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RESERVOIR HEIGHT AFFECT ON THE DYNAMIC BEHAVIOR OF ARCH DAMS

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SUMMARY

The dynamic analysis of an arch dam is in fact a problem of structure-fluid foundation interaction. Interaction between dam and impounded water affects the earthquake response of an arch dam.

In general, interaction between dam & water cause to increase the interior stresses of dam body and the amount of increasing stresses depend on the ratio of the fundamental natural vibration frequency of the impounded water to the fundamental natural frequency of the dam alone.

Most often there exists water in the downstream face of a dam, which its height reaches several meters in addition to water accumulated on the upstream face.

In this paper, it will be shown that a column of water in contact with an arch dam with a height less than one-third of the dam height has no affect on the earthquake response of the dam.

INTRODUCTION

Seymareh dam and H.P.P project is located on the Seymareh river, one of the main branches of the Karkheh river, in the south west of the Islamic republic of Iran.

The site is located in the Zagros Mountains, in the Elam area, North West of Khuzestan province and South East of Elam province, within a distance of 35 Km from the town of Darreh-shahr. Seymareh dam project is a multi-purpose project, with the main aim of providing 480MW electricity.

The project consists of the following main items:

- Concrete arch dam, with a maximum height of 180^{m}, and the crest at elevation 730m.a.s.l.
- The dam incorporates a thrust block on the left abutment, base of witch is at el.700m.a.s.l as well as a thrust block on the right abutment witch its base is at el.685m.a.s.l, located between the dam and chute spillway headworks.

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- A service chute spillway at the right bank.
- A free overfall spillway.
- Two bottom outlets, one at elevation 620m.a.s.l and the other at elevation 640m.a.s.l.
- Irrigation outlet at elevation 686.
- Power plant intake structure at the left bank.
- Powerhouse located far from the dam, within a distance of 1.5 Km, at the left bank of the river equipped with three main generating units each of 160MW capacity.

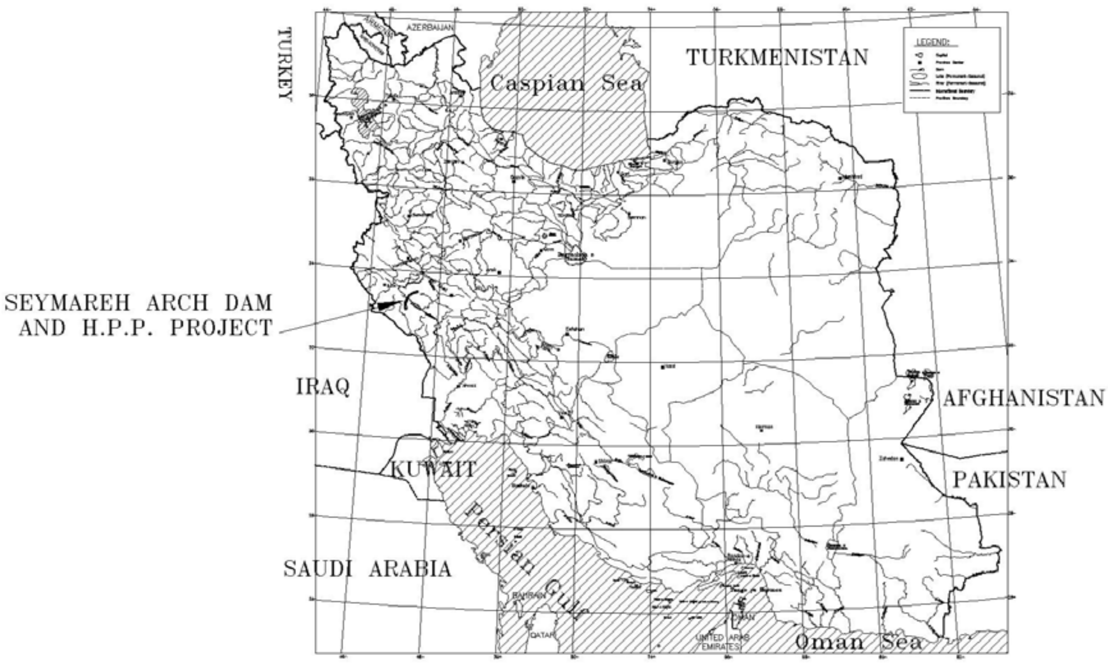

Fig-1.Location of the Seymareh dam in IRAN

The final dam characteristics are summarized as follows:

Dam type	Double arch concrete
Arch type	Parabola
Maximum dam height	180m
Crest length	203m
Thickness at crest	6m
Thickness at dam base (in the reference plane)	24m
Total volume of dam and appurtenant structures	635000m^3
Crest elevation	730 m.a.s.l
Base elevation	550 m.a.s.l
Boldness coefficient (from Lombardi)	9.6
Ratio of the base thickness to the height	0.13

1-Hydrodynamic aspects in dam analysis

Whenever earthquake occurs, dam will be vibrated due to the fact that it is attached to the ground. However water in contact with dam will not be affected directly by ground shaking due to small shear force between reservoir bed and water. However dam vibrations induce hydrodynamic waves which will be propagated in the reservoir.

Dynamic forces which cause stress in a dam are inertial forces induced by ground shaking in addition to hydrodynamic forces exerted from fluid on the dam. Accordingly, the hydrodynamic forces induced in fluid are function of the dam movement. Therefore the system of equation which governs the dam motion and hydrodynamic forces in fluid are coupled.

Interaction between a dam and impounded water affects the earthquake response of arch dams. Dam-water interaction lengthens the fundamental period of a dam.

In general, interaction between dam & water cause to increase the interior stresses of dam body and the amount of increasing stresses depend on the ratio of the fundamental natural vibration frequency of the impounded water to the fundamental natural frequency of the dam alone.

$$\theta_r = \frac{\omega_1^r}{\omega_1^d} = \frac{\frac{\pi c}{2h}}{\frac{2\pi}{T_1}} = \frac{cT_1}{4h}$$

Where:
T_1= fundamental natural period of the dam alone
c= sound velocity of hydrodynamic propagating wave
h= depth of reservoir

For a reservoir with a definite depth, more θ_r will yield to more affect on the dynamic response of a dam. On the contrary, a more rigid dam induces less interaction on the dynamic response of it.

2-Results of dynamic analysis of Seymareh dam

Height of water in the reservoir for normal operation of the Seymareh arch dam is 165m. There is also permanent tail water which its height reaches to 55m (one-third of the water height on the upstream face).

A perfect finite element mesh consisted of dam body and appurtenant structures as well as foundation, upstream reservoir and tail water was created. The results of the modal shape analysis of Seymareh dam are presented as follow:

Table 1- Modal analysis of dam-foundation alone without reservoir

*** Frequencies from block lanczos iteration ***		
Mode No.	Frequency (Hertz)	Mode shape type
1	2.709753658038	AS
2	3.302882238608	S
3	4.533763914760	S
4	4.962802191569	AS
5	5.114491795922	AS
6	5.313374396849	AS
7	6.146741842649	AS
8	6.280210525720	AS
9	7.273961913930	S
10	7.504727064054	S
11	7.700643843512	S
12	8.126181569510	S
13	8.511914196686	AS
14	9.503748740464	AS
15	9.943687470451	AS

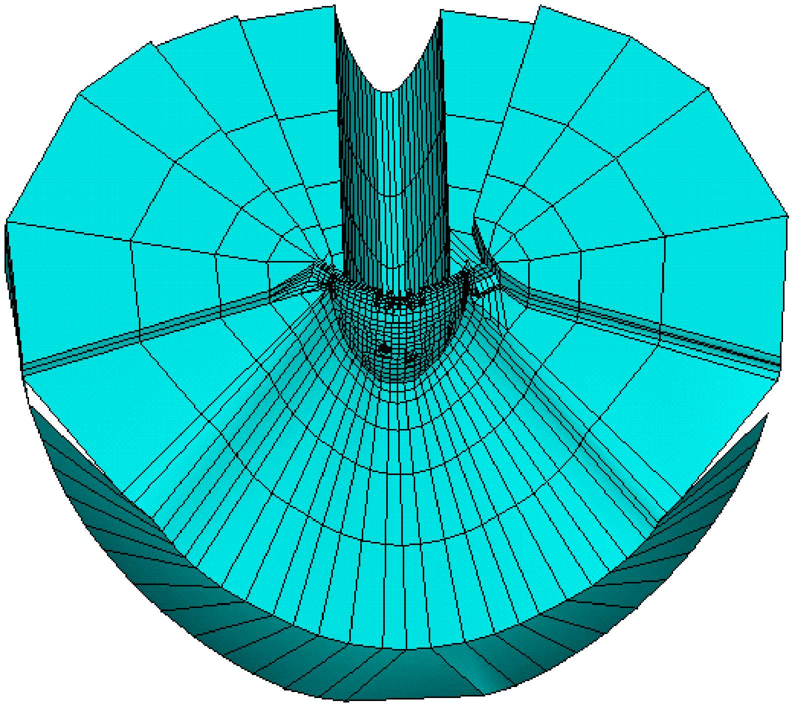

Fig-2.Finite element mesh of dam and foundation

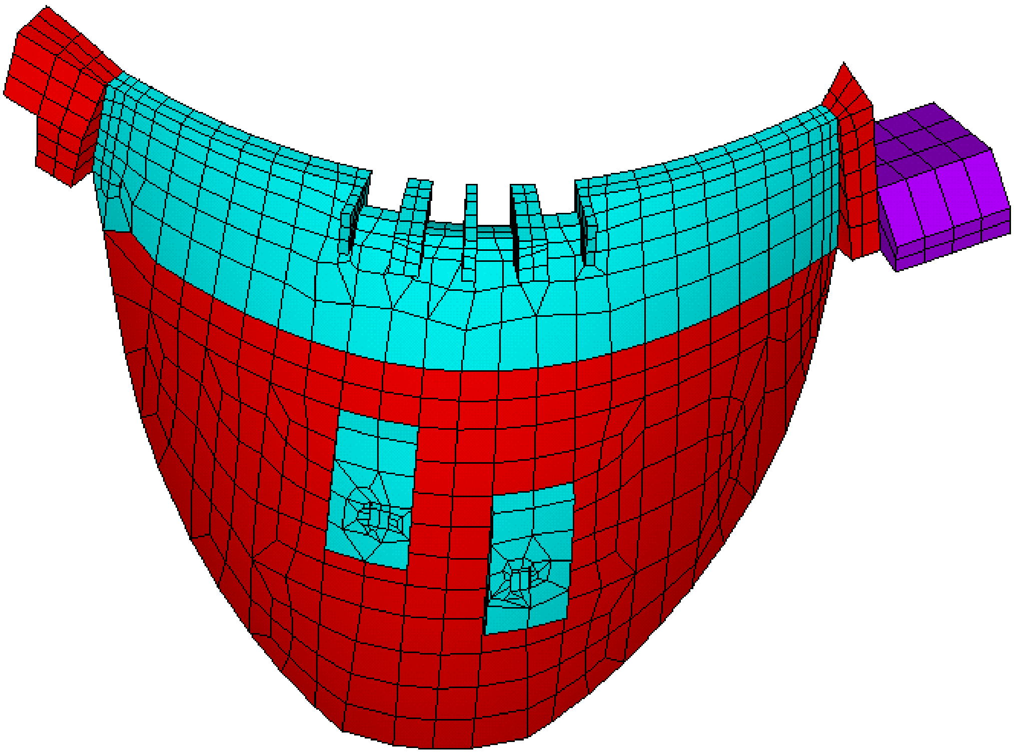

Fig-3.Finite element mesh of dam alone

Table 2- Modal analysis of dam and foundation with upstream reservoir

Frequencies from lanczos unsymmetric eigensolver		
Mode No.	Frequency (Hertz)	Mode shape type
1	2.1718768	AS
2	2.2822670	AS
3	2.7801682	S
4	3.4441896	S
5	3.9309643	S
6	4.0426495	AS
7	4.5484426	S
8	5.0414157	S
9	5.3991020	S
10	5.6136446	AS
11	5.7411252	AS
12	5.8710884	AS
13	6.0152345	AS
14	6.3550677	S
15	6.4108739	AS

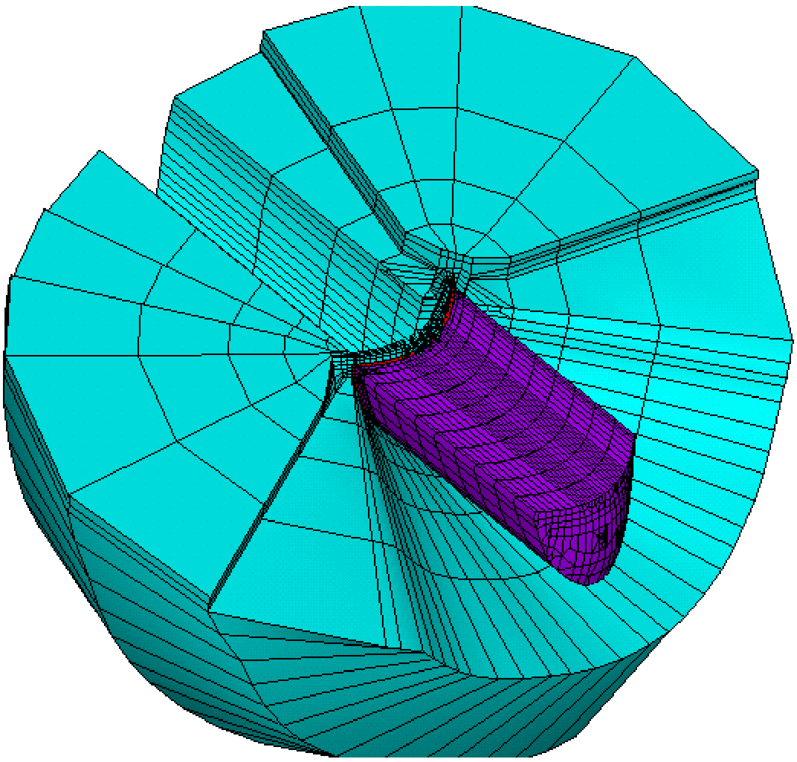

Fig-4.Finite element mesh of dam–foundation and reservoir

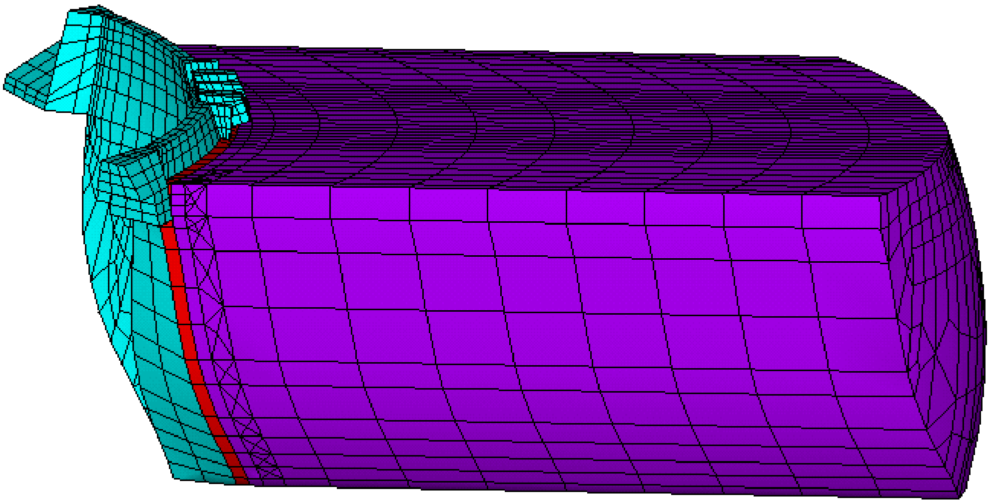

Fig-5.Finite element mesh of dam and reservoir

Table 3-Modal analysis of dam and foundation with upstream reservoir & tailwater

Frequencies from lanczos unsymmetric eigensolver		
Mode No.	Frequency (Hertz)	Mode shape type
1	2.1701241	AS
2	2.2807225	AS
3	2.7788582	S
4	3.4425683	S
5	3.9303166	S
6	4.0350235	AS
7	4.5321788	S
8	5.0364435	S
9	5.3669305	S
10	5.6087918	AS
11	5.7348587	AS
12	5.8468900	AS
13	6.0145954	AS
14	6.2448194	S
15	6.3861274	AS

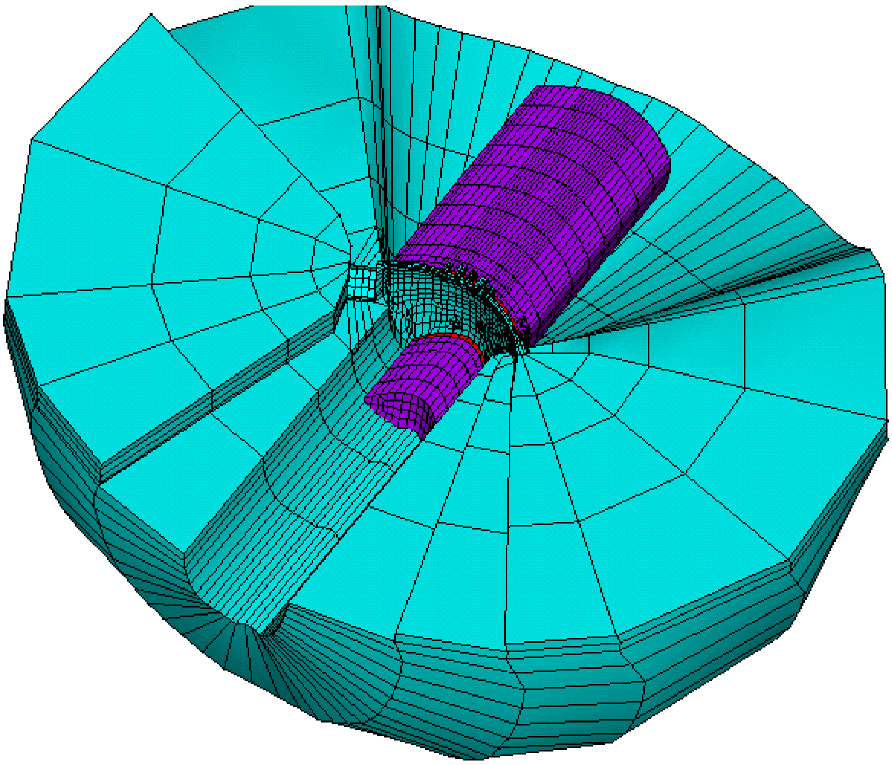

Fig-6.Finite element mesh of dam-foundation-tailwater & reservoir

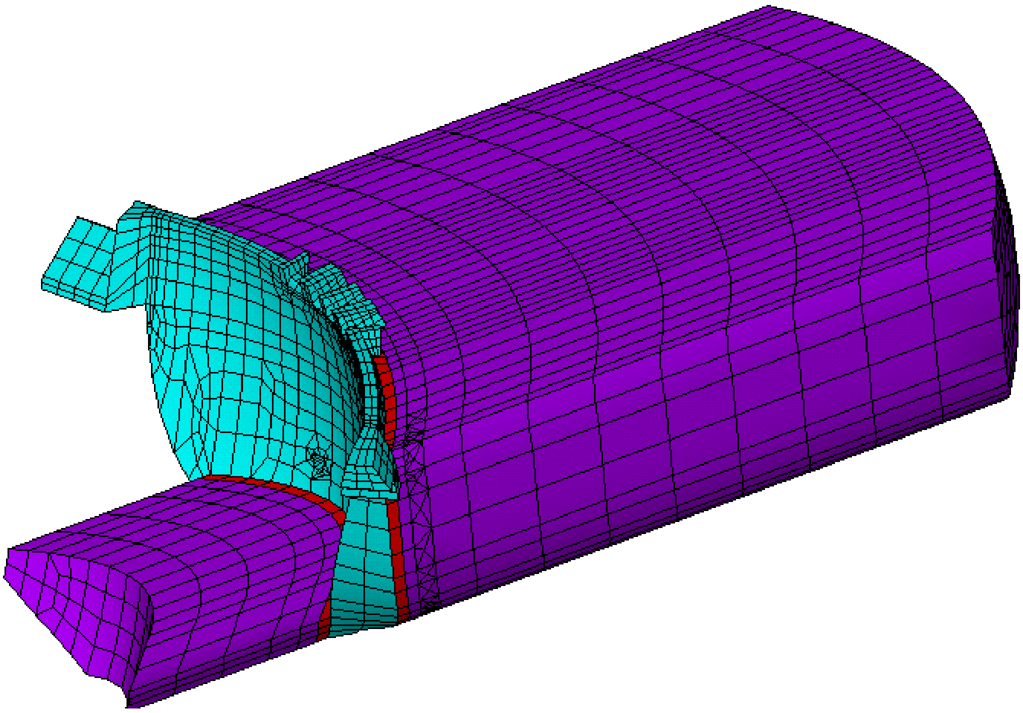

Fig-7.Finite element mesh of dam-tailwater & reservoir

Table 4- Modal analysis of dam-foundation with tailwater

Frequencies from lanczos unsymmetric eigensolver		
Mode No.	Frequency (Hertz)	Mode shape type
1	2.7096	AS
2	3.2983	S
3	4.5324	S
4	4.9318	AS
5	5.1015	AS
6	5.2890	AS
7	6.1473	AS
8	6.2794	AS
9	6.7574	S
10	7.4822	S
11	7.6436	S
12	7.8079	S
13	8.1130	AS
14	8.3469	AS
15	8.4309	AS

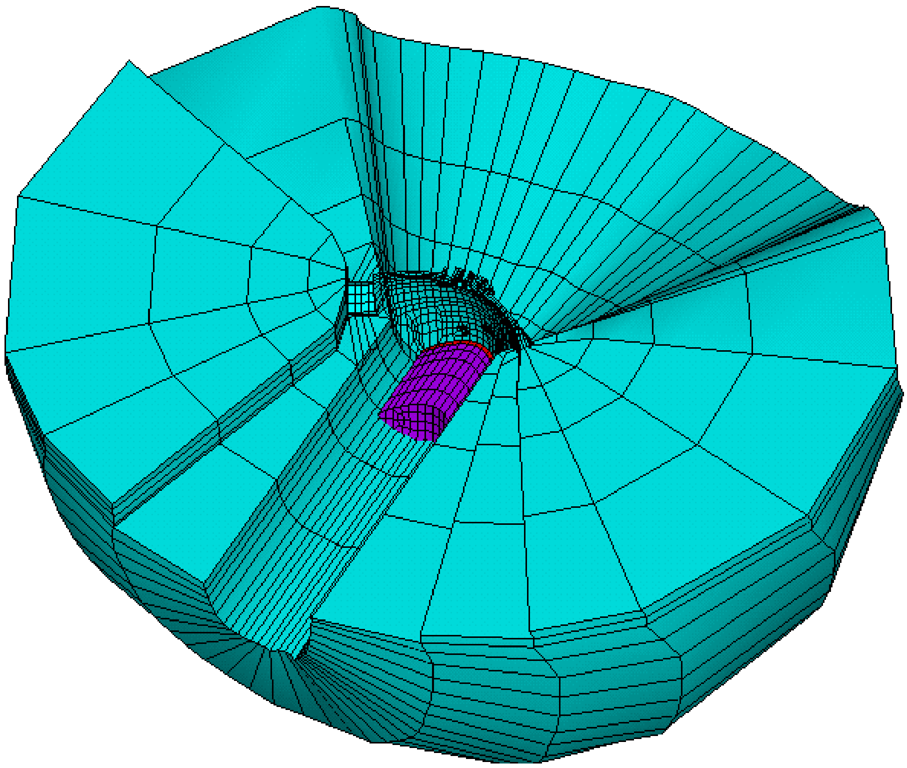

Fig-8.Finite element mesh of dam-foundation & tailwater

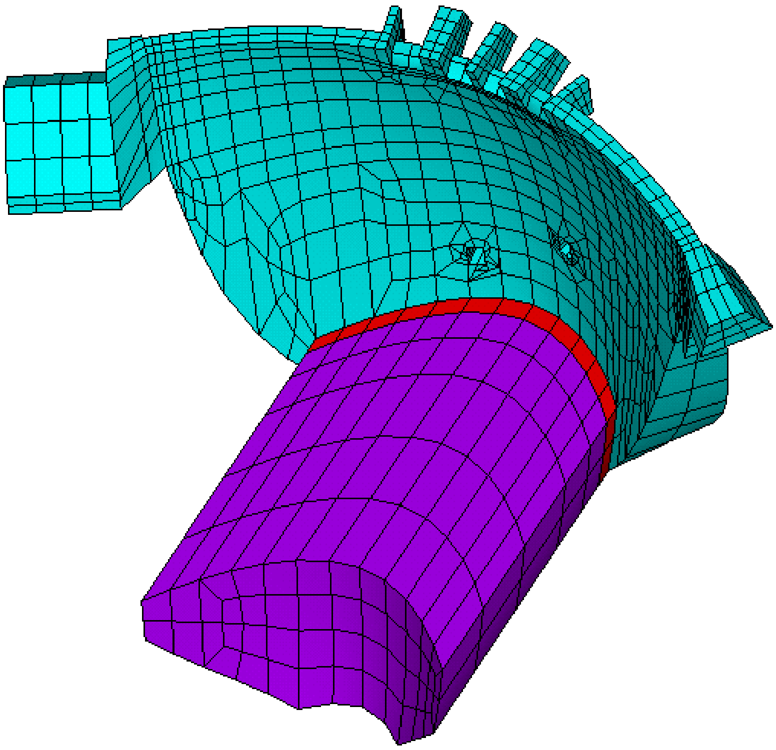

Fig-9.Finite element mesh of dam and tailwater

Note:
S= Symmetric about the reference plane
AS=Ant symmetric about the reference plane

3-Conclusion

As it could easily derive from the tables we can conclude that including tailwater has no affect on the dynamic response of the Seymareh arch dam. It is recommended in order to simplify the finite element mesh neglecting these cases.

4-References

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