EVALUATING STRESS IN DIFFERENT SPOTS OF IZADKHAST DAM BY FLAC MODEL

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Abstract. This paper tries to investigate resistance factors of Izadkhast dam such as pressure of stress distribution. At first, by using instrumentation data of construction period, finite difference method and commercial code of Flac by back analysis method, we reach rational data from preliminary data then continuing project procedure, we divide operation period into the two ten-year periods and the first operation period had began since 2008. Results show that using behavioral model of Mohr-Coulomb in core vertical settlements has appropriate accuracy. Also, analysis of dam total structure show that after construction completion and the first water load, the pore pressure of water created in dam core, amounts 370 kpa which is in the middle of core level.

Keywords: stress evaluation, back analysis, vertical and horizontal transformation, Izadkhast dam, Flac.

1. Introduction

Desiging and constructing embankment dams is one of the sciences which has thousands years of background and many countries located in arid and semi-arid areas such as Iran have beneficial experiences in this regard in early 20th century. Significant transformations had been strated based on done studies by Karell Tarzaghy. Because of diversity of factors affecting embankment dam behavior, specially significant impacts of natural phenomenon such as geological and geotechnical conditions, hydrological and geohyrological conditions of region and climatic conditions which make this scientific discipline face with complex problems that negligence of them can cause project failure and many financial and fatal damages. Destroying many emabankment reservoir dams in world after 1970, proves this claim (Pagano, et al., 2006). During recent decades, different types of numerical methods such as finite element, marginal element and seprated element are applied in solving engineering problems. Today, these methods are used in designing dams, underground spaces such as tunnels, underground stores and slopes. Reliability of designing assumptions depends on input information accuracy of analysis as if they are not being accurate enough or not representing actual values of mechanical parameter of environment, determining values of geomechanical features including stresss, settlement etc., will be difficult (Zoulfaghari, 2005). In investigating embankment dam’s behavior, because there's lack of deterministic criteria for evaluating data, often personal judgments of people are stressed. But, from the first time that numerical situation of layered construction of dam was done, many significant advances, both in numerical methods and physical interpretation of problems has been occurred. Although, only finite number of numerical predictions had modeled deformations of the construction period and the first water load accurately (Clough, and Woodward, 1967). Many scholars have taken steps to evaluate ethology of embankment dams. Ziaei (2014) investigated changes of the pore pressure of Maku dam core during operation period. In that research, based on data proposed by piezometer installed inside the foundation and around the cut off wall, significant downfall in downstreams piezometer level of cut off wall could been seen which shows good performance of this wall. This downfall inside the clay which acts as an impermeable one in this kind of dams, also shows good performance of core. In this research, comparison between resulted diagrams of instrumentation results and also numerical analysis show that there is a good match between measured data by electrical piezometer and software results and dam performance in terms of leak is trustable. Rattue (2000) investigated behavior of Santa Margaret dam in Canada with 171 meter height. In that research, because levee materials had high permeability and levee humidity was equal to the optimal humidity, there was a little pore water pressure in this dam by comparing numerical analysis using obtained parameter of triaxial tests, it was seen that resulted values of analysis does not match with obtained values of measurement and because of that, resulted values of analysis of model were adjusted by performing a trial and error process and it was seen that actual Yung model of dam is 2, 3 times more than obtained values of triaxial tests. Ebrahimnejad, Sediq, Emami Tabrizi and Barari proposed a research named behavior survey of foundation and body settlement of A'lavian dam during operation period. In that research, in addition to the analyzing done measurements regarding displacements and vertical transformations of body and foundation of A'lavian dam with 80 meter height during four years after construction, also interaction between gallery and foundation was done (Jafarzade and Talebi, 2013). Another research was done by Bemaniyazdi under guidance of Dr.Hosseini. In that research, monitoring of Karkhe embankment dam after water load was done and Plaxis and CA2 software were used for back analysis and modeling stress-stress behavior of dam. Main points of this research regarding changes trend of dam behavioral features including pore water pressure and transformations and recreation of these trends by numerical model. Settlement values, pore water pressure and vertical total pressure were analyzed in terms of limit values and changes trend during construction and water load period. Coefficients of pore water pressure and arching were investigated in two done and achieved modes of read out. At the end of that research, predicting dam behavior in effect of reservoir level increase and almost faster decrease than reservoir were done (Haeri, 1996).

In this paper, we investigate behavior of Izadkhast embankment dam during construction and the first water load (which is one of the most important stages of loading and investigating statistical resistance of dams) was done. Also, behavior of this dam was recorded by measurement machines during construction and water load and these information were applied in this research. For investigating this dam behavior in construction and water load mode, Flac software was used and results of this numerical analysis were compared with monitoring results. By this software, displacements and stresss, arching during last stages of construction and water load could be investigated. By back analysis, more realistic parameter are achieved for dam behavior which are usable for analyzing dam behavior under future loadings.

2. Investigating behavior of embankment and rock fill dams during construction

2.1. Stress conditions during construction

Total and effective stress values in dam during construction depends on dam geometry and resistance parameter and compressibility of materials. For a homogeneous dam on solid foundation, elastic analysis shows that vertical stress values in dam axis depends on dam geometry and lateral stress values, in addition to the dam geometry,depends on Poisson ratio of core and shell materials values. During early stages of construction in which, width of levee is more than its height, assumption of increasing stress is equal to the depth of soil multiplied by its weight. But, in next stages, this assumption does not seem rational (Duncan, 1996).

2.2. Dam displacement during the first water load

Displacements of dam because of the first water load can has a complex nature. Input of water force can have following effects:

1. Water forcing on core upstream causes increasing in total lateral stress and push dam down.
2. The impact of water on upstream foundation is in this way that if foundation compressibility will be high, it will be so effective on transformations of dam body. Settlement difference in foundation can cause problems.

3. Decreasing effective stress on upstream shell caused by the phenomenon of immersion partly caused uplift deformation in this area. It should be mentioned in this regard that tangent modulus of materials in unloading is higher than loading.

4. Decreasing parameter of shear resistance and elasticity modulus of upstream shell materials caused by stress and absorption of rock fill materials in upstream shell finally leads to subsidence. Figure 1 shows four effects of water load on dam which are mentioned above.

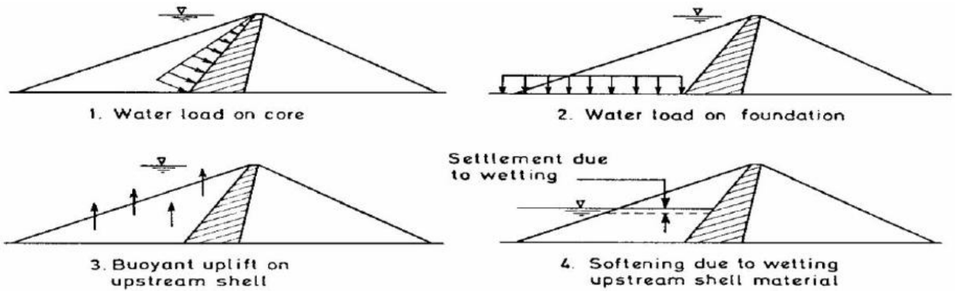


Figure1:Reservoir water loading effects on embankment dam

3. How Flac software work

Flac program for materials propose user following featured models (Zamiran, 2013, Ghorbani and Jamshidi, 2012):

Isotropic elastic model, Mohr-Coulomb plastic model,Drucker-Prager plastic model, Hook-Brown plastic model,hardening-softening strain plastic model, plastic model, reyielding model, Cam-Clay adjusted model. Ofcourse there are more models in Flac software for plastic models, creep models and models which cause pore pressure in dynamic analysis. One of the features of Flac software code is capability of defining behavioral model by using C++ program and adding that to the Flac software code.

4. Introduction of Izadkhast dam

Izadkhast dam located in Fars province. River bed level at the site is 1310 meter above sea level, area level to the dam site is 910 square kilometer, average raining of area (annual raining) is 365 mm per year, average yearly is 110/9, minimum amount is 28.62 million cubic meter (water year of 49-50) and maximum amount is 386/9 million cubic meter (water year of 72-71) in the period of 30 years. Reservoir level of maximum level (1380.4 meter) is 3.27 square kilometer, reservoir volum at maximum level (1380.4 meter) is 95 million cubic meter, input flooding to the reservoir with return period of 100 years is 1000 cubic meter per second, input flooding to the reservoir with return period of 1000 years is 1950 cubic meter per second, input flooding with return period of 10000 years is 3100 cubic meter per second (Zamiran, 2013). This kind of dam is embarkment- rock fill dam with inclined clay core, crest length of dam is 485 meter apart from the length, plug fuse and the bridge over the spillway, crest width of dam is 10 meter, the height from dam bed is 71 meter, the height from foundation is 77 meter, crest level of dam is 1381 meter from sea level, the width of the base in the biggest segment is 330 meter, normal level of dam reservoir is 1378 meter from sea level, reservoir volum in normal level is 82 million cubic meter and reservoir level in normal level of dam is 2.7 square kilometer.

Also, it has grout curtain of 44000 square meter in calcareous masses. Izadkhast dam of Darab has 3 sections of B, E and H tools category and locating maps of dam tools category are shown below. In this dam, different tools such as electrical piezometer, foundation and vertical pipe, barometer cells, hydraulic and magnetic settlement cell, propane and inplace turnkey and accelerometer and meteorological systems were used.

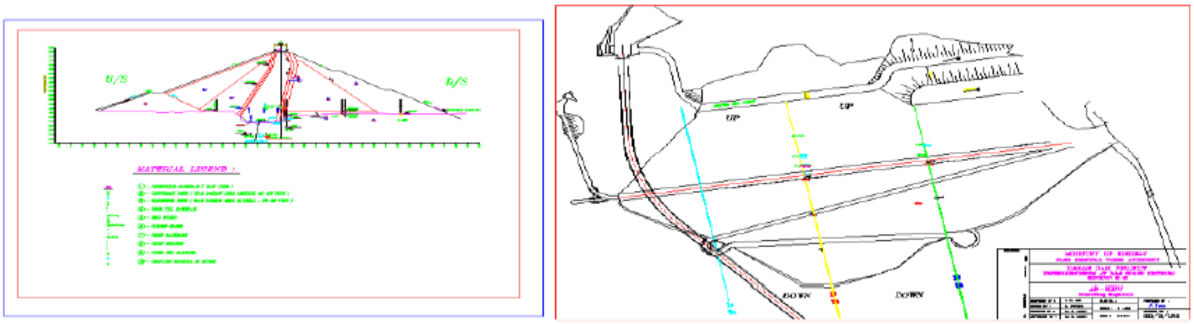


Figure2: Instrumentation layout plan of Darab Izadkhast dam and its section

5. Modeling trend of construction and water load stages of Izadkhast embankment dam

There are different methods for creating elements net in Flac software such as Grid, simple, block and Radial etc.; in this modeling, Block method was used. For creating elements, 6 horizontal blocks (2blocks for foundation and 4 four blocks for body) and 11 vertical blocks (for upstream and downstream shell, upstream and downstream filter-transition, the front space of dam in upstream, downstream and finally in core) were used. Block method could change the mesh density in different areas (9). In defining elements net, it was tried that the length to the width ratio of elements being close to 1 to increase the accuracy of solutions. In Flac software for to the length to the width ratios which are greater than 10, software shows error message. Generally, command for creating a block is as follow (Zamiran, 2013):

Gen x1, y1 x2, y2 x3,y3 x4,y4 i=1 m j =1 n

By above command, a four-square block with coordinates of x4,y4x3,y3x2,y2x1,y1 is formed in which, number of existed elements is equal to m*n. In modeling Izadkhast dam, an element net of 123*53 is used and total dimension of net is 450*141m. Below figure shows intended elements and geometry for modeling body and foundation of Izadkhast dam in Flac software.

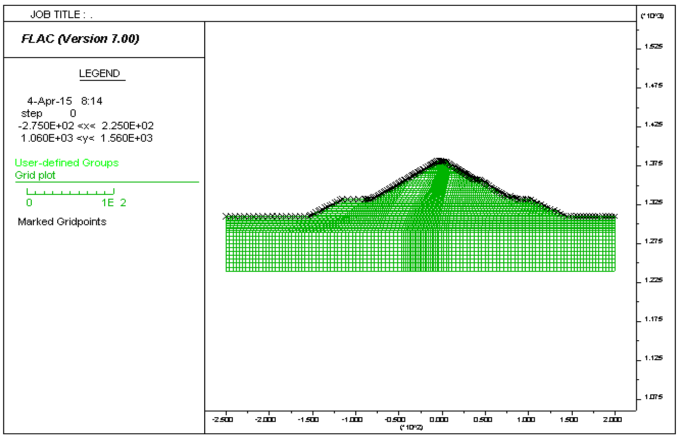


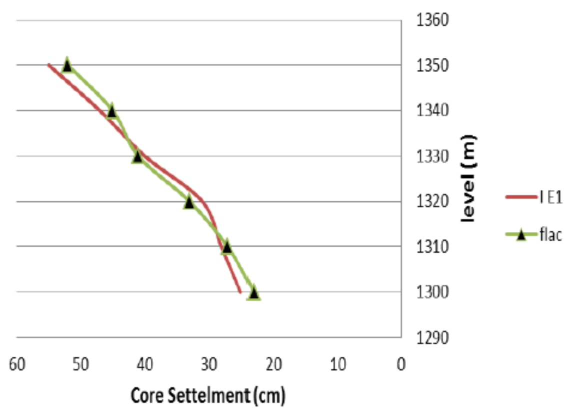
Figure3: Element components and considered geometry For Izadkhast dam in Flac software.

Table1: The initial values of the parameter of materials

e	Ky,m/s	$K_{x,m/s}$	ψ, deg	φ, deg	$C, KN/m^2$	ν	$E, MN/m^2$	$Y, KN/m^3$	materials
0.25	1×10^{-11}	1×10^{-10}	2	30	50	0.25	200	21/3	Foundation
0.30	1×10^{-7}	1×10^{-8}	1	20	17	0.38	15	18	Core
0.33	1×10^{-3}	1×10^{-4}	66	31	0	0.35	24	19	Filter
0.35	1×10^{-2}	1×10^{-3}	4	32	0	0.32	28	19/5	Drain
0.36	1×10^{-1}	1×10^{-2}	5	33	0	0.31	29	20	Transition zone
0.34	1×10^{-1}	1×10^{-1}	1	38	0	0.37	33	18/5	Shell
0.32	1×10^{-3}	1×10^{-4}	3	30	0	0.36	40	21	Cofferdam

6. Investigating vertical and horizontal deformations of dam body

One of the most important behaviors of embankment dam is deformations occurs inside and outside of dam body. During construction period and after that if this phenomenon not controlled, can endanger resistance and efficiency of dam. For measuring inside transformations, two settlement cell – turnkey installed in cross section (E-E) of dam body were used. In this way, for measuring vertical transformations, settlement cell is read outed. Also, physical deformations of dam are measured by continuous finding points of signal points installed in areas of body surface by mapping cameras. Measurement of vertical deformations is done by settlement cell in this way that there are special magnetic levels inside the settlement cell sheath at 5 meter intervals and the lowest level which is the base plate is installed on the rock foundation in which the least relocations had occurred. In (E-E) section, 3 settlement cells named I-E1, I-E2 and I-E3 are located in 3 meter, 53 meter and 103 meter of dam axis respectively in downstream side of shell. For evaluating vertical and horizontal deformations of (E-E) section by Flac software, values of measured settlement were analyzed by above instrument during construction.



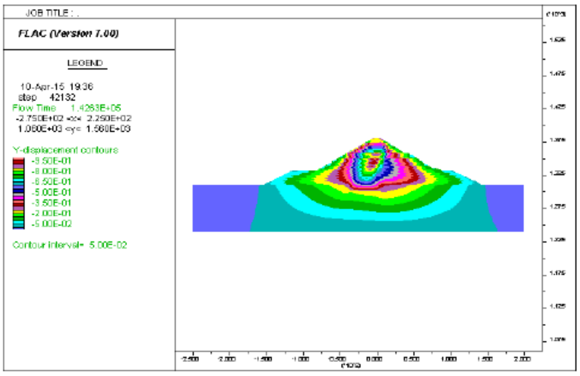


Figure4: Vertical displacement counter in embankment level of 1381 meter and settlement changes in different levels of downstream shell of section (E-E) to the embankment level of 1381 meter.

Above figure shows measured and achieved settlement values from back analysis in downstream shell of dam at the end of embankment is 1381 meter. Error of these data is 0.5. As seen, measured settlements are less than settlement of upstream shell but almost, they have the same changing trend as maximum measured settlement is 92cm and maximum settlement from back analysis is 95cm.

7. Investigating vertical pressures of (E-E) section

In (E-E) section, 3 piezometer were installed in different levels that installed piezometer in 1315 meter level which has the highest total tension was used for back analysis. 2 clusters of 3 installed clusters in this section are in 1342.5 meter and 1365 meter level and both of them are in the core. As seen, changes trend of measured total pressure in core shows acceptable values.

Generally, while embankment dam hieght has increased, results of pressure cells in comparison with the results of software has decreased. Its reason can be possible rotation of piezometer plates and also local arching phenomenon. Based on principles of materials resistance, when one plate has rotated as much as over the horizon, in this case, stress in plate which has angle over the horizon, is equal to:

$$\sigma_\theta = \sigma_y \cos^2 \theta \quad (1)$$

Regarding to the installed pressure cells in dam body, if piezometer plate rotated as much as , finally instead of horizontal stress of σ_y, less stress i.e. σ_θ will recorded.

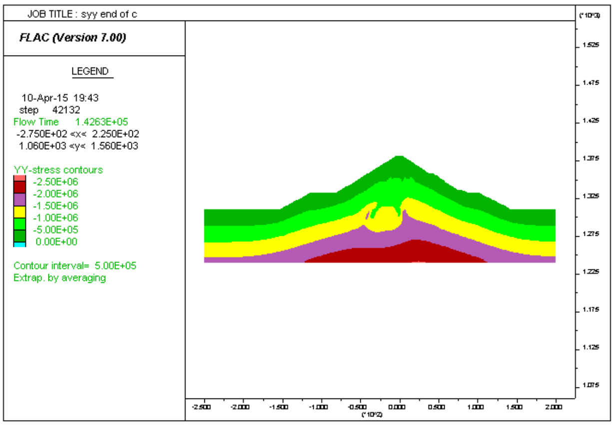


Figure5: Vertical stress counter in embankment level of 1381 meter

For installing piezometer cells in specific level, a hole being digged out and piezometer will put on the hole,, then digged out hole will filled with same materials and again, they will smashed but as filling soil of hole become dense with lighter rollers, always existed soil in hole has less density than soil around the hole and by embankment level increasing, existed solid materials in the hole rely on around space , consequently, local arching phenomenon occurs in hole location and less stress reaches to the piezometer plate. The total stress error is 0.11 averagely.

8. Behavior of Izadkhast dam of Darab during the first water load

Behavior of Izadkhast dam which has 71 meter height, was evaluated by the end of construction when the first water loading was done and reaches 1355 meter levels, behavior of Izadkhast dam will using interpretations of dam read outs by installed instrumentation in its body and also comparing that with done analysis shows natural behavior of dam during construction, except in very minor cases that can be caused by operational problems or damaging very sensitive machines after installation. In the following section, regarding done investigation and also performing back analysis and obtaining real parameter of materials, predictions about dam behavior during operation are proposed.

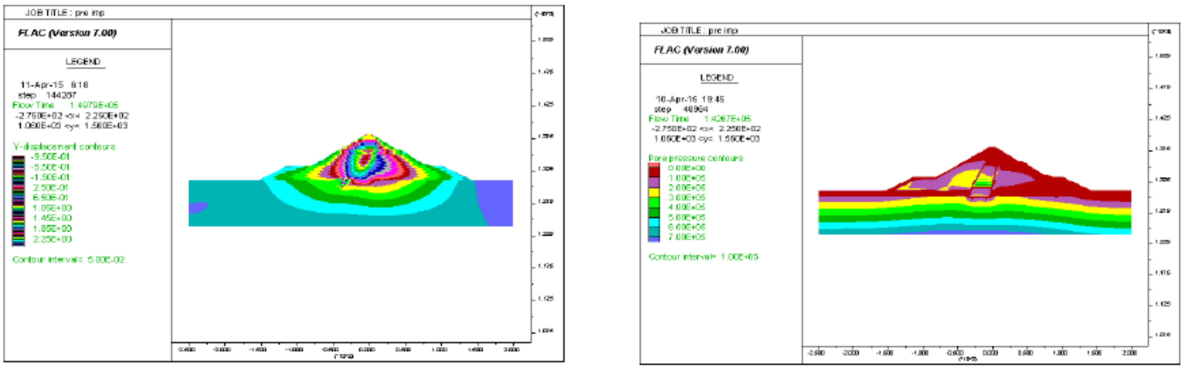


Figure6: Vertical displacement in water loading level of 1355 meter and counter map of pore water pressure in water loading level of 1355 meter.

Regarding done analysis for total body of dam, after construction completion and the first water loading, the pore water pressure in dam core reaches 370 kpa which is in the middle of core level, regarding analysis of dam body, after construction completion, the pore water pressure in dam core reaches 96cm which is in the middle one-third of the core level.

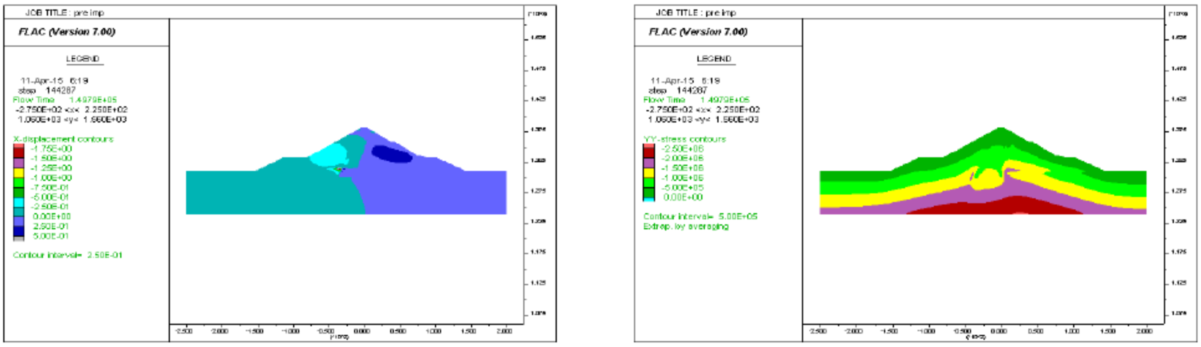


Figure7: Total stress counter in water loading level of 1355 meter and horizontal displacement in water loading level of 1355 meter.

As it is obvious in above figure, horizontal displacement become asymmetrical and the maximum amount is because of water loading in downstream shell. Regarding analysis of dam total body, total stress reduced to the little amount which is also existe in the corner of core level.

9. Conclusion and discussion

In this research, resistance factors of Izadkhast dam were investigated. At first, by using instrumentation data of construction period, finite difference method and commercial code of Flac with back analysis, we reach rational data from preliminary data, then for continuing project trend, we divide operation period into the two ten-year periods and the first operation period was began since 2006. Flac software is a finite difference method which is appropriate for modeling big transformations, the main formulation of Flac 2D program used in this research is base on 2-dimensional plane strain.

Lagrangian computational method and zoning special technique help Flac software for better modeling of plastic transformations and pulp flow in materials. Since no matrix is used during computations, as a result, 2-dimensional long computations do not need large amount of computer memory. Modeling abilities of this program in comparison with other numerical software including plane strain geometric models, plane stree axial symmetry, solving problems in big strain mode for dynamic analysis of embankment dams, possibility of stage construction modeling in embankment dams, ability of sloving model in total stress mode and effective in embankment dams analysis, statistical, linear and non linear dynamic analysis of dams components, solving linear elastic and non-linear elasto-plastic problems (Mohr-coloumb) which are used in embankment dams, investigating between mechanical transformation and fluid flow (2-dimensional consolidations, inflation) in statistical and dynamic analysis, investigating resistance of gables embankment dams, possibility of adding behavioral models to the programming languages of C++ and FISH by user for more advanced analysis of embankment dam. The main drawback of this software is its low speed and models convergence in consolidation problems. Generally, the most important results of this research are as follow:

1. The level of effective strain from the first water loading had decreased till the end of 10-year period but it has decreasing trend since the began of the second 10-year period.
2. Total stress trend in dam body has slow ascending trend which was transferred from the first water loading till the end of the first 10-year period from the low level beside the core to the middle low level of core.
3. Vertical displacement in Izadkhast dam has slow ascending trend which is slower in upstream shell than downstream shell because of water.
4. Horizontal displacement of Izadkhast, like vertical displacement, has ascending trend but the trend of downstream shell is faster because of lack of water.

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