Numerical Analysis of the Geomembrane Behavior in the Sar Cheshmeh Copper Mine Tailings Dam

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Abstract: The use of Geomembranes as Tatrava surface can be considered as valuable and affordable solution compared to other techniques for sealing of earth dams. In one Of the earth dams in Iran (Sar Chesmeh Copper mine dam), the Geomembrane is used to increase the height of the dam. In this study, using by software modeling to try to achieve the optimum thickness for Geomembranes used in The shell was added to the old dam, based on analysis of Seepage and slope stability downstream slope of dam, So using by obtained thickness of the Geomembrane, the smallest leak can cause, and Downstream slope of dam can maintain its consistency and economic aspects are also considered for implementation. To achieve this purpose, Geomembranes with different thickness in the respective place, Considered as a model and determine the optimal thickness of the Geomembrane By comparing the results from the analysis of leakage. Then downstream slope dam stability will examine. then with using of SIGMA/W program from GeoStudio software is applied to evaluate Geomembrane behavior in addition crust to old dam and research be done about sufficiency and insufficiency against enter forces that this evaluation is done base on stress- strain analysis.
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Keywords: Geomembrane, Earth dams, Numerical Analysis, Sealing**.**

1 – Introduction

Geomembrane is made of polymer plastic or rubber membranes that have very low permeability. Polymeric materials which are mainly used in the manufacture of Geomembranes is a thermoplastic polymer. The most important application of Geomembranes, confront with leakage phenomenon or infiltration water or other liquids and gases, toxic and hazardous in their care sites. According to the International Committee Geosynthetic (IGS: Society Geosynthetics International), Geomembrane which are used to in civil engineering are panels, relatively impermeable and the polymer in contact with soil, rock or other geotechnical material. Between the Geomembrane and other Geosynthetic (Geotextile, a Geogrid, etc.), there are important differences. Geomembranes They are designed so that have a low permeability as possible. In other words, the Geomembrane to restrict fluid flow, while other Geosynthetic cause flow of liquid or conduct of it. Geomembrane types include: 1) polymer Geomembrane 2) and Bituminous Geomembrane. Polymeric Geomembranes include thermo plastic (EIA - PVC), the crystalline thermoplastic (VLDPE - LLDPE - HDPE), Thermoplastic Alastvmtrhay (CPE - CSPE). Geomembranes are used in earth dams, the core of earth dams, to increase of dam height, Walls of water and to repair leaking dams.

2 - Sar Cheshmeh Copper Mine Tailings Dam

Sar cheshmeh Copper Mine is located 60 kilometers from city of Rafsanjan. It is used for recovery operations of the copper and water . Therefore, the required water is supplied from the wells, Salt rivers, Return water and in the output in mining, the amount of weaskest water flow is 1000 liters per second. that, Firstly it must be maintained and control in place to prevent environmental pollution, And secondly, after separating the dry material through sedimentation, water returned to the factory and it is used again. The sediment retention dam about 21 km downstream of the mine site In order to collect the weaskest water plant was launched and was operating. The primary Sediment retention dam was kind of gravel dams with copper core and have been Height of 70 meters of river bottom. In terms of specifications, such as the dam has a width of 10m in the crest, Geomembrane is used Because of the low width clay core in the primary sediment retention dam (about 3 meters). Consequently, The initial stage of sediment retention dam Consisting of gravel with a clay core height of 70 m, has been changed to The gravel dam with a mixture of clay and Geomembrane sealing system and with a height of 110 meters, And a total of 37,000 square meters of PVC Geomembrane is used.

3- Analysis of the leak in the Sar cheshmeh Copper dam

The GeoStudio software is used to analysis of the Leak in the mentioned dam. GeoStudio software is including geotechnical software Based on Finite Elements. Through its, can be examine analyzes such as the stress - strain, leakage, flow, Slope stability and Dynamic Analysis. This software includes parts SIGMA / W for the analysis of the stress - strain, SEEP / W for the analysis of the flow and Leakage, SLOPE / W for the analysis of the slope stability, QUAKE / W for the dynamic analysis and other application areas. In this section, using the SEEP / W will be analysis of the Leakage in the sar cheshmeh cooper dam. Sar cheshmeh copper dam is shown in Figure 1. Also the geotechnical parameters and leakage barrier material is presented in Table 1.

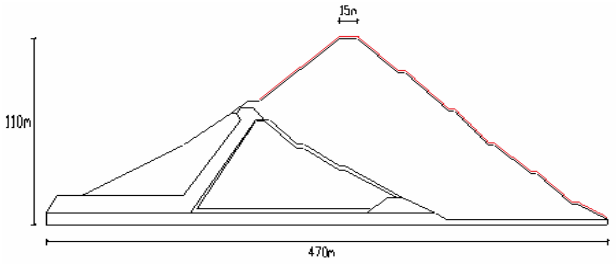

Figure 1 - section of the Sar Cheshmeh Copper dam

Table 1 - Geotechnical parameters and leakage of the barrier materials

Material properties	Specific gravity (KN/m^3)	Drained angle of internal	Cohesion Drained (Kpa)	Shear Modulus	Bulk Modulus	horizontal permeability (cm/s)
upstream gravel	20	47	-	80	170	10^{-1}
clay core	19	22	20	10	90	10^{-6}
downstream weir	20	47	-	86	115	10^{-2}
the shell was added	22.5	44	-	86	115	10^{-3}
Geomembrane	-	-	-	-	-	10^{-12}
The andesite Foundation	22.5	-	-	700	2600	5×10^{-6}

Axial standard test results on Geomembrane cover show antiseptic values like delivery stress 1700 Pa, rapture stress in 3500 Pa tension and rapture strain 10% . For finding useful and optimized width of Geomembrane in dam, it is necessary that Geomembrane with different widths are modeled like Figure 1. With using of SEEP/W program is analyzed leakage of Sar cheshmeh copper mine Tailings Dam. First, said dam section is modeled in SEEP/W program (Figure 2), then Geomembrane with 1, 2, 3 and 4 mm thickness is modeled in add crust location to old dam and in three section of dam, the rate of passing flow rate is calculated from their sections by software. Finally, with notice to passing flow rate and economical aspect of plan, optimize thickness get base on leakage analysis. Water head is shown with red color point on dam body.

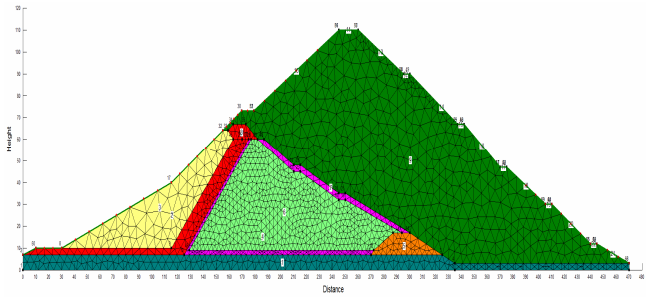

Figure 2- modeling section of Sar cheshmeh copper mine in SEEP/W program

Sections that are considered for passing flow rate calculation are:

1. One section is considered from dam upside to dam substratum.
2. A section that pass from dam center
3. A tangent section to dam body in downside that get final sediment rate from substratum and dam body (total sediment).

Section number 1

This section is shown in Figure 3 that starts from upside part and it continues to dam substratum. This section is chosen with error and exam way that can say about most of passing flow rate in dam body is related to this section.

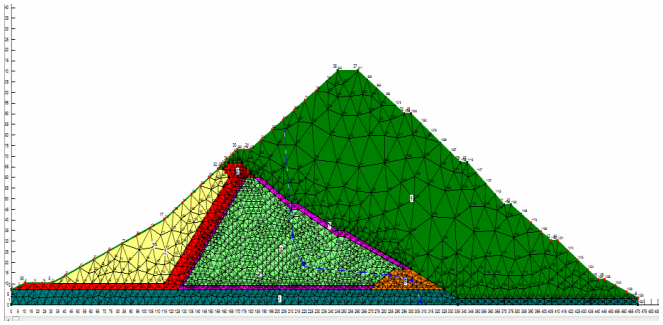

Figure 3- Section Number 1

After choosing section, are done analysis activities. Passing flow rate from section is shown for different states in Table 2.

Table 2- passing flow rate from section number 1 under influence of Geomembrane with different thicknesses

Geomembrane thickness	1	2	3	4	Without Geomembrane
Passing flow rate	9.527×10^{-3}	4.26×10^{-3}	1.28×10^{-3}	0.237×10^{-3}	14.903×10^{-3}

With notice to Table 2, reduce percentage of passing flow rate is illustrated in Table 3 for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 1.

Table 3- reduce percentage of passing flow rate for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 1.

Geomembrane thickness (mm)	1	2	3	4
Reduction of passing flow rate in proportion to without Geomembrane (%)	36	72	92	98

With notice to Table 3 can be said that optimize thickness for Geomembrane base on passing flow rate from section number 1 is 3 mm because passing flow rate reduces in proportion without Geomembrane as 92% and so the reduction rate of passing flow rate for thickness less than 3 mm in comparing with without Geomembrane state is less than threshold that it can proper dam stability. About 4 mm thickness however passing flow rate in proportion to without Geomembrane state reduce 98 percentages but with notice to cost of Geomembrane performance, using of 4 mm thickness is not acceptable of economical aspect.

Section number 2

This section is shown in Figure 4 and it passes from dam center.

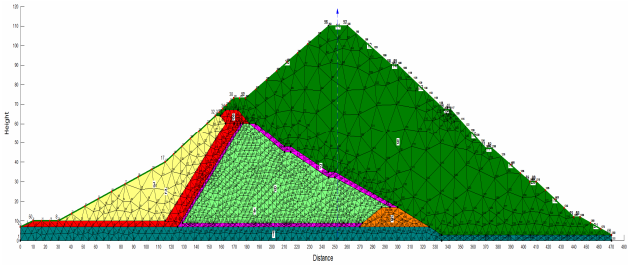

Figure 4- Section Number 2

After choosing section, are done analysis activities. Passing flow rate from section is shown for different states in Table 4.

Table 4- passing flow rate from section number 2 under influence of Geomembrane with different thicknesses

With notice to table 2, reduce percentage of passing flow rate is illustrated in Table 3 for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 2.

Geomembrane thickness	1	2	3	4	Without Geomembrane
Passing flow rate (m^3/s)	11.246×10^{-3}	4.899×10^{-3}	1.3824×10^{-3}	0.2988×10^{-3}	16.6294×10^{-3}

Table 5- reduce percentage of passing flow rate for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 2.

Geomembrane thickness (mm)	1	2	3	4
Reduction of passing flow rate in proportion to without Geomembrane (%)	32.36	70.54	91.68	98.2

With notice to Table 5 can be said that optimize thickness for Geomembrane base on passing flow rate from section number 2 is 3 mm because passing flow rate reduces in proportion without Geomembrane as 91.68% and so the reduction rate of passing flow rate for thickness less than 3 mm in comparing with without Geomembrane state is less than threshold that it can proper dam stability. About 4 mm thickness however passing flow rate in proportion to without Geomembrane state reduce 98.2 percentages but with notice to cost of Geomembrane performance, using of 4 mm thickness is not acceptable of economical aspect.

Section number 3

This section is shown in Figure 5; it is a section that is tangent on dam body in downside that it gives final sediment rate from dam substratum and body (total sediment). For clearing this section should be clicked on all points of dam body fundamental in downside.

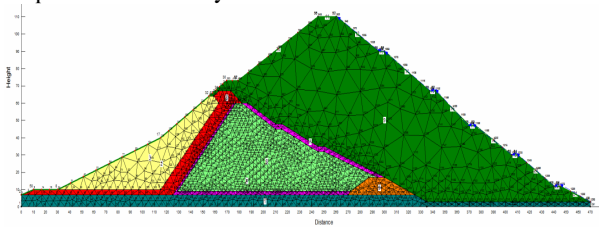

Figure 5- Section Number 3

After choosing section, are done analysis activities. Passing flow rate from section is shown for different states in Table 6.

Table 6- passing flow rate from section number 3 under influence of Geomembrane with different thicknesses

Geomembrane thickness	1	2	3	4	Without Geomembrane
Passing flow rate (m^3/s)	8.2843×10^{-3}	3.3876×10^{-3}	1.0135×10^{-3}	0.2278×10^{-3}	13.5082×10^{-3}

With notice to table 6, reduce percentage of passing flow rate is illustrated in Table 7 for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 3.

Table 7- reduce percentage of passing flow rate for different thicknesses of Geomembrane in proportion to without Geomembrane state for section number 3.

Geomembrane thickness (mm)	1	2	3	4
Reduction of passing flow rate in proportion to without Geomembrane (%)	38.67	74.92	92.49	98.31

With notice to Table 7 can be said that optimize thickness for Geomembrane base on passing flow rate from section number 3 is 3 mm because passing flow rate reduces in proportion without Geomembrane as 92.49% and so the reduction rate of passing flow rate for thickness less than 3 mm in comparing with without Geomembrane state is less than threshold that it can proper dam stability. About 4 mm thickness however passing flow rate in proportion to without Geomembrane state reduce 98.31 percentages but with notice to cost of Geomembrane performance, using of 4 mm thickness is not acceptable of economical aspect.
With notice to results of three sections, can be said base on leakage analysis that for using Geomembrane as add crust cover to old dam is considered 3 mm thickness. After selecting a thickness of 3mm for Geomembranes used in the shell was added to the old dam, check dam downstream slope stability are addressed in two modes. One case is when do not use the Geomembrane and the latter is when the Geomembrane thickness 3mm to be used. To check the stability of the dam downstream slope from SLOPE / W section, GeoStudio software is used. For this purpose, the stable flow is considered. In Figure 7 slip surfaces in the downstream of the dam when is not used the Geomembrane is displayed. And In Figure 8 slip surfaces in the downstream of the dam when the Geomembrane thickness 3mm to be used is displayed.

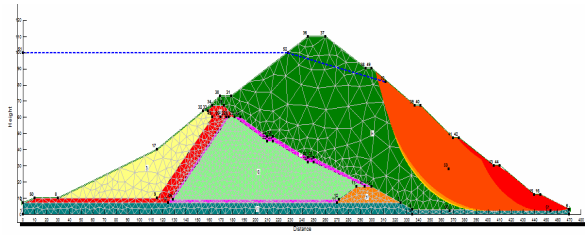

Figure 7 - The slip surfaces related to Without the Geomembrane

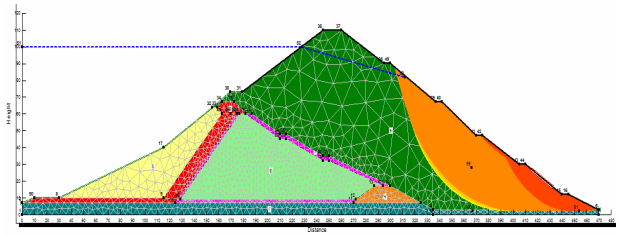

Figure 8 - the Slip surfaces associated with the use of Geomembranes with a thickness of 3mm

It should be noted that the red color shown in Figures 3 and 4, Shows the critical mode of the slip. And farther away from the red, we can reduce the risk of slip. Obtained Coefficient of confidence is obtained in the case without the Geomembrane by 0.68 and in the 3mm thickness of the Geomembrane by the 1.604. That means when is not used the Geomembrane, the lower dam would be unstable, when the Geomembrane thickness 3mm to be used , stability of the Dam will provide.

Stress – strain Analysis with the SIGMA/W program

Modeling section of dam in SIGMA/W program is shown in Figure 9.

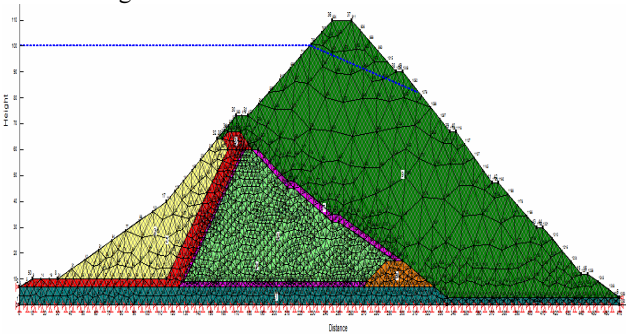

Figure 9 - cross of the modeling at the Dam Copper in the SIGMA/W program

Results of SIGMA/W program is shown in figure 10-16 as graphical.

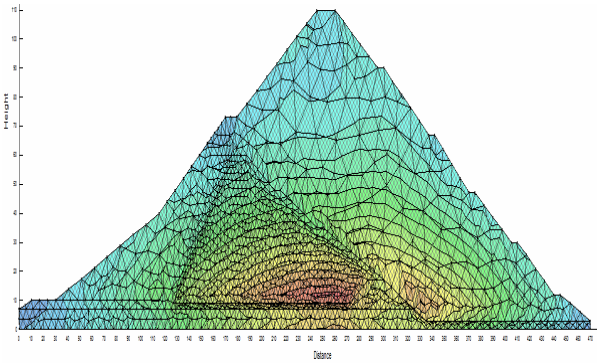

Fig 10- meter of horizontal total stress

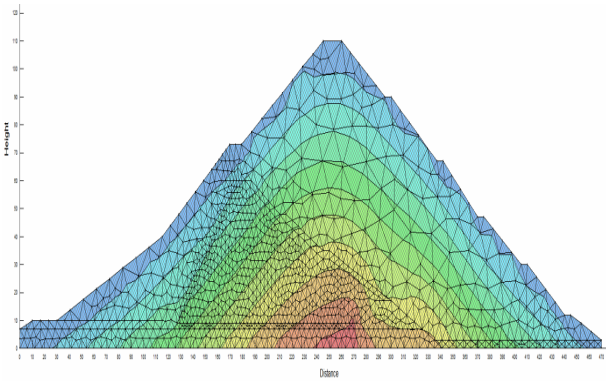

Fig 11 - meter of vertical total stress

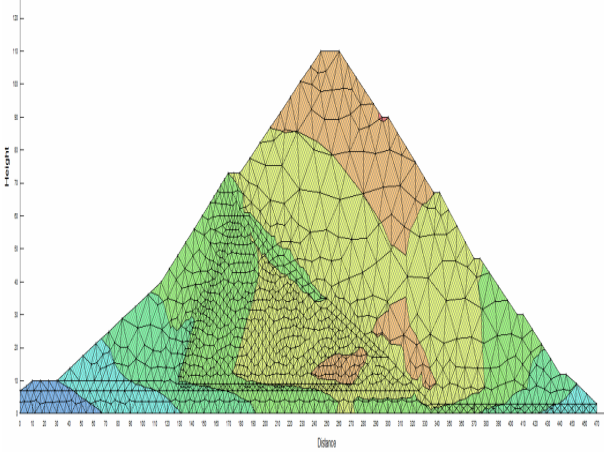

Fig 12 - meter of horizontal effective stress

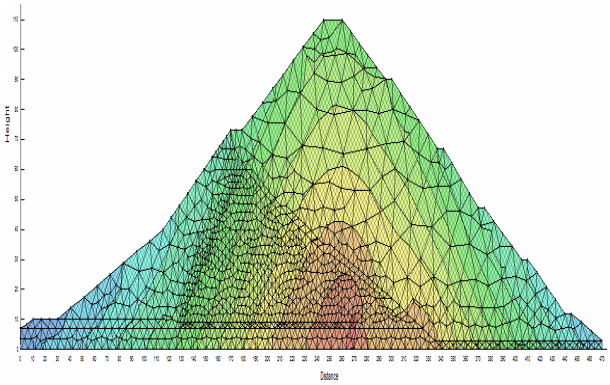

Fig 13 - meter of vertical effective stress

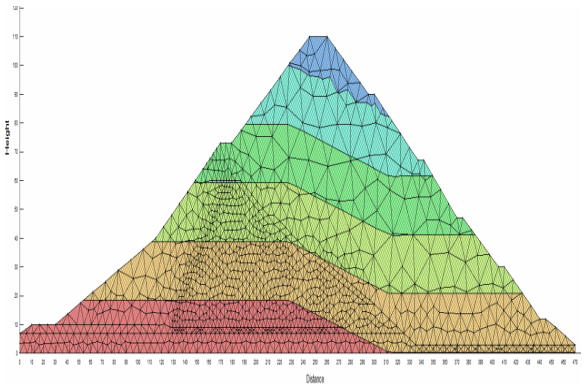

Fig 14 - meter of Pressure of hole water

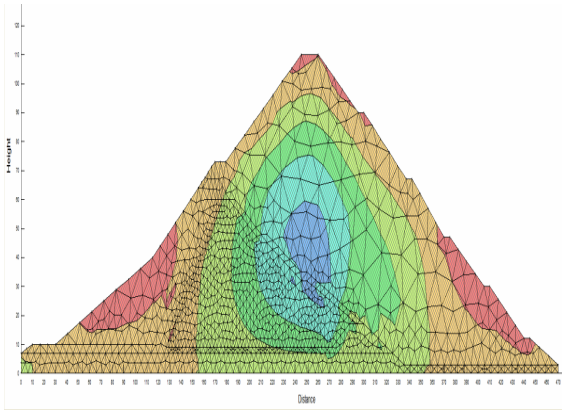

Fig 15 - meter of horizontal strain

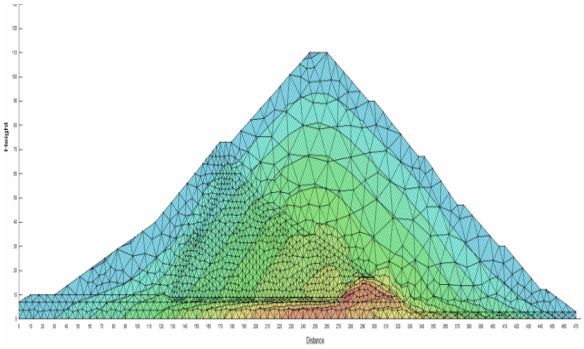

Fig 16 - meter of vertical strain

Conclusion

Impermeable Geomembrane used as cover in the dams is a new method. Similar dams used in the lower elevations of the dam with height Copper is very limited. Similar application of that in dams with lower hieght than Sar cheshmeh Copper dam, With increase of the height is very limited. In the Sar cheshmeh Copper dam due to dam construction, its sealing to prevent destructive leakage Is of considerable importance. Because of the low width of the clay core in the old dam to increase the height of the dam must be used Geomembrane for the sealing barrier. Due to the high cost of the Geomembrane implementing, Geomembrane thickness used will impact significantly on project costs. So, the Geomembrane must be used with required minimal thickness. We can say optimized for Geomembranes used in shell thickness was added to the old dam, is 3mm. Obtained Coefficient of confidence is obtained in the case without the Geomembrane by 0.68 and in the 3mm thickness of the Geomembrane by the 1.604 That means when is not used the Geomembrane, the lower dam would be unstable, when the Geomembrane thickness 3mm to be used , stability of the Dam will provide. With notice to figures 10-16 have seen that regions that are used Geomembrane cover in their surface are illustrated stress in acceptable range dominantly blue and green. In figure 7 that is meter of hole water pressure, have been seen that in upside of dam from base floor to approximately height 18 m from upside base, hole water pressure have maximum value. Best way for decreasing water leankage in this area will be use of Geomembrane to decrease until range rate that is happen maximum hole water pressure. With notice to tension meter, maximum of produce tension is 938.299 Pa and is tensional in a range that is used Geomembrane And with notice to tension rate and rapture tension in tensional for using Geomembrane is 1700 Pa and 3500 Pa respectively. So using Geomembrane against enter tension show enough resistance. Also maximum rate of produce strain in Geomembrane is 3.26% and with notice to Geomembrane rapture strain is 10%, so produce strains in geomembrain is located in acceptable range too.

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