Static and dynamic analysis of Lali bridge basin and caisson foundation

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Abstract
The static and dynamic analysis of Lali bridge basin and caisson foundation is discussed in this paper. The bridge is on Karoon River at elevation 240 m. The river water level is now at 110 and after water is impounded behind Gotvand Dam, the water level will rise to 235 meter. The bridge is cable stay type and will basically rest on two piers, each having two caissons foundations. The caissons have a deck of 16 by 32 meter with 5 meter thickness and are of diameter of 10 meter and depth of 20 meter in rock foundation. The submergence has important consequences on the basin stability and caisson design. The heave and stability of the basin as well as the details of the geotechnical design of the foundation caissons will be discussed.
Keywords: caisson, submergence, geotechnical design, dynamic

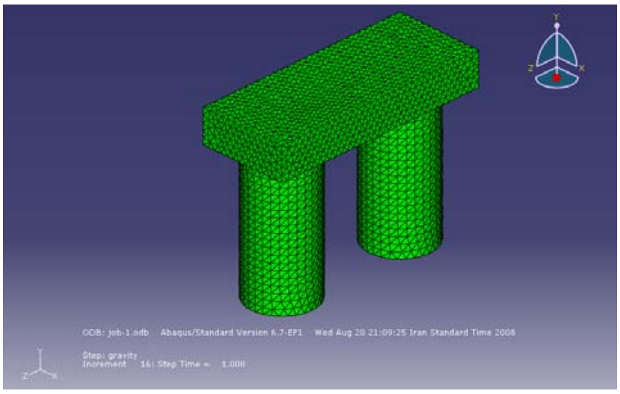
1. INTRODUCTION

The geotechnical report study of the Lali Bridge was assigned to this expert by Bolandpayeh Company. The static analysis of Lali bridge basin and caisson foundations were presented in 3rd International Bride Conference, Tehran May 2008 [1] and can also be viewed in web site : http://www.arsalanghahraman.com/lalibridgepaper.pdf . Basin time history analysis and spectrum analysis and caisson design will be presented in this paper.

For completeness the geological plan , the abutment figure and the caisson group and the rock mass properties is reproduced here, see Figure 1, 2 and 3 and Table 1. The bridge caisson foundations are located in sandstone layer. The caisson group consists of deck of 16 by 32 meters with 5 meter thickness and two caissons of 10 meter diameter and depth of 20 meters and the shell of the caissons are 1 meter thick and the bottom shell is two meters thick, the inner part will be filled with lean concrete. The caisson group is located in the left and right abutment and will be fully inundated after Gotvand dam is impounded.

Figure 1. Rock Mass unit ASA3 foundation of rock socket for bridge

Figure 2. The thick bedded sandstone geological unit A7 and rock mass unit ASA3 for the rock socket bridge foundation



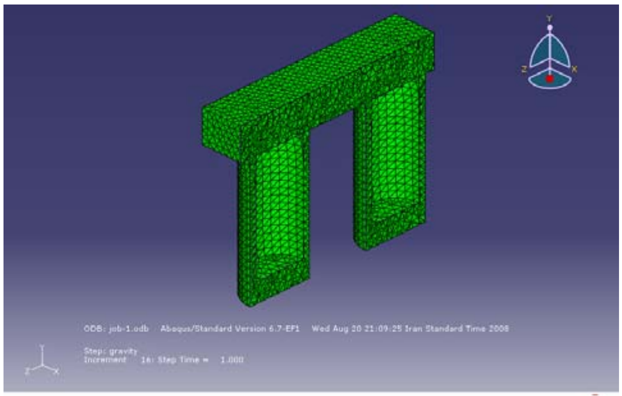


Figure 3. Caisson group and shell

Table 1- Table of Rock Mass Properties

Layer No	Layer Designation	Description	C Mpa	Φ degrees	E Mpa	Sigc Mpa	Sigcm Mpa
1	GJ	Marlstone Siltstone Sandstone	0.46	34	3247	0.71	5.2
2	M	Sequence of Marlstone Sandstone	0.135	25	919	0.1	1.02
3	ASM	Sandstone Mudstone	0.46	34	3247	0.71	5.2
4	ASI5	Sandstone Siltstone	0.46	34	3247	0.71	5.2
5	ASA4	Sandstone	1	47	6667	4	19
6	ASI4	Sandstone Siltstone	0.46	34	3247	0.71	5.2
7	ASA3	Sandstone Siltstone	0.7	40	5160	2.2	5.2
8	ASI3	Sandstone Siltstone	0.46	34	3247	0.71	5.2
9	ASA2	Sandstone	1	47	6667	4	19
10	ASI2	Siltstone Sandstone	0.46	34	3247	0.71	5.2
11	ASA1	Sandstone	1	47	6667	4	19
12	ASI1	Sandstone Siltstone	0.46	34	3247	0.71	5.2

2. DYNAMIC ANALYSIS OF THE BASIN

The Summary of Seismic report and DBL , MDL, and MCL earthquakes and the Design Spectrum will be presented here. The tender seismic study was reported in three volumes. The summary of the DBL, MDL, and MCL earthquakes are presented in the following table.

Table 2- Final Values of Peak Horizontal Ground Acceleration for Different Level of Seismic Design

Level of Seismic Design	Peak Horizontal Acceleration (g)	Peak Vertical Acceleration (g)
DBL	0.194	0.103
MDL	0.442	0.285
MCL	0.572	0.365

For preparation of Spectrum UBC and similar earthquakes were used

UBC 97 Seismic Zone Factor : Zone 4
Seismic Source Type : Type B
Soil Profile type : S_b (Rock)
Distance to Known Seismic Source : 10km.

Figure 4 shows the spectrum used in the analysis, The Nagah for DBL0.194 g , Tabas for MDL 0.442g and Abbar for MCL 0.572g earthquake acceleration time histories were used for the dynamic analysis and are shown in Figures 5, 6 and 7.

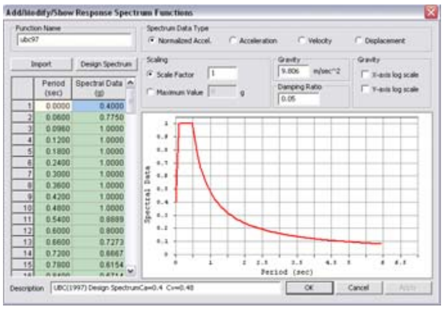


Figure 4. Spectrum used in the analysis , max acceleration 1 g

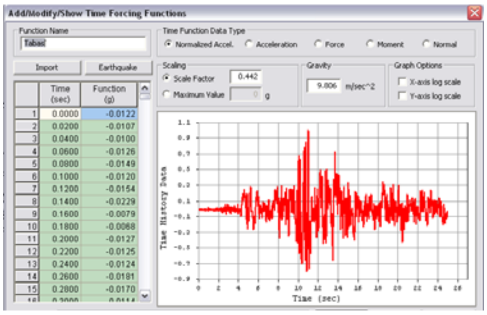


Figure 6.Time history of Tabas earthquake used for MDL max acceleration 0.442g

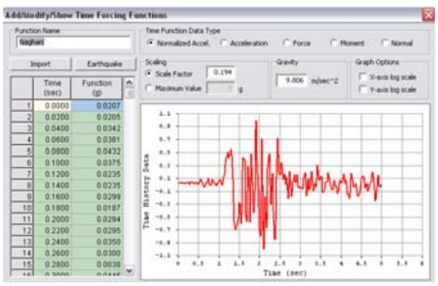


Figure 5. Time history of Naghan earthquake used for DBL max acceleration 0.194 g

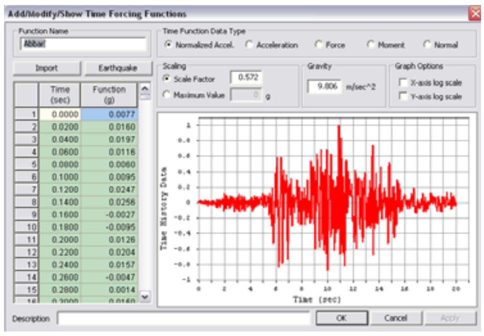


Figure 7. Time history of Abbar earthquake used for MCL max acceleration 0.572g

3. FINITE ELEMENT ANALYSIS OF THE EMBANKMENT

The finite element of the Lali basin is created by Midas/GTS which is a three dimensional geotechnical software, see Figure 8. It should be mentioned that the layer properties and dip direction are used in the model. Submergence also has been taken into consideration**.**

Spring and dashpot on the model boundaries were assigned to create absorbent boundaries. the springs are used to simulate self weight and the dashpots are used to simulate the shear and pressure wave absorption. 30 mode shapes were analyzed and the predominant mode shape number 1 and number 2 were used to assign proportional damping to be equivalent to 0.05 damping ratio. It should be mentioned that the first mode has period of 1.43 and the second mode has a period of 1.36 seconds, see Figures 9 and 10, and the participation factor is more than 40 percent for these modes. The results of the time history analysis are shown in Figures 11,12 and 13. The spectral displacement is shown in Figure 14.

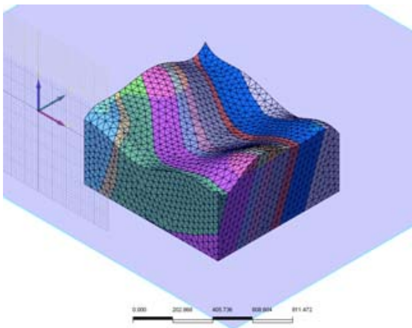


Figure 8.Finite element model about 28000 elements and 100000 degrees of freedom with water surface at elevation 240 m

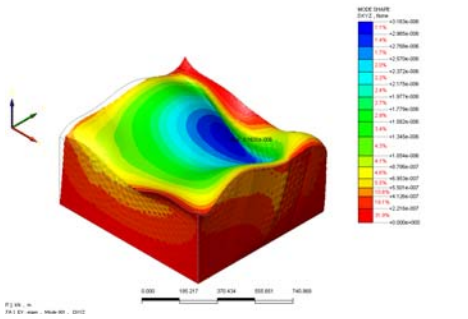


Figure 9. First mode 1.42 seconds

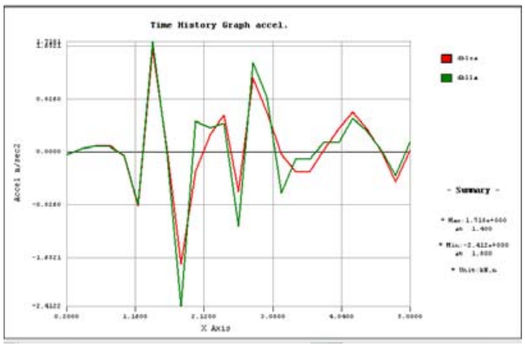


Figure 11. Acceleration in x direction of the caisson locations , right and left embankment, for DBL Naghan earthquake max 1.7 m/sec2

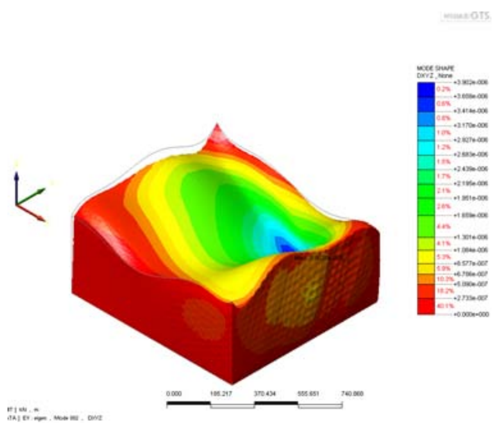


Figure 10: Second mode 1.36 seconds

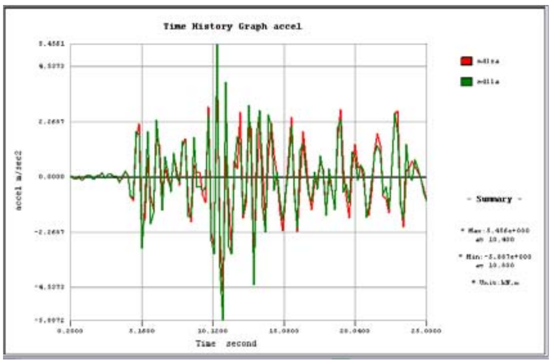


Figure 12. Acceleration in x direction of the caisson locations, right and left embankment, for MDL Tabas earthquake max 5.45 m/sec2

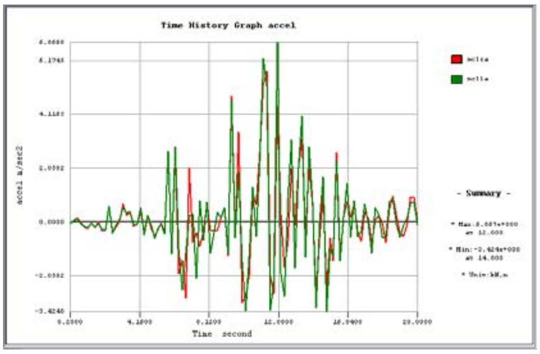


Figure 13. Acceleration in x direction of the caisson locations, right and left embankment, for MCL Abbar earthquake max 6.86 m/sec2

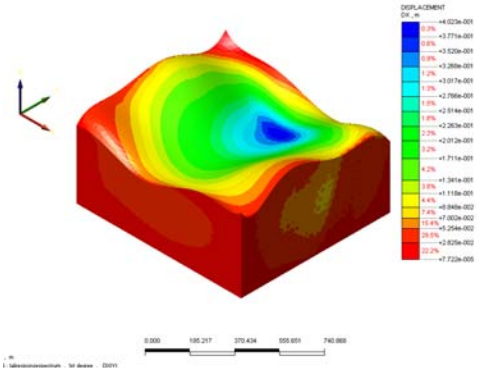


Figure 14. Spectral displacement in x direction, max 40 cm

4. RESPONSE OF CAISSON FOUNDATIONS

The software used is MIDAS/GTS which is widely used in three dimensional geotechnical analysis. The caisson, lean concrete and rock strata are modeled by solid elements and the deck is modeled by plate element.

: The property of the rock surrounding the caisson is cohesion of 427 Kpa and friction angle of 30 degrees from the geotechnical classifications.

Depending on the condition of construction of caissons and the strength of the lean concrete filling the caisson, the following 3 cases are considered:

The choice of three cases is based on Hexa consultant and Bolandpayeh foreign consultants. The major revision was assumption of zero cohesion between the concrete and rock. Thus the interface has only friction angle and no cohesion.

1: Interface between caisson and rock with cohesion of 0 Kpa and friction angle of 35 degrees

2: Interface between caisson and rock with cohesion of 0 Kpa and friction angle of 25 degrees

3: Interface between caisson and rock with cohesion of 0 Kpa and friction angle of 0 degrees

Results for load condition 1 will be presented.

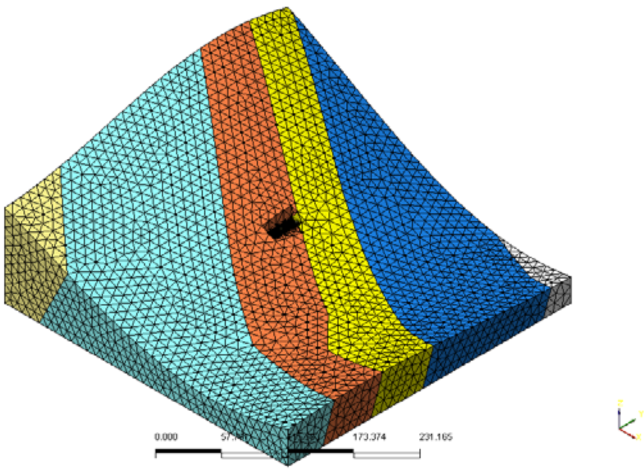


Figure 15. The finite element model of the caisson and rock, 76000elements

The critical load combinations lc1 to lc8 are as follows:

StrVIX	Linear Add	DEAD	1.3	lc1 max
		STAY	1.25	lc2 min
		SELF	1.25	
		SPECX	1	
		SPECY	0.3	
StrVIY	Linear Add	DEAD	1.3	lc3 max
		STAY	1.25	lc4 min
		SELF	1.25	
		SPECY	1	
		SPECX	0.3	
StrVIIX	Linear Add	DEAD	0.85	lc5 max
		STAY	0.9	lc6 min
		SELF	0.9	
		SPECX	1	
		SPECY	0.3	
StrVIIY	Linear Add	DEAD	0.85	lc7max
		STAY	0.9	lc8 min
		SELF	0.9	
		SPECY	1	
		SPECX	0.3	

And the description is as follows:

Load Case	Description
DEAD	Dead Loads
MOVING	40 ton Truck Moving Load in 4 Lanes
SPECX	Earthquake in Longitudinal Direction of Bridge
SPECY	Earthquake in lateral Direction of Bridge
STAY	Cable Forces
SELF	Self Weight of Steel Structure and End Ballast
SETT	Foundation Settlement
TEMP	Temperature Load
Brake	Brake Load
PEDL	Parapet Dead Load
TEMPG+	Positive Gradient Temperature
TEMPG-	Negative Gradient Temperature
WindH	Wind Loads in River Direction
WindL	Wind Loads in Bridge Direction

TABLE: Joint Reactions

	Joint ID	Combination	StepType	F1	F2	F3	M1	M2	M3		
				Kn	Kn	Kn	Kn-m	Kn-m	Kn-m		
lc 1	181	StrVIX	Max	-13042	-1860	-108586	-4831	-630737	-26169	Critical Load Combinations	
lc2	181	StrVIX	Min	15278	1883	-64174	154245	723530	27981		
lc3	181	StrVIY	Max	-5604	-6169	-154519	-184879	-232986	-58875		
lc4	181	StrVIY	Min	7840	6192	-18241	334293	325778	60687		Upstream Caisson
lc5	181	StrVIIX	Max	-13131	-1859	-83132	-26852	-639295	-26249		
lc6	181	StrVIIX	Min	15190	1883	-38721	132224	714971	27902		
lc7	181	StrVIIY	Max	-5692	-6169	-129066	-206900	-241544	-58954		
lc8	181	StrVIIY	Min	7751	6192	7213	312272	317220	60607		
lc 1	164	StrVIX	Max	-13042	-1883	-108586	-154244	-630736	-27982	Critical Load Combinations	
lc2	164	StrVIX	Min	15278	1860	-64174	4830	723529	26170		
lc3	164	StrVIY	Max	-5604	-6192	-154519	-334292	-232985	-60687		Downstream Caisson
lc4	164	StrVIY	Min	7840	6169	-18241	184878	325778	58875		
lc5	164	StrVIIX	Max	-13131	-1883	-83132	-132223	-639295	-27903		
lc6	164	StrVIIX	Min	15190	1859	-38721	26851	714971	26249		
lc7	164	StrVIIY	Max	-5692	-6192	-129066	-312272	-241543	-60607		
lc8	164	StrVIIY	Min	7751	6169	7213	206899	317220	58954		

Figure 16. Table of joint forces on upstream and downstream caissons by geotechnical engineer units and sign convention

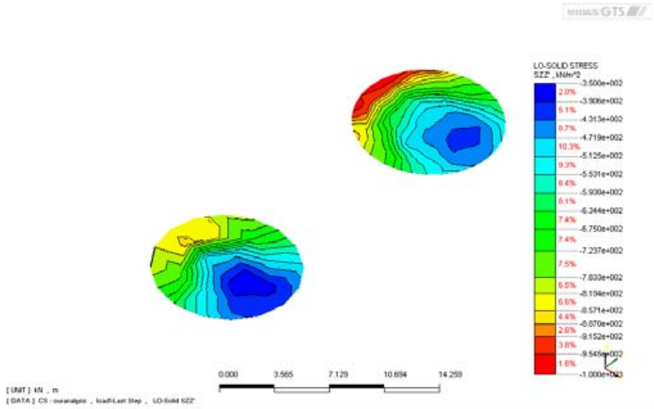


Figure 17. **Pressure exerted on caisson tip lc1 with interface of zero cohesion and 35 degrees friction angle between caisson and surrounding rock**

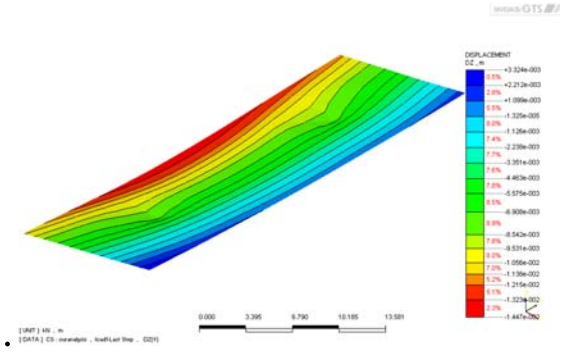


Figure 18. Settlement of the deck lc1 with interface of zero cohesion and 35 degrees friction angle between caisson and surrounding rock.

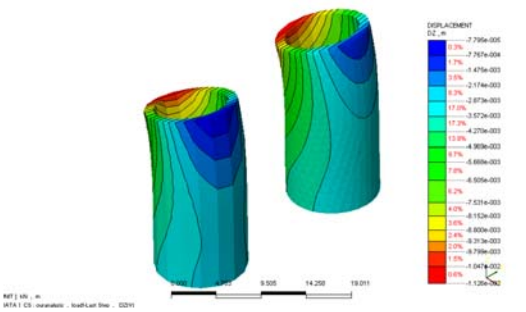


Figure 19. Settlement of the caisson lc1 with interface of zero cohesion and 35 degrees friction angle between caisson and surrounding rock.

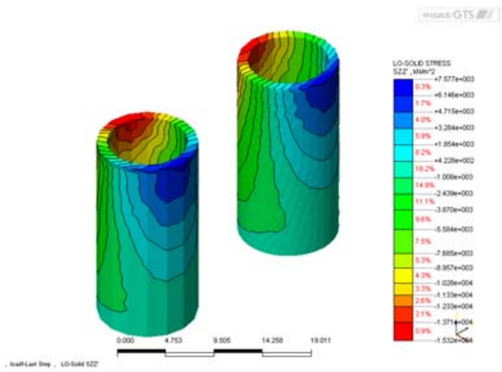


Figure 20. Vertical stress in caisson lc1 with interface of zero cohesion and 35 degrees friction angle between caisson and surrounding rock.

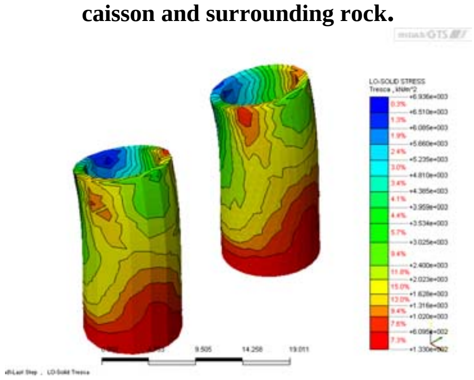


Figure 21. Tresca stress in caisson lc1 with interface of zero cohesion and 35 degrees friction angle between caisson and surrounding rock.

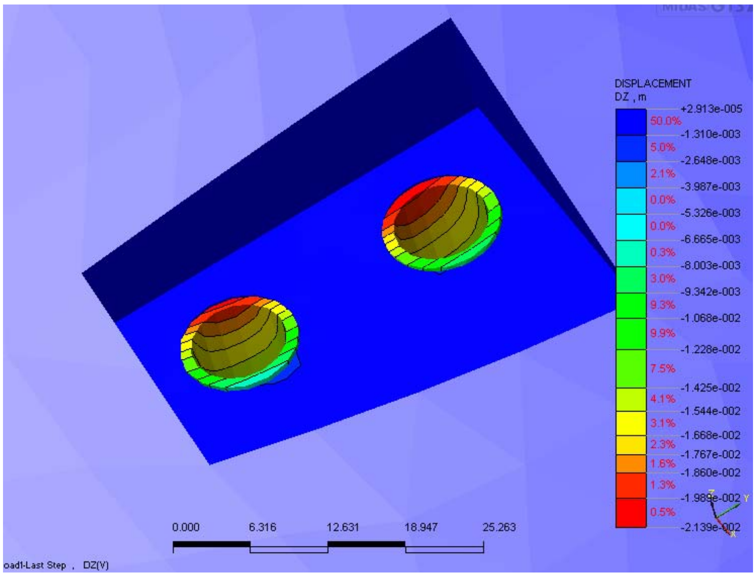


Figure 22. Interface slip between caisson and surrounding rock

5. CONCLUSIONS

The analysis carried out for the Lali bridge caisson foundation and basin for static and dynamic analysis shows that, proper construction of the caissons are essential for Lali Bridge, such that the friction can be maintained between the caisson and surrounding rock. The displacements and rotations are suitable for the caissons. However if the construction method is faulty and the surrounding rock is disturbed due to blasting and proper shotcrete and rock bolt installation is not carried out during construction, the displacements and rotations increase up to three times and the worst cases are for load combinations lc1, lc3 andlc7.

6. ACKNOWLEDGMENT

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7. REFERENCES

1. Ghahramani, Arsalan (2008), “Design of Abutment and Pier Caissons of Lali Bridge” 3rd International Bridge Conference, Tehran, Iran
2. Ghahramani, Arsalan (2007-2008), “*Series of Geotechnical Reports for Lali Bridge”*, 8 Reports, Presented to Bolandpayeh Company, Tehran, Iran