumentation.

1. INTRODUCTION

During the construction and operation of an embankment dam, various parameters, such as total stress, pore pressure and settlement affect the stability of dam. The most important parameters among these is the pore pressure in the core during construction and operation. To study of these parameters, numerical modeling of dam behavior in drained or undrained loading and unloading using is essential. In this study, the result of instruments in the construction and operation of the Kinevars dam, which include the actual values of stress and settlement is compared with the values obtained from the analysis of stress-settlement that obtained from numerical modeling.

Kinevars dam is located in Zanjan province, about 14 km southwest of Abhar city. This dam is built on Abhar-rud River. Supplying drinking water demand of Abhar city and Khorramdarah city is an important objective of this dam [1]. In the following figure, Kinevars dam and its structure are shown.
The dam specification is presented as following [1]:

- Dam Type: earth-rock fill dam with Vertical Clay Core
- Maximum dam height from the bottom: 45 meters
- Crest length: 374 meters
- Crest width: 8 meters
- The total volume of the reservoir in the normal elevation: 16 million cubic meters
- Type overflow: free overflow ogee
- Type water tightening system: two parallel cement slurry wall with grout curtain

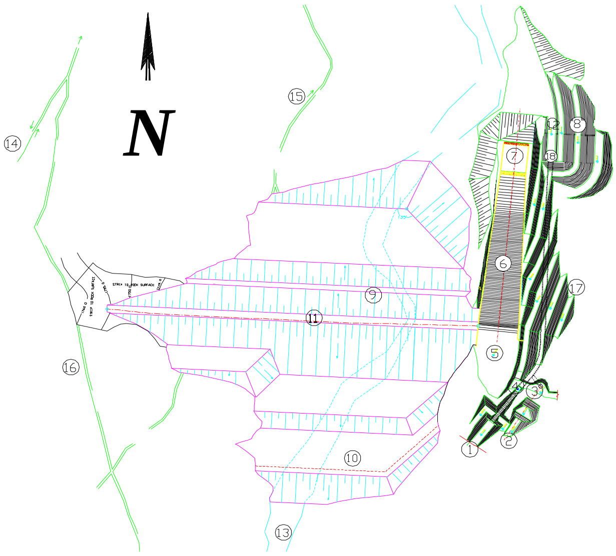

Figure 1. Kinevars dam and its structure

In order to investigate the behavior of the dam, the instrumentation are designed as described in Table 1 for 5 sections in the dam [2].

Table 1- Instrument list of Kinevars dam

Instrument	Number of Installed
stand pipe Piezometer	21
vibrating wire Piezometer	43
Total pressure cell	8
Observing well	6
leakage Measurement device	1
Reservoir water level meter	1
Inclinometer-settlement	9
Benchmark	27
Total	116

In figure 2 and figure 3, instrument in sections 8 and 11 are shown [2].

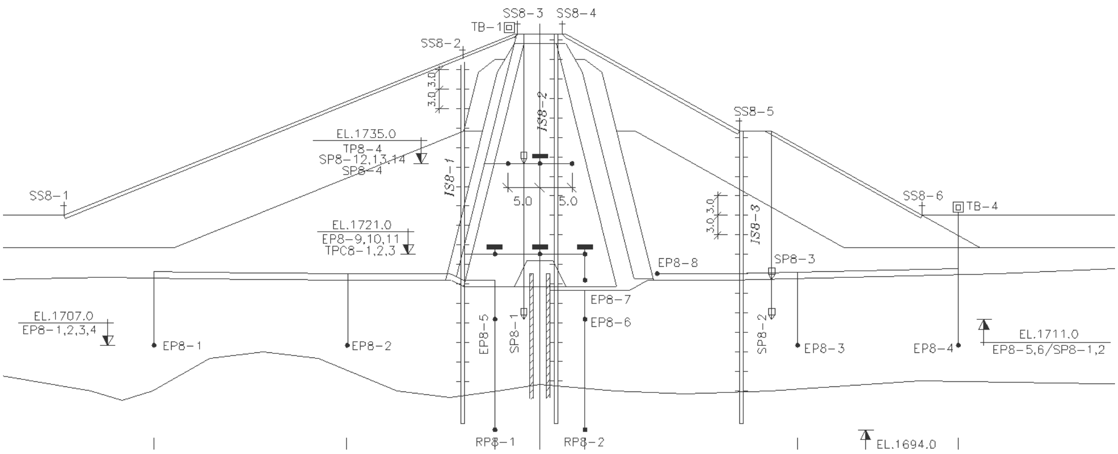

Figure 2. instrument in Section 8

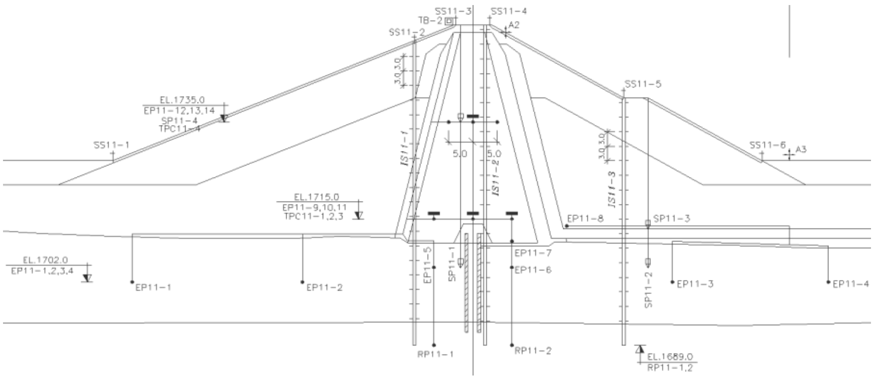

Figure 3. instrument in section 11

2. NUMERICAL MODELING

In this paper, for numerical modelling, boundary condition and loading for construction and impounding were used based on the actual data of construction and impounding.

The results of numerical modeling was compared with the results of instrumentation for core. The studied parameters are:

- Pore water pressure
- Total pressure
- Settlement

In Figure 4, 5 and 6 the geometry for sections 11, the modelled mesh with boundary conditions for stress-strain finite element analysis and finite element mesh with boundary conditions for seepage analysis are shown, respectively.

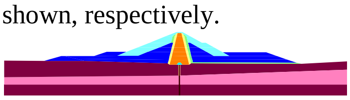

Figure 4. Geometric model for section 11

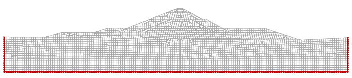

Figure 5. Finite element mesh and boundary conditions for stress-strain analysis

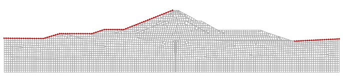

Figure 6. Finite element mesh and boundary conditions for seepage analysis

In Table 2, the parameters used in the analysis is presented. These parameters are the result of tests conducted on materials and designed Dam reports.

Table 2- The parameters used in the analysis

Ky/Kx	Kx (cm/s)	C´ (Kpa)	φ´ (degree)	υ	Rf	n	K	E (Mpa)	Ɣ (KN/m3)	Material
0.1	4.0E-08	17	29	0.4	0.75	0.4	130	-	20.5	Core
1	1.0E-02	5	36	0.3	0.70	0.4	200	-	19	Filter
1	1.0E+01	5	38	0.3	0.70	0.4	200	-	19	Drain
1	1.0E-03	5	40	0.3	0.62	0.5	350	-	21	Alluvial Shell
1	1.0E-03	5	44	0.3	0.62	0.5	500	-	22	Rockfill Sell
1	1.0E-03	-	-	0.3	-	-	-	300	22	Alluvial Foundation
1	1.0E-05	-	-	0.3	-	-	-	1000	24	Rock foundation
1	1.0E-06	-	-	0.3	-	-	-	1200	23	Cutoff Wall

Because of the nonlinear nature of the soil materials, it is recommended to use the nonlinear behavior for material. In this analysis, the hyperbolic models (Duncan And Chang 1970) [3] is used. The foundation and Cutoff wall is modeled as a linear elastic (because of these materials are linear in low stresses)[4].

The process of building the dam structure is modeled in eight steps close to reality, as shown in Figure 7. The actual process of dam embankment and loading process are shown in the model.

After the completion of each step and zeroing up the created shapes (due to their compensation during the construction stages), the next stage is modeled.

Then, the reservoir is impounded according to the actual conditions after the completion of the simulated dam construction, which is presented in Figure 8 of the impounding process in reality and in the modeling.

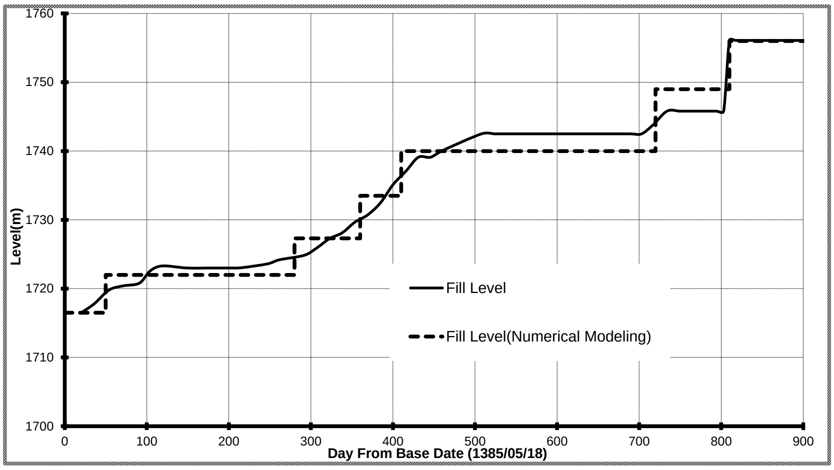

Figure 7. Compare the Real embankment filling with the model

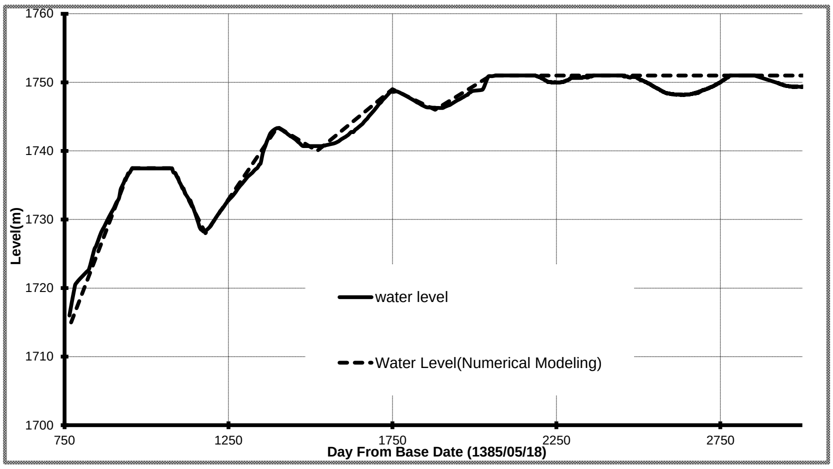

Figure 8. Compare actual impounding trend with model

3. Pore Water Pressure In Core

The results of modeling and instrumentation for the pore water pressure in the core are shown in Figures 9 and 10.

As it is known during the construction period, the general trend of the results of the instrumentation and the modeling is coincide, but because of the limitation in the number of loading steps in the modeling, the water pressure fluctuations is a function of the loading, but in reality, this loading is gradual and the pressure of generation and dissipation is gradual either.

But the remarkable thing is that overall, after the end of each stage, the end result is very close.

After impounding, the results are very close to each other and the results are coincide. Thus, according to the results, the water surface line is forming in the core.

The difference in results of the two instruments (EP 11-12 and EP 11-13) is due to the excess pore water pressure that is not yet dissipated and after impounding (and always) shows a pressure above the reservoir water level.

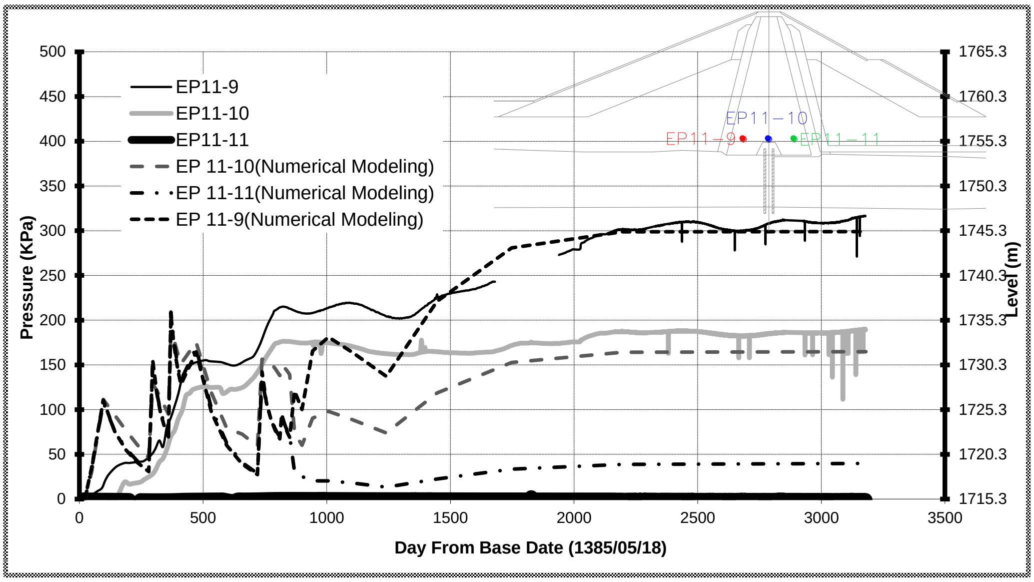

Figure 9. Comparison of pore water pressure in the core at the level 1715

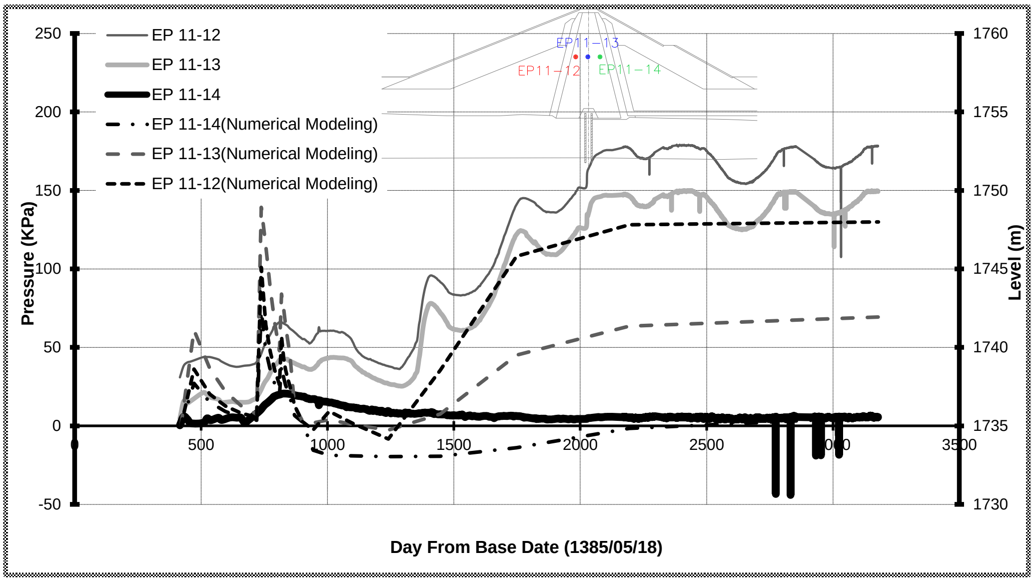

Figure 10. Comparison of pore water pressure in the core at the level 1730

4. Total Stress In The Core

The results of modeling and instrumentation for total stress changes in the core are shown in Figures 11 and 12.

As it is known during the construction, the results of the instrument and the modeling are completely overlapping, but there are very few fluctuations due to the limited number of loading steps in the modeling.

After impounding, the results are very close together and the results are coincide.

The difference in results of TPC 11-4, as mentioned earlier, is due to the localized arching at the instrument location and the results of the modeling seem to be more realistic.

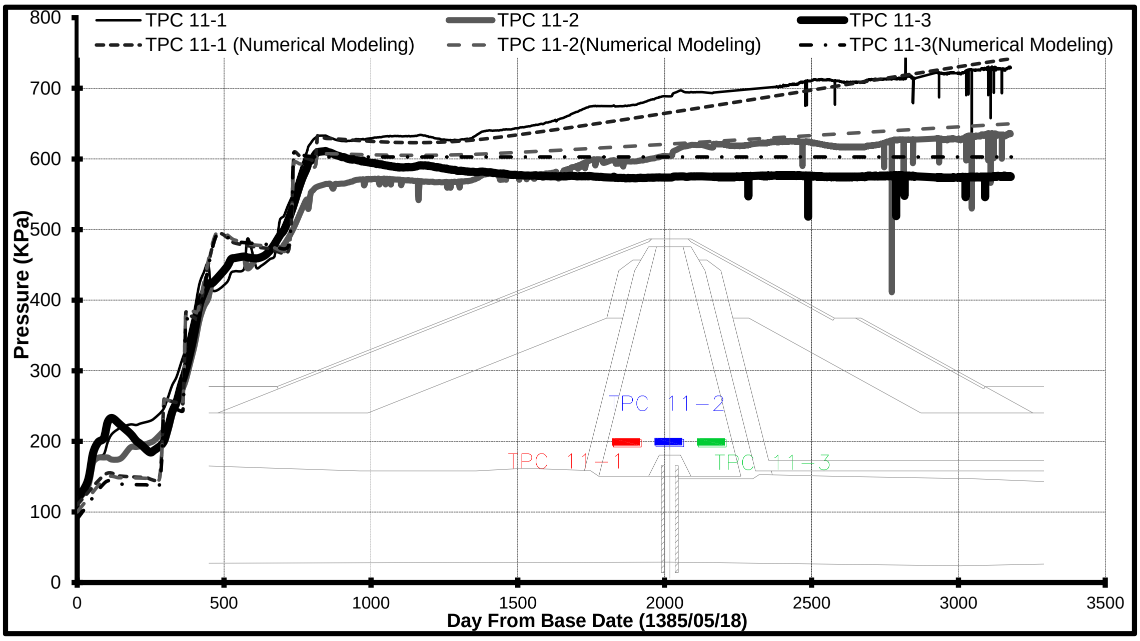

Figure 11. Compare the results of the total stress at the level of 1715

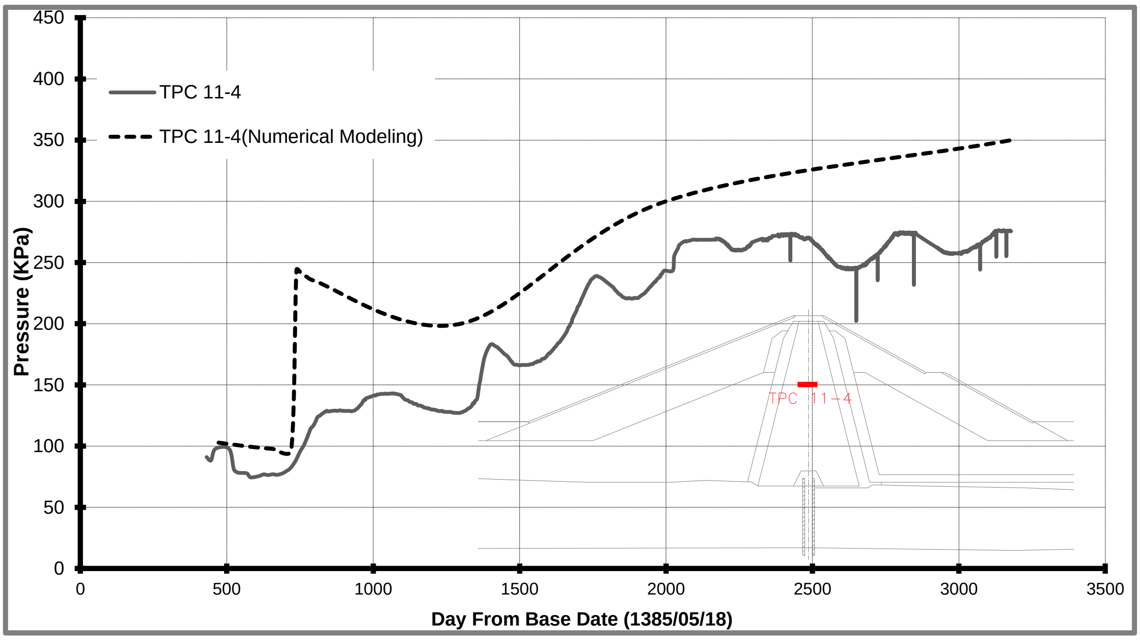

Figure 12. Compare the results of the total stress at the level of 1735

5. SETTLEMENT AT THE CORE

The results of modeling and instrumentation for settlement changes in the core of dam are presented in figures 14 and 15.

As it is known during the construction and impounding process, the general trend of the instrument results and numerical modeling is coincide.

The results show that the assumed parameters are very close to reality.

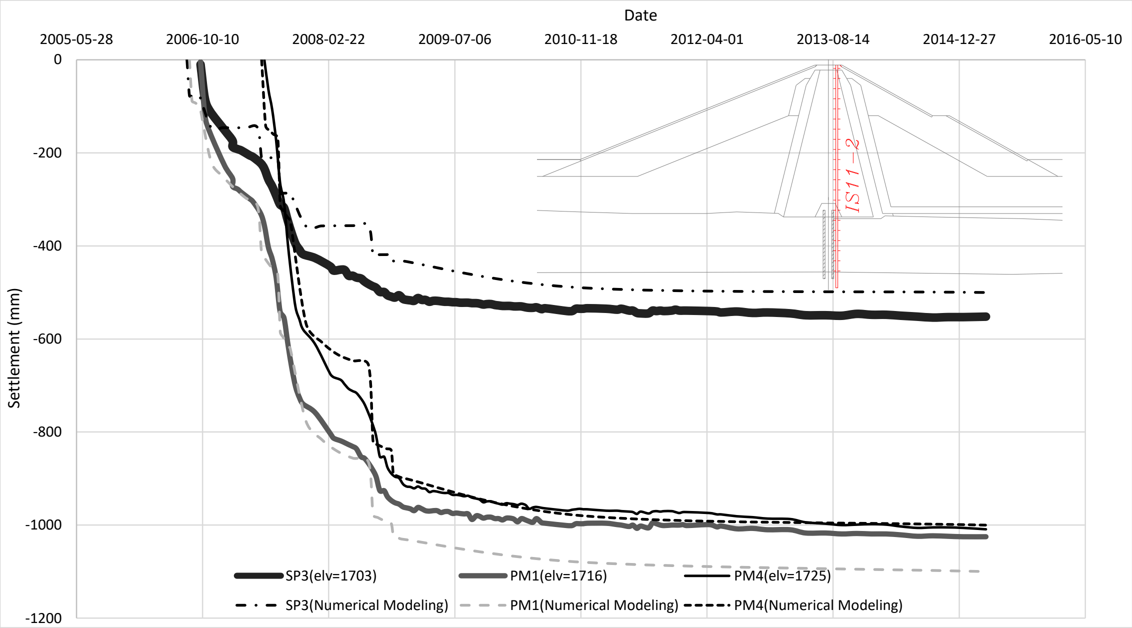

Figure 13. Compare the results of the settlement in core at levels 1703, 1716 and 1725

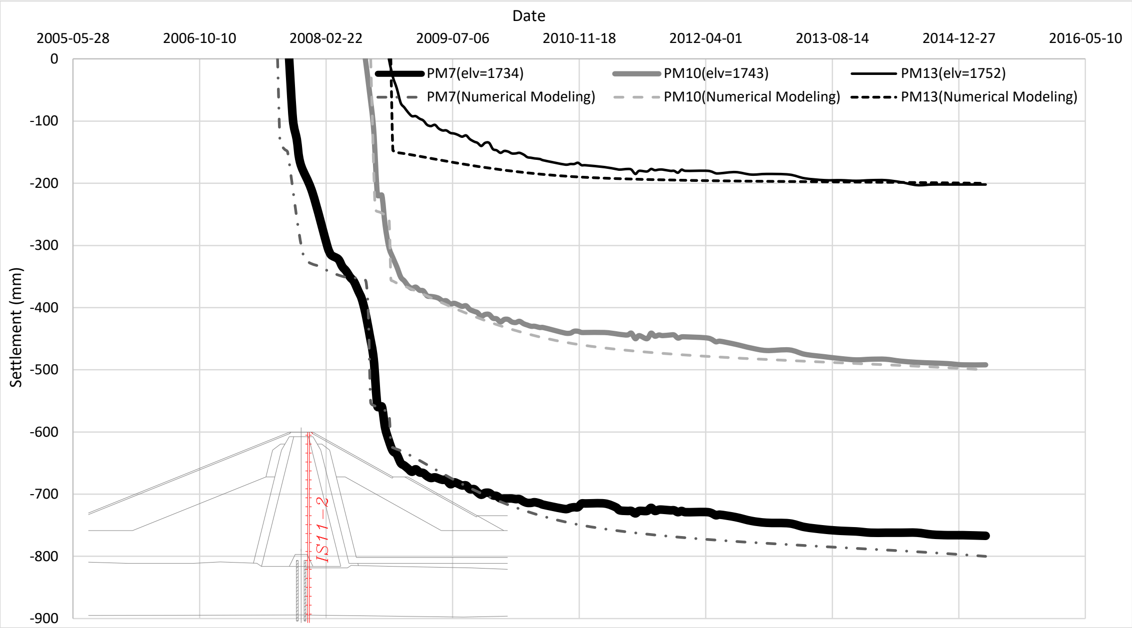

Figure 14. Comparison of the results of settlement in core at the levels of 1734, 1743, and 1752

6. CONCLUSIONS

The results of the numerical modeling presented in this paper are summarized as follows:

• Common methods for embankment dams modeling are reliable.

• Duncan's nonlinear elastoplastic behavioral model is suited for modeling the behavior of the core of the earth's dam.

• During the construction period, the modeling process results and the model for the pore water pressure parameter and total stress are completely overlapping, but there are very few fluctuations due to the limited number of loading steps in the modeling.

• After impounding, the results of pore water pressure and total stress are very close to each other and the results are coincide.

• In examining the results of the total stress calculated from the instrumentation results, due to the localized arching on the instrument location, these results should be carefully considered.

• As the results of the instrument showed, during the construction and impounding period, the general trend of the settlement in instrument and numerical modeling is coincide.

• The results obtained from this paper indicate that the assumed parameters are very close to reality.

7. ACKNOWLEDGMENT

We would like to give special thanks to Iran water resources management company, Tehran and Zanjan Regional Water Authorities (as the client of this projects) for their contributions.

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