طرح` نگهداشت و افزایش تولید 27 مخزن

Calculation Note For BRIDGE

نگهداشت و افزایش تولید میدان نفتی بینک

D00	OCT.2023	IFC	R.Berlouie	M.Fakharian	S.Faramarzpour	
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Status:

IDC: Inter-Discipline Check
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REVISION RECORD SHEET

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CONTENTS

1. INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

2. Scope

This report covers the foundation calculation report of the “Close drain sump pit ”. The foundation modelled by “SAP v21.1.0 ” software.

3. CODES, SPECIFICATIONS AND REFERENCE DOCUMENTS

The following codes and specifications are adopted in this report:

[1] ACI 318M-14 “Building Code Requirements for Structural Concrete”

[2] INBC Part 6 “Iranian National Building Code, Part 6 (3rd Edition)”

[3] INBC Part 9 “Iranian National Building Code, Part 9 (4th Edition)”

[4] Iranian Standard No. 2800 “Iranian Code of practice for Seismic Resistant Design of Buildings (Iranian Standard No. 2800, 4th Edition)”

[5] Iranian Code of loading bridges

4. MATERIAL PROPERTIES

4.1. Concrete Grade

f’c = 30 MPa (Min. compressive characteristic strength at 28 days on cylinder specimen)

4.2. Reinforcing Steel

Deformed High Tensile Strength Steel Bars, Grade III in accordance with ASTM A706 (Fy=4000 kg/cm2) or ASTM A615 Grade 60 (Fy=4000 kg/cm2) and with

minimum tensile strength of 6000 kg/cm2 meeting the specific requirements set forth in ACI 318 or approved equivalent.

Material properties are delivered in the following table.

TABLE 1 -MATERIAL PROPERTIES

Foundation Concrete	F'c = 30 Mpa(28- day cylindrical sample)
Long. reinforcement bar	Fy = 400 Mpa(AIII)
Trans. reinforcement bar	Fy = 400 Mpa(AIII)
Bolt Type	HV 8.8
Electrode Type	E 70

5. DESIGN INFORMATIOn

5.1. Location of the Structure

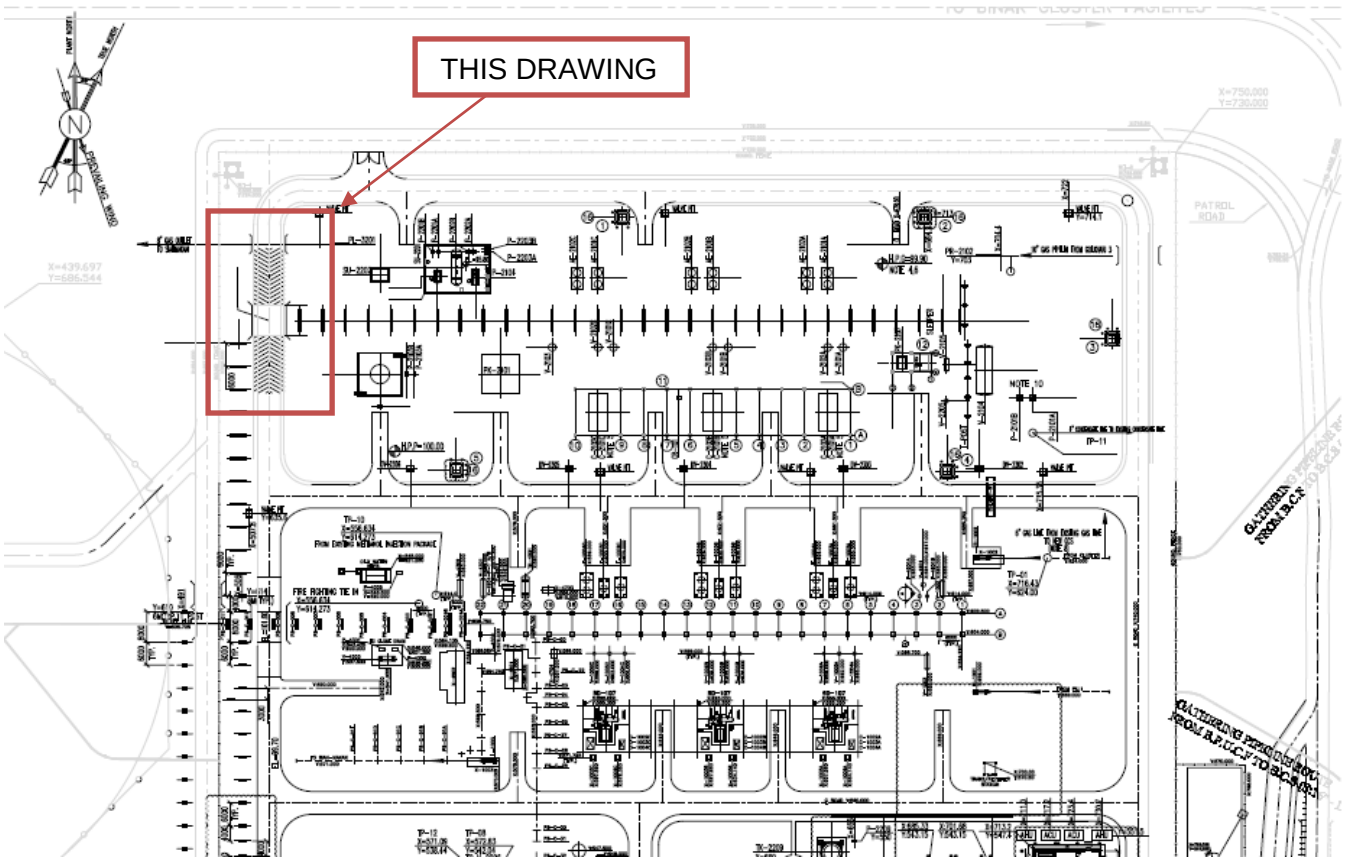

FIG 1 - Location of Structure

6. STRUCTURE 3D ANALYSIS MODEL

SAP2000 have been used in order to modeling, analyses and design of this structure and its foundation.

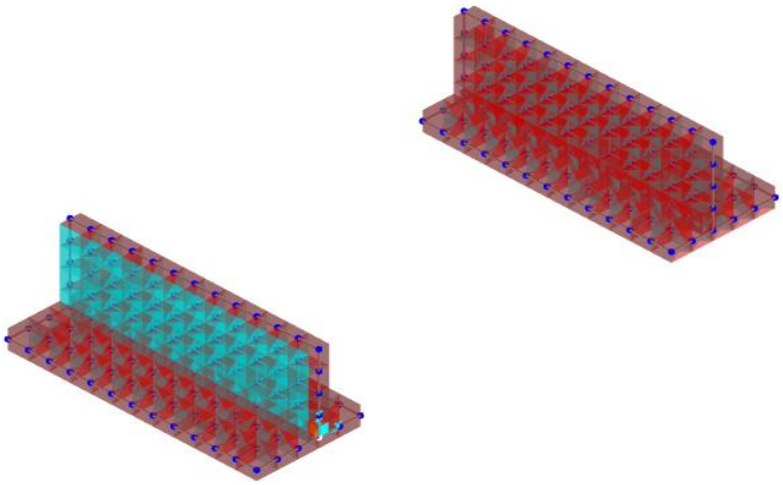

FIG 2 - Structure 3D Model in SAP2000

7. Calculation

7.1. Method of Design

Structural elements have been designed in two analytical models.

Model One (Main Model): It has been designed with considering the mechanical loads with Friction load. In this case seismic load should be calculated by SAP2000 and the Operation loads are in the mass source.

Model Two (Frictionless Model): It has been designed with considering the mechanical loads without Friction and including the loads with pure seismic load. In this case operating load has been omitted in mass source.

8. LOADS

The basic loads assumption and hypothesis are reported in paragraph below.

8.1. Self-Weight (DL)

The self-weight of structural elements (introduced Dead Load/DL in SAP) is automatically considered by SAP program with the specific weights below:

- Plain concrete 2400 kg/m3
- Reinforced concrete 2500 kg/m3
- Structural steel and Bars 7850 kg/m3
- Soil 2100 kg/m^3

8.2. Live Load

Live loads in these structures is Vehicle Load. This load include a truck weighting 40 tons and 10 meter long. According to the blow figure assigned to the part of bridge slab that has the greatest impact.

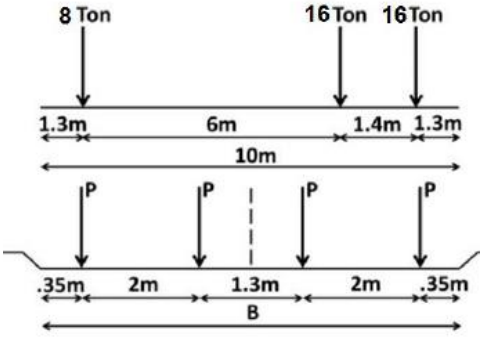

FIG 3 - Vehicle load

8.3. Soil Load

The static loads assumption and calculation are according to following procedure.

8.3.1. Static Soil Load on wall

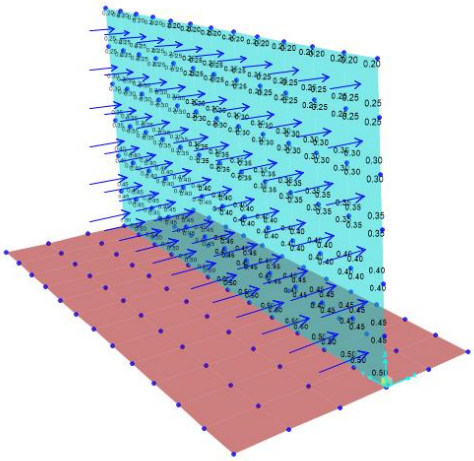

FIG 4 - applied Soil pressure

Calculation of soil pressure in height is as below:

K0=0.5
$\gamma_{sat} = 2\ ton/m3$
Surcharge=2 ton/m

z=	0	Soil pressure(kg/m2):	3000
z=	3.0	Soil pressure(kg/m2):	0

To apply soil pressure on walls with joint pattern uses equation based on above table as follows:

Y=-1000z+3000+2000

8.3.2. Static Soil Load on foundation

Soil load includes the soil over both the heel and toe. This is assumed straight-up-and-down column of earth.

Toe: $D_s = H_t \times \gamma_s = 1.1 \times 2.0 = 2.20\ \text{ton/m}^2$

Heel: $D_s = H_h \times \gamma_s = 2.80 \times 2.0 = 5.60\ \text{ton/m}^2$

Following figures show the weight of soil (Ton/m2):

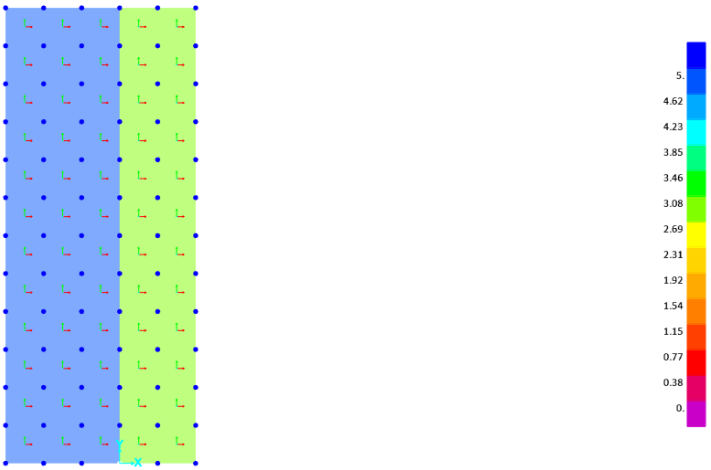

FIG 5 - applied Soil pressure on foundation

8.4. Water Load

8.4.1. Static water load on wall (water X&Y)

Water pressure is applied from a height of 1 m below the ground level.

z=	0	water pressure(kg/m2):	2000
z=	2.00	Water pressure(kg/m2):	0

Y=-1000z+2000

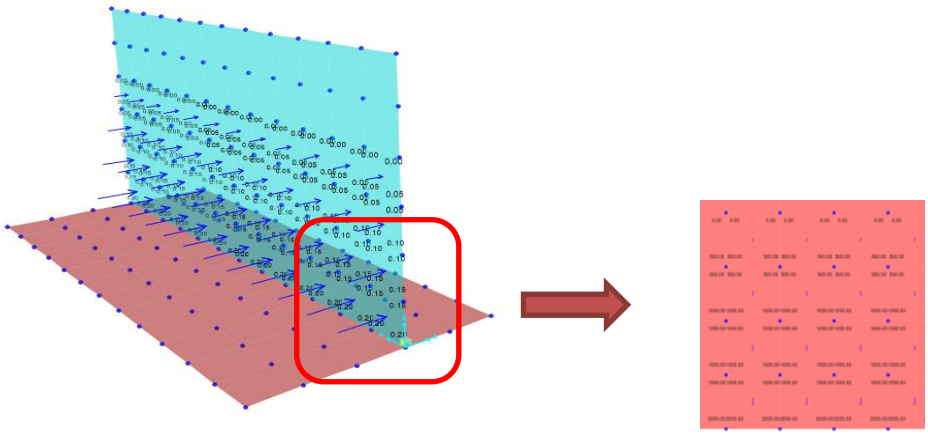

FIG 6 - applied water pressure on wall

8.4.2. Static water load on foundation (water X&Y)

Water load includes the water over both the heel and toe. This is assumed straight-up-and-down column of earth.

$$F_w = H_t \times \gamma_w = 2.00 \times 1.0 = 2.00 \text{ ton/m}^2$$

Following figures show the weight of water (Ton/m2):

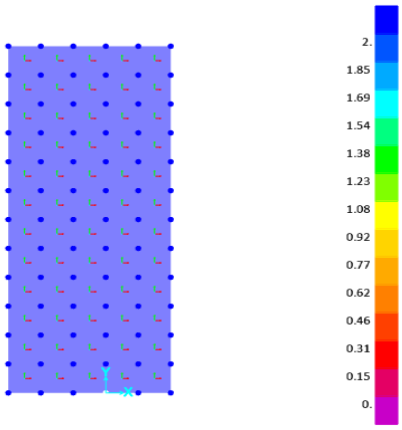

FIG 7 - applied water pressure on foundation

8.5. Temperature load :

As per [6], the temperature variation used for concrete structure is:

$$\Delta T = 28\ ^\circ C$$

8.6. Seismic Load

Seismic Loads are calculated according to standard 038.3rd that is summarized in below :

The structure doesn't have any irregularities and its height is less than 50 m from base level.so, both static equivalent Lateral procedures could be used.

$V = C_s W$

Where:

C_s = the seismic response coefficient from Equation below:

W = the effective seismic weight of the structure

This weight includes dead weight of the supporting structure and supported components, plus operational weight of the contents of the components such as tanks, vessels, pipes, etc. In addition, where the snow or ice load is more than 0.25W, it shall be included in W.

$$C_s = \frac{S_a}{R/I_e}$$

Where:

Sa= mapped spectral response acceleration parameter (g), determined from hazard analysis.

R= the response modification factor for structure

I_e= the importance factor for structure

Vertical seismic component

The vertical seismic load effect, Ev, shall be determined in accordance with the following Equation :

$$Ev = 0.2S_{DS}D$$

S_{DS} = Design, 5% damped, spectral response acceleration parameter (g) at short periods (0.2 sec).

D = effect of dead load

Loads case name: EQZ=0.2×0.75×W=0.15×W (where W=DL+OPR1+OPR FUTURE)

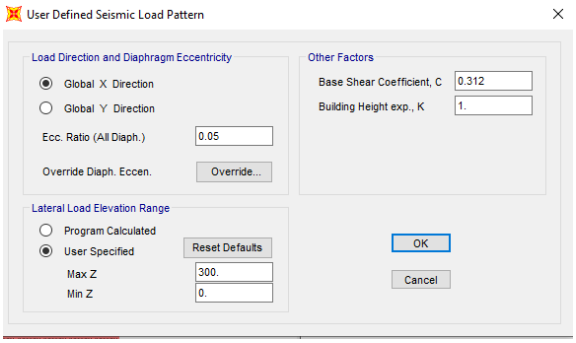

FIG 8 - X Direction Seismic Load

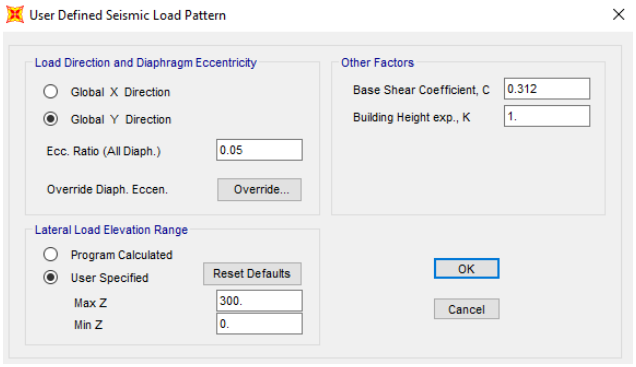

FIG 9 - Y Direction Seismic Load

This Earthquake coefficient will apply in SAP2000 model to be multiplied in W (seismic weight of structure) that will compute automatically by SAP2000 software by "mass source multiplier" definition as below:

Dead and Live Load

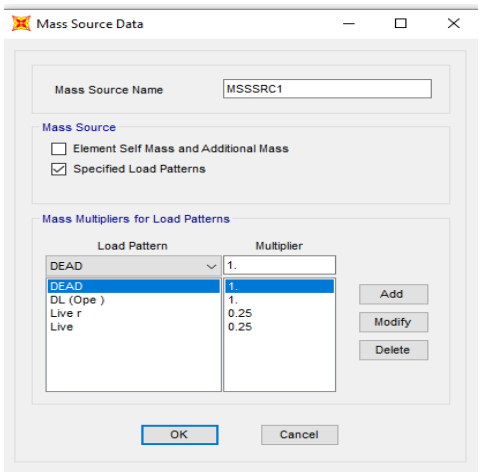

FIG 10 - Mass Source

According to Geotechnical report:

Soil Type: II

$I(importance\ factor\ according\ to\ table\ 12-1)=1.25$

$T = 0.05\,H^{\frac{3}{4}}=0.05 \times 3.0^{0.75} = 0.113\text{s}$

$T0 = 0.1$

$Ts = 0.5 \quad S = 1.5 \quad S0 = 1$

	OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless
▶	MODAL	Mode	1	0.720476	0.82	0
	MODAL	Mode	2	0.482025	0	0.91
	MODAL	Mode	3	0.365814	0	0.02494
	MODAL	Mode	4	0.211641	0.16	0

FIG 11 - Period in X Direction(mode 1 ,T=0.72)

	OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless
	MODAL	Mode	1	0.720476	0.82	0
▶	MODAL	Mode	2	0.482025	0	0.91
	MODAL	Mode	3	0.365814	0	0.02494
	MODAL	Mode	4	0.211641	0.16	0

FIG 12 - Period in Y Direction(mode 2 ,T=0.482)

0<T<T0 $S_{ax\&y} = S_{DS} = 0.75$

$$C_{x\&y} = \frac{SaI}{R} \qquad Cx\&y = \frac{0.75 \times 1.25}{3} = 0.312$$

8.6.1. Seismic Load of wall :

$$C_{x\&y} = \frac{SaI}{R} \qquad Cx\&y = \frac{0.75 \times 1.25}{3} = 0.312$$

Seismic load of each wall applied as follow on each area:

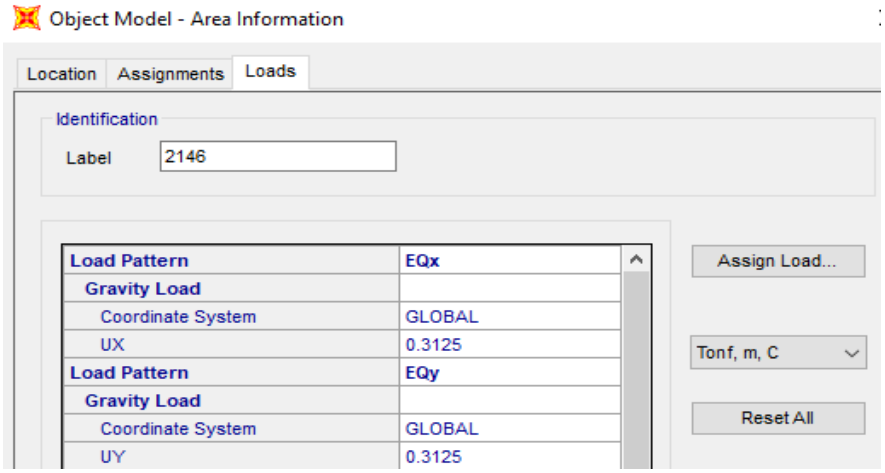

FIG 13 - Applied wall seismic coefficient

9. P-Delta Effect

P-Delta effect on model applied as follow:

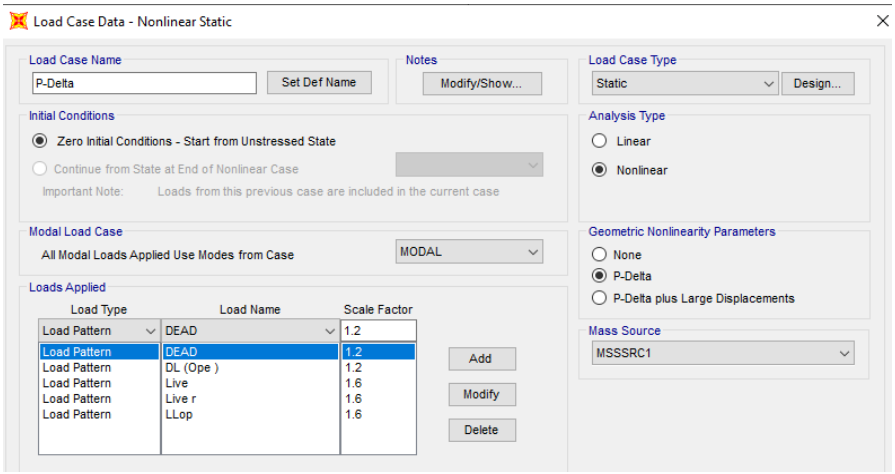

FIG 14 - P-Delta

10.LOADING COMBINATIONS

Foundations, structures and members of structures shall be designed for the most severe loading combination given in below Table. Loads shall be combined as specified in the Table (According to Iranian Seismic Design Code for Petroleum Facilities (3 rd. edition)

10.1. Strength Design:

1.4D+1.4F+1.6H+TLst

1.2D+1.6L+0.5(Lr or S)+1.2F+1.6H+TLst

1.2D+1.6(Lr or S)+(L)+1.2F+1.6H+TLst

$1.2D + L + .5(Lr\ or\ S) + 1.2F + 1.6H + \mathrm{TLst}$

1.2D+E+L+0.2S+1.2F+1.6H+TLst

$0.9D + 1.6H$+TLst

$0.9D + E + 0.9F + 1.6H$+TLst

10.2. Allowable Design:

$$D + F + H + TLst$$

$$D + L + F + H + TLst$$

$$D + F + H + (Lr\ OR\ S)$$

$D + F + H + 0.75L + 0.75(Lr\ or\ S)$

$D + F + H$+0.7E

$D + F + H$+0.75(0.7E)+0.75L+0.75S

$0.6D + H$

$0.6D + 0.7E + 0.6F + H$

**F is Water load And H load is soil load

11.ANALYSIS AND DESIGN

11.1. Foundation Controls

Model analysis is done by Sap 2000 software.in model loads are applied, some graphical Outputs from modeling are shown as follows:

According to Sap 2000 results Maximum moment for foundation slab is approximately 6.00 ton.m

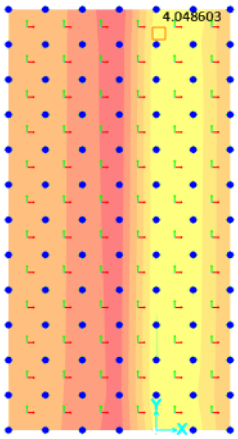

FIG 15 - Foundation Moment (M22) ton.m

11.1.1. Foundation reinforcing:

$$M_{11_{max}} = 6\ ton-m/m \quad \& \quad M_{22_{max}} = 2\ ton-m/m$$

$$foundation\ thickness = 60\ cm$$

$$A_{s_{min}} = 0.0018 * 100 * 60 = 10.80\ \frac{cm2}{m}$$

$$USE\ \phi 16\ @200$$

11.1.2. Uplift Control Under Foundation :

As observed in image below, in worse load combinations uplift of Foundation is inappreciable and it has not any bad effect on stability.

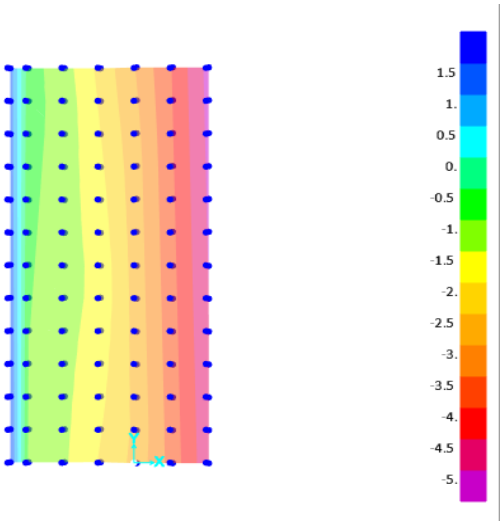

FIG 16 - Uplift Control

$$U_{water} = \gamma h = 2.00 \times 1000 = 2000 \frac{kg}{m2}$$

$$U_{water} = 2000 \times 2.5 \times 6 = 30000\ kg = 30\ ton$$

Weight of walls $= 2500 \times (3 \times 0.5 \times 6) = 22500\ kg = 22.50\ ton$

Weight of Soil on Foundation$= (2.80 + 1.1) \times (1 + 1.50) \times 2000 = 19500 kg = 19.00\ ton$

Weight of Foundation$= 2500 \times (2.50 \times 6.0) \times 0.60 = 2250 kg = 2.250 ton$

Slab weight $= 2500 \times (1.5 \times 2.5 \times 0.5) = 32400\ kg$

$$SF = \frac{22.50 + 19.00 + 2.25 + 32.40}{30} = 2.53 > 1.00\ ok$$

11.1.3. Soil pressure control

Model was constructed as below geometry and analyzed in all services and ultimate load cases which have load combinations for nonlinear analysis.

Deformation of all footings in envelope of service combination has been illustrated in below image:

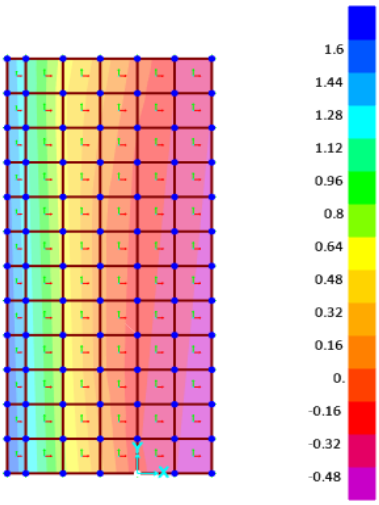

FIG 17 - Maximum Soil Pressure

$$q_{max} = 1.60 \frac{kg}{cm^2} < 1.75 \frac{kg}{cm^2} \rightarrow O.K.$$

11.1.4. Displacement Check

As observed in below image, maximum vertical displacement of footing under envelope of all service combinations is about 1.86 cm. Therefore, we have:

TABLE: Joint Displacements						
Joint	OutputCase	CaseType	StepType	U1	U2	U3
Text	Text	Text	Text	cm	cm	cm
1323	Env-A	Combination	Max	1.71	0.39	-2.03
1321	Env-A	Combination	Max	1.71	0.37	-1.82
1367	Env-A	Combination	Max	1.71	0.33	-0.96
1387	Env-A	Combination	Max	1.71	0.31	-0.33
1407	Env-A	Combination	Max	1.71	0.28	0.39
79	Env-A	Combination	Max	1.71	0.26	1.21
1	Env-A	Combination	Max	1.71	0.35	-1.59
2	Env-A	Combination	Max	1.71	0.35	-1.58
1322	Env-A	Combination	Max	1.71	0.37	-1.80
1324	Env-A	Combination	Max	1.71	0.39	-2.00
1368	Env-A	Combination	Max	1.71	0.33	-1.03
1388	Env-A	Combination	Max	1.71	0.31	-0.41
1408	Env-A	Combination	Max	1.71	0.28	0.36
80	Env-A	Combination	Max	1.71	0.26	1.19

$$q = K_s.\Delta = 0.62 \times 1.71 = 1.06 \frac{kg}{cm^2} < 1.75 \frac{kg}{cm^2} \rightarrow O.K.$$

11.2. Wall Controls

11.2.1. wall reinforcing design

Moment capacity is :$\emptyset 25@200\ mm$

As					
Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)	phi
35	100	45	4000	300	0.9
Mn	Rn1	m1	ρ_{req}	As(req)	SELECT PHI
3888888.889	19.204	15.686	0.004997	22.486	25.00

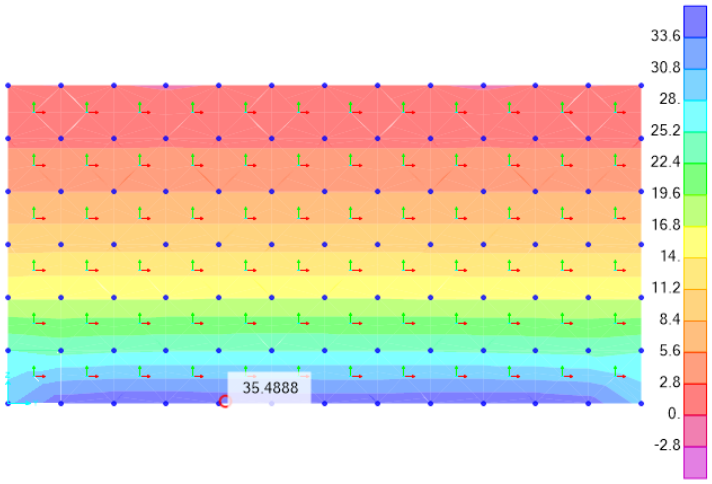

FIG 18 - max load combination on wall (M22=35.50 ton.m)

According to Sap 2000 results Maximum moment for wall slab is approximately 35.50 ton.m so we used Ø25@200 as follows:

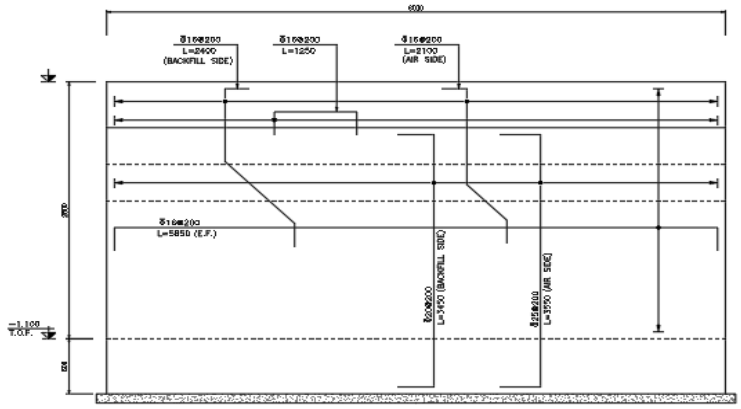

FIG 19 - Wall Reinforcement Ø25@200

12.Shear Control Under walls :

$$F_{soil} = \frac{1}{2} K_0 \gamma h^2 = 0.5 \times 0.5 \times 2 \times 1000 \times 2.80^2 = 3920\ kg/m$$

$$F_w = \frac{1}{2} \gamma_w h^2 = 0.5 \times 1 \times 1000 \times 1 \times 2^2 = 1000\ kg/m$$

$$F_t = Fw + Fsoil = 4920\ \frac{kg}{m}\ \text{in 1 m} = \quad 4920\ kg = 4.92\ ton$$

$$V_c = 0.53\sqrt{fc}\ bw\ d = 0.53\sqrt{300} \times 100 \times 45 = 41309.41\ \ kg = 41.309\ \ ton\ (\text{in 1 m}) \gg Ft\ ok$$

According to sap analysis result maximum shear on wall is under critical load combination is a follows

TABLE: Element Forces - Area Shells						
Area	OutputCase	M11	M22	M12	V13	V23
Text	Text	Tonf-m/m	Tonf-m/m	Tonf-m/m	Tonf/m	Tonf/m
1106	Env-A	12.14312	2.54384	0.11211	18.19	1.583
1106	Env-A	3.2984	0.61875	0.00369	18.19	2.477
1104	Env-A	3.28759	0.56468	0.07162	17.664	0.429
1104	Env-A	12.11083	2.38237	0.15265	17.664	0.257
1104	Env-A	12.22268	2.45125	0.17132	17.449	0.257
1104	Env-A	3.50694	0.71957	0.09028	17.449	0.429
1102	Env-A	3.51135	0.74164	0.1175	17.348	0.242
1102	Env-A	12.20706	2.37318	0.18732	17.348	0.231
1102	Env-A	12.11333	2.46081	0.20986	17.063	0.231
1102	Env-A	3.5604	0.746	0.13894	17.063	0.242
1100	Env-A	3.56574	0.7727	0.15581	16.995	0.254
1100	Env-A	12.09158	2.35206	0.23623	16.995	0.239
1084	Env-A	3.05092	0.61368	0.11139	16.889	-0.519
1084	Env-A	11.21023	2.37091	0.16252	16.889	-0.247
1100	Env-A	11.97484	2.42385	0.24704	16.805	0.239
1100	Env-A	3.54443	0.74702	0.16661	16.805	0.254
1098	Env-A	3.54718	0.76075	0.18003	16.8	0.276
1098	Env-A	11.9622	2.36065	0.26509	16.8	0.21
1098	Env-A	11.80954	2.3992	0.27561	16.564	0.21
1098	Env-A	3.51242	0.72916	0.19055	16.564	0.276
1096	Env-A	3.51564	0.74523	0.19461	16.531	0.276
1096	Env-A	11.79331	2.31801	0.28187	16.531	0.273

TABLE: Element Forces - Area Shells						
Area	OutputCase	M11	M22	M12	V13	V23
Text	Text	Tonf-m/m	Tonf-m/m	Tonf-m/m	Tonf/m	Tonf/m
1096	Env-A	11.68347	2.38185	0.28056	16.383	0.273
1096	Env-A	3.47981	0.71785	0.1933	16.383	0.276
1094	Env-A	3.48275	0.73254	0.19077	16.35	0.278
1094	Env-A	11.668	2.30452	0.27612	16.35	0.282
1086	Env-A	3.30073	0.70984	0.08497	16.343	0.08
1086	Env-A	11.45752	2.30884	0.14169	16.343	0.016
1086	Env-A	11.19285	2.28397	0.14214	16.339	0.016
1086	Env-A	3.03818	0.55002	0.08542	16.339	0.08
1088	Env-A	11.46227	2.33262	0.17058	16.3	0.057
1088	Env-A	3.30237	0.71805	0.09143	16.3	0.245
1094	Env-A	11.61202	2.37551	0.26949	16.291	0.282
1094	Env-A	3.45608	0.72934	0.18414	16.291	0.278
1092	Env-A	11.5868	2.39395	0.24582	16.29	0.283
1092	Env-A	3.43306	0.74308	0.16263	16.29	0.261
1092	Env-A	3.45844	0.74113	0.17428	16.263	0.261
1092	Env-A	11.59852	2.30804	0.25747	16.263	0.283
1090	Env-A	3.43528	0.75418	0.14769	16.235	0.252
1090	Env-A	11.57172	2.31854	0.22812	16.235	0.161
1088	Env-A	3.39911	0.74558	0.10872	16.234	0.245
1088	Env-A	11.52592	2.34195	0.18896	16.234	0.057
1090	Env-A	11.52755	2.35011	0.20992	16.216	0.161
1090	Env-A	3.40062	0.75312	0.12949	16.216	0.252
1106	Env-A	3.7303	-0.14987	-0.10974	14.42	2.477
1106	Env-A	10.69001	1.96001	-0.08186	14.42	1.583
1126	Env-A	-0.97463	-0.23617	0.2659	13.017	1.393
1126	Env-A	-0.95823	-0.30857	0.41084	13.017	3.65
1084	Env-A	9.57176	1.98692	0.238	12.747	-0.247
1084	Env-A	3.4837	-0.15209	0.32398	12.747	-0.519
1127	Env-A	-0.94811	-0.26124	0.35308	12.471	0.835
1127	Env-A	-0.99651	-0.34554	0.24954	12.471	0.432
1127	Env-A	-0.90331	-0.20067	0.25592	12.219	0.432
1127	Env-A	-0.99163	-0.26215	0.35946	12.219	0.835
1128	Env-A	-0.98878	-0.24787	0.37224	12.104	0.303
1128	Env-A	-0.91916	-0.27995	0.28197	12.104	0.016
1128	Env-A	-0.93177	-0.16389	0.30972	11.669	0.016
1128	Env-A	-1.00003	-0.2408	0.39999	11.669	0.303

TABLE: Element Forces - Area Shells						
Area	OutputCase	M11	M22	M12	V13	V23
Text	Text	Tonf-m/m	Tonf-m/m	Tonf-m/m	Tonf/m	Tonf/m
1129	Env-A	-0.99553	-0.21832	0.43247	11.652	0.274
1129	Env-A	-0.95334	-0.27173	0.3294	11.652	0.062
1137	Env-A	-1.28476	-0.28845	0.20944	11.426	-0.751
1137	Env-A	-2.11817	-0.45123	0.19015	11.426	0.437
1129	Env-A	-1.06584	-0.19016	0.3546	11.346	0.062
1129	Env-A	-1.02553	-0.2314	0.45767	11.346	0.274
1130	Env-A	-1.02229	-0.21521	0.4837	11.297	0.271
1130	Env-A	-1.08065	-0.26418	0.37223	11.297	0.151
1130	Env-A	-1.23517	-0.21519	0.39211	11.01	0.151
1130	Env-A	-1.06587	-0.23286	0.50412	11.01	0.271
1131	Env-A	-1.06232	-0.21509	0.51899	10.98	0.276
1131	Env-A	-1.25217	-0.30019	0.40318	10.98	0.177
1136	Env-A	-1.27969	-0.21679	0.34494	10.868	0.17
1136	Env-A	-1.84956	-0.3793	0.29058	10.868	0.315
1136	Env-A	-2.12514	-0.48608	0.23852	10.836	0.315
1136	Env-A	-1.27655	-0.25067	0.29287	10.836	0.17
1131	Env-A	-1.38801	-0.23906	0.41162	10.804	0.177
1131	Env-A	-1.10767	-0.22968	0.52726	10.804	0.276
1135	Env-A	-1.84505	-0.35673	0.30205	10.8	0.18
1135	Env-A	-1.28005	-0.21861	0.39673	10.8	0.271
1132	Env-A	-1.10459	-0.21425	0.5292	10.76	0.252
1132	Env-A	-1.40347	-0.31639	0.41643	10.76	0.198
1132	Env-A	-1.48538	-0.25307	0.41282	10.676	0.198
1132	Env-A	-1.1475	-0.20983	0.52576	10.676	0.252
1134	Env-A	-1.6612	-0.30245	0.35154	10.674	0.193
1134	Env-A	-1.23073	-0.18307	0.45455	10.674	0.242
1133	Env-A	-1.55704	-0.25108	0.39465	10.651	0.172
1133	Env-A	-1.18582	-0.19181	0.50372	10.651	0.247
1135	Env-A	-1.23097	-0.18427	0.42412	10.633	0.271
1135	Env-A	-1.66301	-0.31151	0.32944	10.633	0.18
1133	Env-A	-1.14517	-0.19818	0.51654	10.623	0.247
1133	Env-A	-1.49812	-0.31675	0.40692	10.623	0.172
1134	Env-A	-1.18375	-0.18145	0.48417	10.622	0.242
1134	Env-A	-1.56996	-0.31568	0.38116	10.622	0.193
1147	Env-A	-0.98436	-0.23767	0.45634	10.219	0.18
1147	Env-A	-0.44435	-0.0825	0.48376	10.219	0.384

TABLE: Element Forces - Area Shells						
Area	OutputCase	M11	M22	M12	V13	V23
Text	Text	Tonf-m/m	Tonf-m/m	Tonf-m/m	Tonf/m	Tonf/m
1146	Env-A	-0.97292	-0.25841	0.41824	10.169	0.649
1146	Env-A	-0.44731	0.04223	0.41812	10.169	0.568
1148	Env-A	-0.44635	-0.05975	0.51901	10.156	0.207
1148	Env-A	-0.97986	-0.21518	0.48805	10.156	0.129
1147	Env-A	-0.44833	0.06673	0.45521	10.12	0.384
1147	Env-A	-0.97006	-0.24413	0.42779	10.12	0.18
1148	Env-A	-1.0106	-0.22842	0.51922	10.058	0.129
1148	Env-A	-0.44001	-0.11881	0.55017	10.058	0.207
1149	Env-A	-0.44177	-0.12763	0.57928	10.039	0.186
1149	Env-A	-1.00736	-0.21223	0.54569	10.039	0.115
1145	Env-A	-0.53221	-0.03904	0.25441	10.032	0.094
1145	Env-A	-1.07866	0.45292	0.36872	10.032	3.039
1149	Env-A	-1.05212	-0.23011	0.56766	9.919	0.115
1149	Env-A	-0.43648	-0.09662	0.60101	9.919	0.186
1150	Env-A	-0.43828	-0.10559	0.6177	9.912	0.178
1150	Env-A	-1.04857	-0.21234	0.5834	9.912	0.114
1151	Env-A	-0.43727	-0.07967	0.62841	9.807	0.174
1151	Env-A	-1.09188	-0.21171	0.59428	9.807	0.094
1150	Env-A	-1.09497	-0.22714	0.59234	9.806	0.114
1150	Env-A	-0.4356	-0.0713	0.62664	9.806	0.178
1152	Env-A	-0.43911	-0.04842	0.61079	9.741	0.146
1152	Env-A	-1.13174	-0.1955	0.58002	9.741	0.091
1151	Env-A	-1.13407	-0.20715	0.58989	9.732	0.094
1151	Env-A	-0.43763	-0.04104	0.62403	9.732	0.174
1153	Env-A	-0.44224	-0.01792	0.56304	9.705	0.074
1153	Env-A	-1.16969	-0.17864	0.53912	9.705	0.083
1154	Env-A	-0.44332	0.03054	0.48005	9.702	0.001525
1154	Env-A	-1.21574	-0.18123	0.47224	9.702	0.098
1152	Env-A	-1.17176	-0.18899	0.56149	9.684	0.091
1152	Env-A	-0.44093	-0.01135	0.5925	9.684	0.146
1153	Env-A	-1.2155	-0.18002	0.50706	9.638	0.083
1153	Env-A	-0.44255	0.05317	0.53098	9.638	0.074
1155	Env-A	-0.43626	0.11957	0.34658	9.515	-0.031
1155	Env-A	-1.2641	-0.21367	0.34946	9.515	0.079
1154	Env-A	-1.26447	-0.21549	0.41505	9.453	0.098
1154	Env-A	-0.43497	0.14258	0.42286	9.453	0.001525

TABLE: Element Forces - Area Shells						
Area	OutputCase	M11	M22	M12	V13	V23
Text	Text	Tonf-m/m	Tonf-m/m	Tonf-m/m	Tonf/m	Tonf/m
1146	Env-A	-0.48545	0.19982	0.40824	9.444	0.568
1146	Env-A	-0.94815	-0.26125	0.40835	9.444	0.649
1156	Env-A	-1.41434	0.4445	0.34085	9.162	-0.783
1156	Env-A	-0.42314	-0.03004	0.38985	9.162	0.638
1145	Env-A	-0.95827	-0.30797	0.46711	8.849	3.039
1145	Env-A	-0.48077	0.22932	0.3528	8.849	0.094
1155	Env-A	-1.26921	-0.2492	0.27374	8.691	0.079
1155	Env-A	-0.45431	0.21025	0.27087	8.691	-0.031
1156	Env-A	-0.45158	0.2267	0.24504	8.172	0.638
1156	Env-A	-1.27742	-0.28637	0.19605	8.172	-0.783
1126	Env-A	-1.11664	0.43252	0.67135	8.123	3.65
1126	Env-A	-0.77228	-0.57697	0.52074	8.123	1.393
1105	Env-A	3.52388	0.72296	0.05046	7.195	0.313
1105	Env-A	0.00814	0.0178	0.03452	7.195	0.686
1103	Env-A	3.58001	0.74992	0.09839	7.185	0.137
1103	Env-A	0.01064	0.09229	0.07999	7.185	0.282
1101	Env-A	0.01269	0.06693	0.09701	7.172	0.118
1101	Env-A	3.58535	0.77663	0.11391	7.172	0.127
1099	Env-A	0.01251	0.07507	0.12035	7.126	0.072
1099	Env-A	3.56706	0.76472	0.13922	7.126	0.142
				MAX=	18.19	

Maximum shear load is less than shear capacity of wall that is acceptable.

12.1. Retaining wall control

12.1.1. Overturning Control

Overturning moments are horizontally applied forces multiplied by the moment arm from the bottom of the footing to their point of application. Overturning controls are considering in two static and earthquake condition. Resisting load consist of total weight of structure and soil weight.

In static Condition:

$$Resisting\ Moment\ in\ Bottom\ of\ Toe = 8.70\ Ton.m$$

$$Overturning\ Moment\ in\ Bottom\ of\ Toe = 2.10\ Ton.m$$

$$\rightarrow F.S. = \frac{M_{resisting}}{M_{overturning}} = 4.12 > 1.75 \rightarrow O.K.$$

In Earthquake Condition:

$$Resisting\ Moment\ in\ Bottom\ of\ Toe = 6.70\ Ton.m$$

$$Overturning\ Moment\ in\ Bottom\ of\ Toe = 3.06\ Ton.m$$

$$\rightarrow F.S. = \frac{M_{resisting}}{M_{overturning}} = 2.16 > 1.0 \rightarrow O.K.$$

12.1.2. Sliding Control

The sum of all the horizontal forces pushing against the wall must be resisted to prevent a sliding failure. Sliding control results are reported as below:

Driving Force	Resistance Force	Ratio
$F_d=P_a=2239$	5490	2.16
$F_d=P_{Dead}+0.7P_E=2559$	4637	1.81
$F_d=P_a=3160$	5490	1.73

12.2. Slab design

12.2.1. Slab reinforcing design

$$M_{11_{max}} = 56\ ton-m/m \quad \& \quad M_{22_{max}} = 32\ ton-m/m$$

$$slab\ thickness = 50\ cm$$

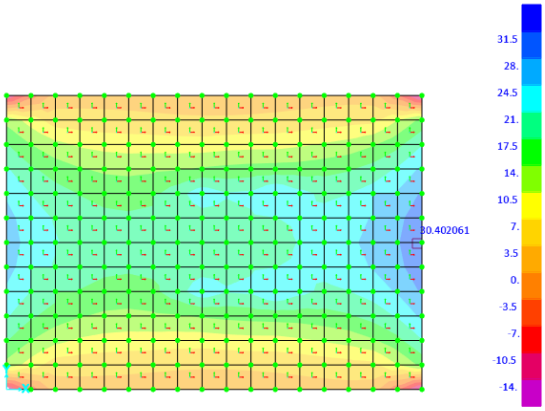

FIG 20 - max load combination on slab (M22=30.00 ton.m)

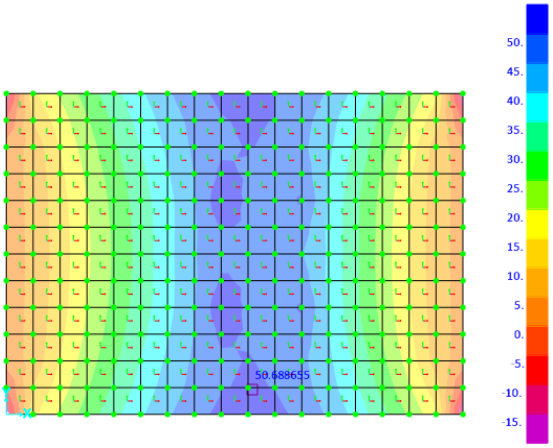

FIG 21 - max load combination on slab (M11=50.00 ton.m)

As					
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)
	30	100	45	4000	300
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)
	3333333.333	16.461	15.686	0.004257	19.158

As					
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)
	50	100	45	4000	300
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)
	5555555.556	27.435	15.686	0.007274	32.731

12.2.1. Deflection Control

The function of passageway slab is similar to one way slab because of walls as supports in one direction.

Therefore to control the deflection of slab, below mentioned controls have been done according to Iranian National Building Code No.9 for Reinforced Concrete Structures section 9-9-3-1.

Slab thickness= 50cm, maximum l_e= 850cm

1.5cm > 850/20=42.50 cm O.K.

→So according to 9-9-3-2 there is no need to control deflection

But deflection has been controlled conservatively:

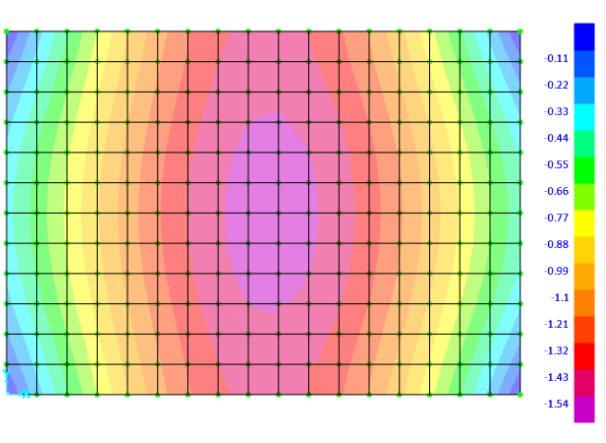

FIG 22 - Max DEFLECTION

13.ATTACHMENT

13.1. COMPUTED FILES

Calculation Note For GCS BRIDGE 2

14.LOADS

The basic loads assumption and hypothesis are reported in paragraph below.

14.1. Self-Weight (DL)

The self-weight of structural elements (introduced Dead Load/DL in SAP) is automatically considered by SAP program with the specific weights below:

- Plain concrete 2400 kg/m3
- Reinforced concrete 2500 kg/m3
- Structural steel and Bars 7850 kg/m3
- Soil 2100 kg/m^3

14.2. Live Load

Live loads in these structures is Vehicle Load. This load include a truck weighting 40 tons and 10 meter long. According to the blow figure assigned to the part of bridge slab that has the greatest impact.

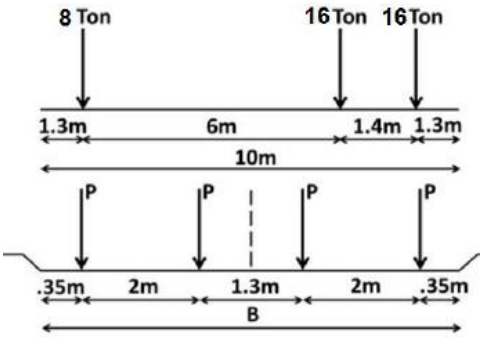

FIG 23 - Vehicle load

14.3. Soil Load

The static loads assumption and calculation are according to following procedure.

14.3.1. Static Soil Load on wall

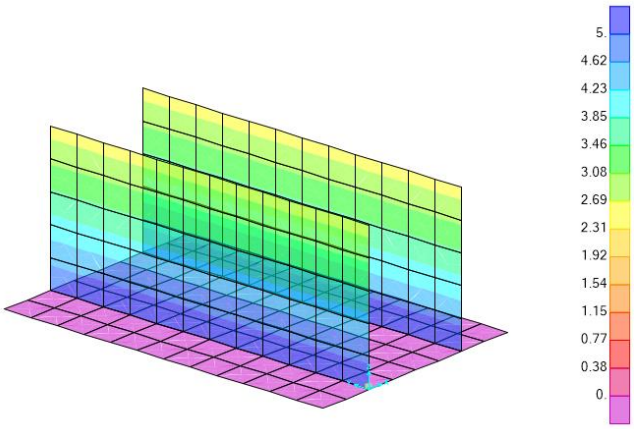

FIG 24 - applied Soil pressure

Calculation of soil pressure in height is as below:

K0=0.5
$\gamma_{sat} = 2\ ton/m3$
Surcharge=2 ton/m

z=	0	Soil pressure(kg/m2):	4500
z=	2.50	Soil pressure(kg/m2):	0

To apply soil pressure on walls with joint pattern uses equation based on above table as follows:

Y=-1000z+2500+2000

14.3.2. Static Soil Load on foundation

Soil load includes the soil over both the heel and toe. This is assumed straight-up-and-down column of earth.

Toe: $D_s = H_t \times \gamma_s = 1.1 \times 2.0 = 2.20\ \text{ton/m}^2$

Heel: $D_s = H_h \times \gamma_s = 2.50 \times 2.0 = 5.00\ \text{ton/m}^2$

Following figures show the weight of soil (Ton/m2):

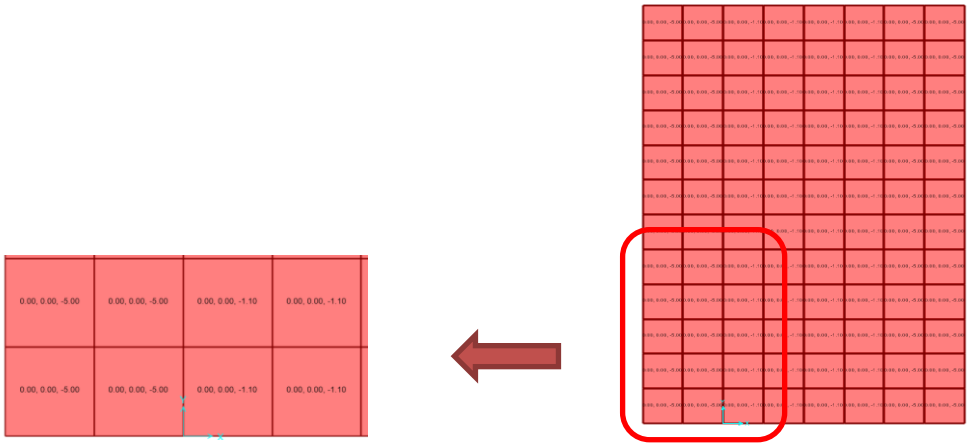

FIG 25 - applied Soil pressure on foundation

14.4. Water Load

14.4.1. Static water load on wall (water X&Y)

Water pressure is applied from a height of 1 m below the ground level.

z=	0	water pressure(kg/m2):	2000
z=	2.00	Water pressure(kg/m2):	0

Y=-1000z+2000

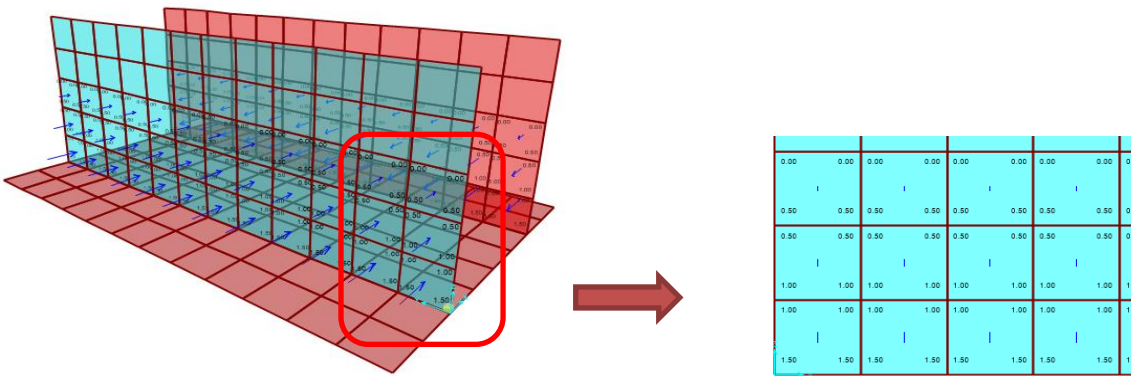

FIG 26 - applied water pressure on wall

14.4.2. Static water load on foundation (water X&Y)

Water load includes the water over both the heel and toe. This is assumed straight-up-and-down column of earth.

$$F_w = H_t \times \gamma_w = 1.50 \times 1.0 = 1.50 \text{ ton/m}^2$$

Following figures show the weight of water (Ton/m2):

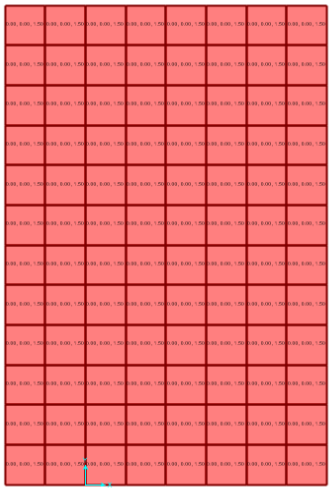

FIG 27 - applied water pressure on foundation

14.5. Temperature load :

As per [6], the temperature variation used for concrete structure is:

$$\Delta T = 28\ ^\circ C$$

14.6. Seismic Load

Seismic Loads are calculated according to standard 038.3rd that is summarized in below:

The structure doesn't have any irregularities and its height is less than 50 m from base level.so, both static equivalent Lateral procedures could be used.

$V = C_s W$

Where:

C_s = the seismic response coefficient from Equation below:

W = the effective seismic weight of the structure

This weight includes dead weight of the supporting structure and supported components, plus operational weight of the contents of the components such as tanks, vessels, pipes, etc. In addition, where the snow or ice load is more than 0.25W, it shall be included in W.

$$C_s = \frac{S_a}{R/I_e}$$

Where:

Sa= mapped spectral response acceleration parameter (g), determined from hazard analysis.

R= the response modification factor for structure

I_e= the importance factor for structure

Vertical seismic component

The vertical seismic load effect, Ev, shall be determined in accordance with the following Equation :

$Ev = 0.2S_{DS}D$

S_{DS} = Design, 5% damped, spectral response acceleration parameter (g) at short periods (0.2 sec).

D = effect of dead load

Loads case name: EQZ=0.2×0.75×W=0.15×W (where W=DL+OPR1+OPR FUTURE)

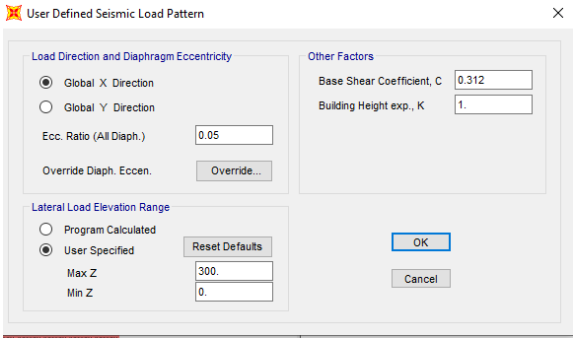

FIG 28 - X Direction Seismic Load

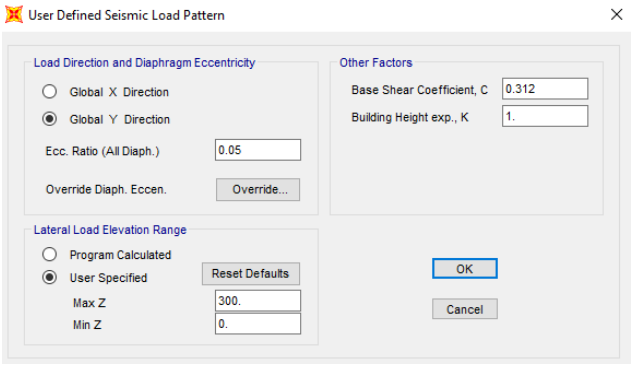

FIG 29 - Y Direction Seismic Load

This Earthquake coefficient will apply in SAP2000 model to be multiplied in W (seismic weight of structure) that will compute automatically by SAP2000 software by "mass source multiplier" definition as below:

Dead and Live Load

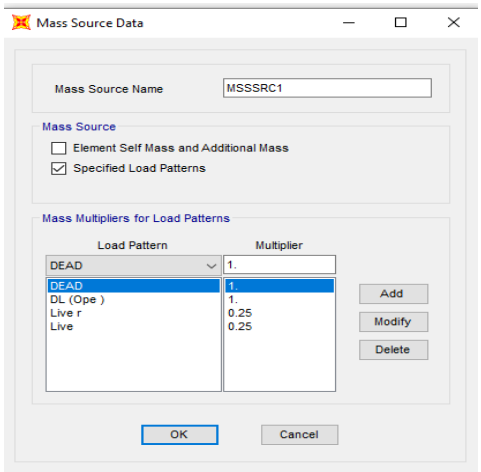

FIG 30 - Mass Source

According to Geotechnical report:

Soil Type: II

$I(importance\ factor\ according\ to\ table\ 12-1)$=1.25

$T = 0.05\,H^{\frac{3}{4}}$=$0.05 \times 3.0^{0.75} = 0.113$s

$T0 = 0.1$

$Ts = 0.5 \quad S = 1.5 \quad S0 = 1$

	OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless
▶	MODAL	Mode	1	0.720476	0.82	0
	MODAL	Mode	2	0.482025	0	0.91
	MODAL	Mode	3	0.365814	0	0.02494
	MODAL	Mode	4	0.211641	0.16	0

FIG 31 - Period in X Direction(mode 1 ,T=0.72)

	OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless
	MODAL	Mode	1	0.720476	0.82	0
▶	MODAL	Mode	2	0.482025	0	0.91
	MODAL	Mode	3	0.365814	0	0.02494
	MODAL	Mode	4	0.211641	0.16	0

FIG 32 - Period in Y Direction(mode 2 ,T=0.482)

0<T<T0 $S_{ax\&y} = S_{DS} = 0.75$

$$C_{x\&y} = \frac{SaI}{R} \qquad Cx\&y = \frac{0.75 \times 1.25}{3} = 0.312$$

14.6.1. Seismic Load of wall :

$$C_{x\&y} = \frac{SaI}{R} \qquad Cx\&y = \frac{0.75 \times 1.25}{3} = 0.312$$

Seismic load of each wall applied as follow on each area:

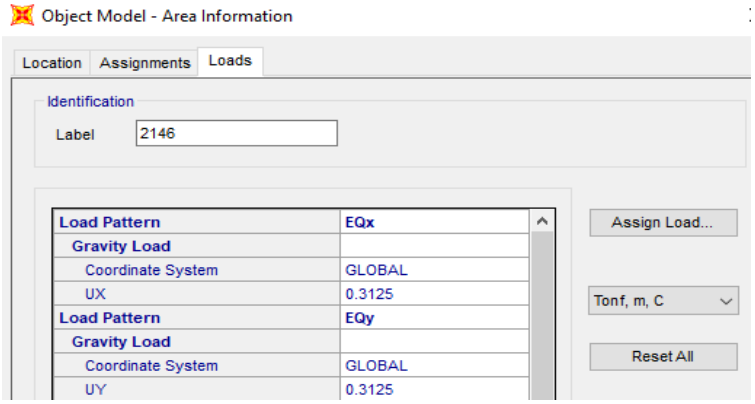

FIG 33 - Applied wall seismic coefficient

15.P-Delta Effect

P-Delta effect on model applied as follow:

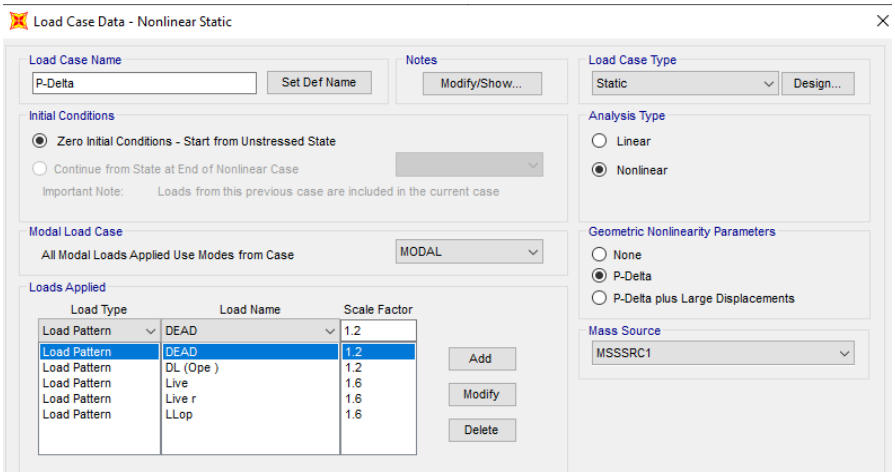

FIG 34 - P-Delta

16.LOADING COMBINATIONS

Foundations, structures and members of structures shall be designed for the most severe loading combination given in below Table. Loads shall be combined as specified in the Table (According to Iranian Seismic Design Code for Petroleum Facilities (3 rd. edition)

16.1. Strength Design:

$1.4D$+1.4F+1.6H+TLst

1.2D+1.6L+0.5(Lr or S)+1.2F+1.6H+TLst

1.2D+1.6(Lr or S)+(L)+1.2F+1.6H+TLst

$1.2D + L + .5(Lr\ or\ S) + 1.2F + 1.6H + \mathrm{TLst}$

1.2D+E+L+0.2S+1.2F+1.6H+TLst

$0.9D + 1.6H$+TLst

$0.9D + E + 0.9F + 1.6H$+TLst

16.2. Allowable Design:

$$D + F + H + TLst$$

$$D + L + F + H + TLst$$

$$D + F + H + (Lr\ OR\ S)$$

$D + F + H + 0.75L + 0.75(Lr\ or\ S)$

$D + F + H$+0.7E

$D + F + H$+0.75(0.7E)+0.75L+0.75S

$0.6D + H$

$0.6D + 0.7E + 0.6F + H$

**F is Water load And H load is soil load

17.ANALYSIS AND DESIGN

17.1. Foundation Controls

Model analysis is done by Sap 2000 software.in model loads are applied, some graphical Outputs from modeling are shown as follows:

According to Sap 2000 results Maximum moment for foundation slab is approximately 6.00 ton.m

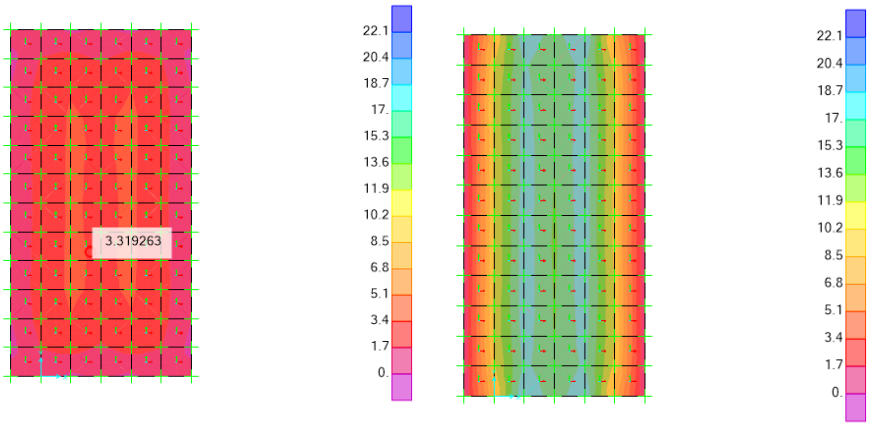

FIG 35 - Foundation Moment (M22,M11) ton.m

17.1.1. Foundation reinforcing:

$$M_{11_{max}} = 18\ ton-m/m \quad \& \quad M_{22_{max}} = 4.00\ ton-m/m$$

$$foundation\ thickness = 40\ cm$$

$$A_{s_{min}} = 0.0018 * 100 * 40 = 7.20\ \frac{cm2}{m}$$

$$USE\ \phi 20\ @200$$

As						
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)	phi
	18	100	35	4000	300	0.9
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)	SELECT PHI
	2000000.000	16.327	15.686	0.004221	14.775	20.00

17.1.2. Uplift Control Under Foundation :

As observed in image below, in worse load combinations uplift of Foundation is inappreciable and it has not any bad effect on stability.

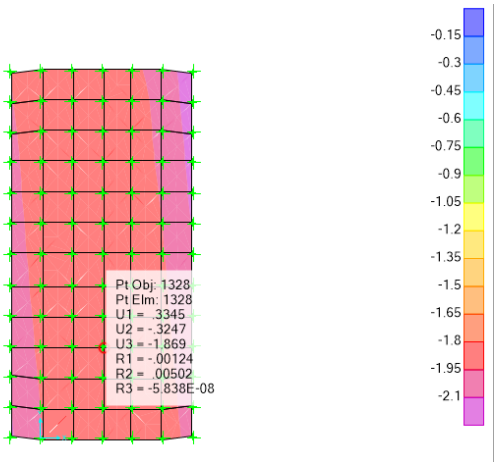

FIG 36 - Uplift Control

$$U_{water} = \gamma h = 1.50 \times 1000 = 1500 \frac{kg}{m2}$$

$$U_{water} = 1500 \times 3.0 \times 6.0 = 27000\ kg = 27.00\ ton$$

Weight of walls $= 2500 \times (2.5 \times 0.4 \times 6) = 15000\ kg = 15.00\ ton$

Weight of Soil on Foundation$= (12 \times 1.10 \times 2000) + (6 \times 2.50 \times 2000) = 56400 kg = 56.40\ ton$

Weight of Foundation$= 2500 \times (6.00 \times 6.00) \times 0.40 = 36000 kg = 36 ton$

Slab weight $= 2500 \times (2.0 \times 6.0 \times 0.4) = 12000\ kg = 12 ton$

$$SF = \frac{15.00 + 56.40 + 36.00 + 12}{27.00} = 4.42 > 1.00\ ok$$

17.1.3. Soil pressure control

Model was constructed as below geometry and analyzed in all services and ultimate load cases which have load combinations for nonlinear analysis.

Deformation of all footings in envelope of service combination has been illustrated in below image:

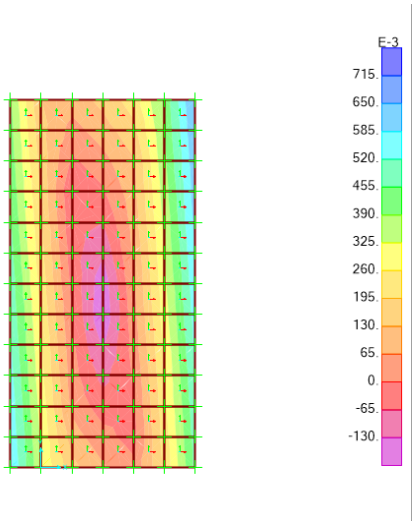

FIG 37 - Maximum Soil Pressure

$$q_{max} = 0.60\ \frac{kg}{cm^2} < 1.75 \frac{kg}{cm^2} \rightarrow O.K.$$

17.1.4. Displacement Check

As observed in below image, maximum vertical displacement of footing under envelope of all service combinations is about -2.17 cm. Therefore, we have:

TABLE: Joint Displacements

Joint	OutputCase	CaseType	StepType	U1	U2	U3
247	Env-A	Combination	Min	-0.335	-0.325	-2.176
246	Env-A	Combination	Min	-0.335	-0.325	-2.162
245	Env-A	Combination	Min	-0.336	-0.325	-2.148
244	Env-A	Combination	Min	-0.336	-0.325	-2.134
243	Env-A	Combination	Min	-0.336	-0.325	-2.120
1367	Env-A	Combination	Min	-0.333	-0.324	-2.111
242	Env-A	Combination	Min	-0.336	-0.325	-2.107
1368	Env-A	Combination	Min	-0.333	-0.325	-2.097
241	Env-A	Combination	Min	-0.336	-0.325	-2.093
1369	Env-A	Combination	Min	-0.333	-0.325	-2.083
240	Env-A	Combination	Min	-0.336	-0.325	-2.079
1370	Env-A	Combination	Min	-0.334	-0.325	-2.069

239	Env-A	Combination	Min	-0.336	-0.325	-2.065
1371	Env-A	Combination	Min	-0.334	-0.325	-2.055
238	Env-A	Combination	Min	-0.336	-0.325	-2.051
1372	Env-A	Combination	Min	-0.334	-0.325	-2.041
237	Env-A	Combination	Min	-0.336	-0.325	-2.036
1373	Env-A	Combination	Min	-0.334	-0.325	-2.027

Allowable Deflection=2.5cm>2.17

17.2. Wall Controls

17.2.1. wall reinforcing design

Moment capacity is :Ø22@200 mm

As						
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)	phi
	22.5	100	35	4000	300	0.9
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)	SELECT PHI
	2500000.000	20.408	15.686	0.005324	18.635	22.00

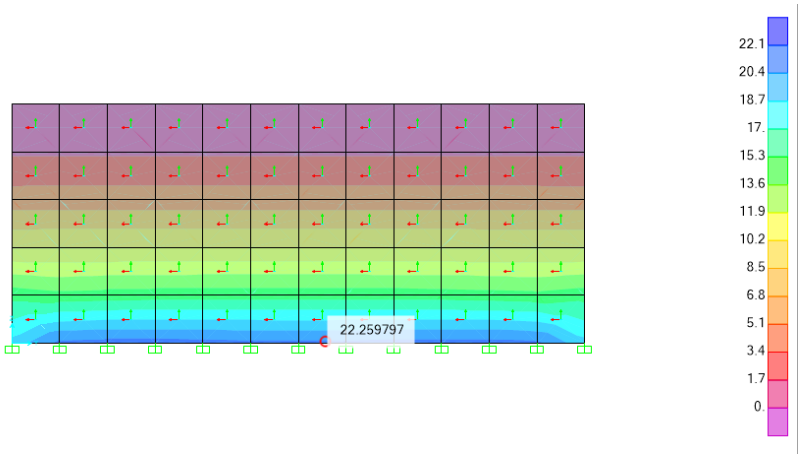

FIG 38 - Max load combination on wall (M22=22.50 ton.m)

According to Sap 2000 results Maximum moment for wall slab is approximately 22.50 ton.m so we used Ø22@200 as follows:

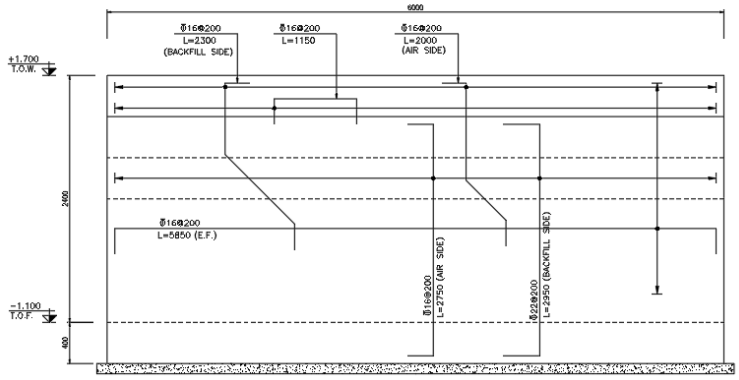

FIG 39 - Wall Reinforcement Ø22@200

18.Shear Control Under walls :

$$F_{soil} = \frac{1}{2} K_0 \gamma h^2 = 0.5 \times 0.5 \times 2 \times 1000 \times 2.50^2 = 3125 \text{ kg/m}$$

$$F_w = \frac{1}{2} \gamma_w h^2 = 0.5 \times 1 \times 1000 \times 1 \times 2^2 = 1000 \text{ kg/m}$$

$$F_t = Fw + Fsoil = 4920 \frac{kg}{m} \text{ in 1 m} = 4920 \text{ kg} = 4.92 \text{ ton}$$

$$V_c = 0.53\sqrt{fc}\, bw\, d = 0.53\sqrt{300} \times 100 \times 35 = 32129.54 \text{ kg} = 32.13 \text{ ton (in 1 m)} \gg Ft \text{ ok}$$

According to sap analysis result maximum shear on wall is under critical load combination is a follows

TABLE: Element Forces - Area Shells					
Area	OutputCase	CaseType	StepType	V13	V23
Text	Text	Text	Text	Tonf/m	Tonf/m
122	Env-A	Combination	Max	1.139	12.239
122	Env-A	Combination	Max	0.194	12.239
131	Env-A	Combination	Max	0.139	12.2
131	Env-A	Combination	Max	-0.214	12.2
121	Env-A	Combination	Max	5.017	12.195
121	Env-A	Combination	Max	3.446	12.195
132	Env-A	Combination	Max	-1.552	12.159
132	Env-A	Combination	Max	-1.949	12.159

TABLE: Element Forces - Area Shells					
Area	OutputCase	CaseType	StepType	V13	V23
Text	Text	Text	Text	Tonf/m	Tonf/m
122	Env-A	Combination	Max	1.139	12.087
122	Env-A	Combination	Max	0.194	12.087
131	Env-A	Combination	Max	0.139	12.063
131	Env-A	Combination	Max	-0.214	12.063
124	Env-A	Combination	Max	0.152	11.26
124	Env-A	Combination	Max	0.035	11.26
129	Env-A	Combination	Max	0.047	11.238
129	Env-A	Combination	Max	0.031	11.238
123	Env-A	Combination	Max	0.408	11.201
123	Env-A	Combination	Max	0.024	11.201
130	Env-A	Combination	Max	0.101	11.172
130	Env-A	Combination	Max	-0.143	11.172
123	Env-A	Combination	Max	0.408	11.073
123	Env-A	Combination	Max	0.024	11.073
130	Env-A	Combination	Max	0.101	11.06
130	Env-A	Combination	Max	-0.143	11.06
124	Env-A	Combination	Max	0.152	11.032
124	Env-A	Combination	Max	0.035	11.032
129	Env-A	Combination	Max	0.047	11.026
129	Env-A	Combination	Max	0.031	11.026
125	Env-A	Combination	Max	0.152	10.833
125	Env-A	Combination	Max	-0.012	10.833
128	Env-A	Combination	Max	0.05	10.818
128	Env-A	Combination	Max	0.04	10.818
125	Env-A	Combination	Max	0.152	10.612
128	Env-A	Combination	Max	0.05	10.612
128	Env-A	Combination	Max	0.04	10.612
125	Env-A	Combination	Max	-0.012	10.612
126	Env-A	Combination	Max	0.115	10.573
126	Env-A	Combination	Max	0.014	10.573
127	Env-A	Combination	Max	0.083	10.563
127	Env-A	Combination	Max	0.023	10.563

Maximum shear load is less than shear capacity of wall that is acceptable.

18.1. Retaining wall control

18.1.1. Overturning Control

Overturning moments are horizontally applied forces multiplied by the moment arm from the bottom of the footing to their point of application. Overturning controls are considering in two static and earthquake condition. Resisting load consist of total weight of structure and soil weight.

In static Condition:

$$Resisting\ Moment\ in\ Bottom\ of\ Toe = 8.70\ Ton.m$$

$$Overturning\ Moment\ in\ Bottom\ of\ Toe = 2.10\ Ton.m$$

$$\rightarrow F.S. = \frac{M_{resisting}}{M_{overturning}} = 4.18 > 1.75 \rightarrow O.K.$$

In Earthquake Condition:

$$Resisting\ Moment\ in\ Bottom\ of\ Toe = 5.50\ Ton.m$$

$$Overturning\ Moment\ in\ Bottom\ of\ Toe = 3.80\ Ton.m$$

$$\rightarrow F.S. = \frac{M_{resisting}}{M_{overturning}} = 2.19 > 1.0 \rightarrow O.K.$$

18.1.2. Sliding Control

The sum of all the horizontal forces pushing against the wall must be resisted to prevent a sliding failure. Sliding control results are reported as below:

Driving Force	Resistance Force	Ratio
$F_d=P_a=2256$	4263	1.88
$F_d=P_{Dead}+0.7P_E=2218$	3489	1.57
$F_d=P_a=2774$	4263	1.53

18.2. Slab design

18.2.1. Slab reinforcing design

$$M_{11_{max}} = 17\ ton-m/m \quad \& \quad M_{22_{max}} = 22\ ton-m/m$$

$$slab\ thickness = 40\ cm$$

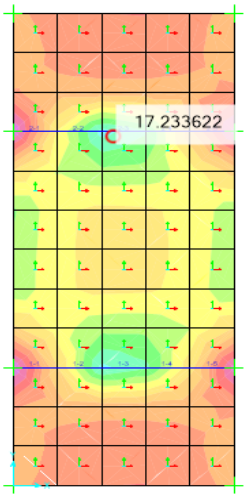

FIG 40 - max load combination on slab (M22=17.23 ton.m)

FIG 41 - max load combination on slab (M11=23.00 ton.m)

As						
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)	phi
	22.5	100	35	4000	300	0.9
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)	SELECT PHI
	2500000.000	20.408	15.686	0.005324	18.635	22.00

As						
INPUT	Mu(ton.m)	b(cm)	d(cm)	Fy (kg/cm^2)	fc(kg/cm^2)	phi
	18	100	35	4000	300	0.9
OUTPUT	Mn	Rn1	m1	ρ_{req}	As(req)	SELECT PHI
	2000000.000	16.327	15.686	0.004221	14.775	22.00

18.2.1. Deflection Control

The function of passageway slab is similar to one way slab because of walls as supports in one direction.

Therefore to control the deflection of slab, below mentioned controls have been done according to Iranian National Building Code No.9 for Reinforced Concrete Structures section 9-9-3-1.

Slab thickness= 40cm, maximum l_e= 240cm

0.66cm < 240/20=12.00 cm O.K.

→So according to 9-9-3-2 there is no need to control deflection

But deflection has been controlled conservatively:

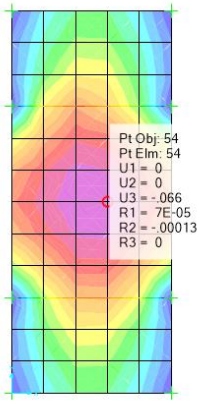

FIG 42 - Max DEFLECTION