5.1.2 Substructure

(1) General conditions

(a) Unit weight

Reinforced concrete	: Wc	= 2.5	tf/m^3
Soil on the front part of footing	: Wa	= 1.8	tf/m^3
Backfillingsoil	: γ s	= 1.9	tf/m^3

(b) Coefficient of earth pressure

For the calculation of the abutments, Coulomb's earth pressure theory was adopted.

Vertical earth pressure	: Kv	= 1.0	
Horizontal earth pressure	: Ka	= 0.333	

(c) Live load

Live load as a surcharge	: q	= 3.03	tf/m^2

(d) Material strength and allowable stresses

1) Concrete

Specified design strength		σ ck = 240.0	kgf/cm^2
(Blinding concrete)		σ ck = 160.0	kgf/cm^2
Allowable flexural stress		σ ca = 80.0	kgf/cm^2
Allowable shear stress		τ a = 3.90	kgf/cm^2
Allowable bond stress	General use	τ oa = 16.0	kgf/cm^2
	at corner	τ oa = 28.0	kgf/cm^2
Young's Modulus		Ec = 2.5×10^6	kgf/cm^2

Allowable stresses for the seismic calculation will be increased by 1.5 times.

2) Reinforcing steel

Condition	Rate of increase	Allowable tensile strength	
Ordinary time	1.00	σ sa = 1800.0	kgf/cm^2
(in water, underground)		σ sa = 1600.0	kgf/cm^2
Seismic time	1.50	σ sa = 2700.0	kgf/cm^2

3) Ratio of Young's Modulus (Es/Ec) n = 15

(e) Cover of reinforcing steel

Location		Cover (cm)
Beam		10.0
Wall	Outside	10.0
Footing	Upper side	10.0
Slab	Lower side	10.0 (15.0)

* For the pile foundation type, the value in the bracket will be applied.

(2) Applied Structural Types of Substructures

Applied structural types of substructures according to Clause 3.2.3 Type of Bridges are listed as below:

Name of Roundabout	Types of Abutment	Types of Pier
R/A-2 A'Naseem Garden	Inverted T-type	Rigid frame with two columns
R/A-3 Barka	Inverted T-type	Rigid frame with two columns (P3～P8) T shaped (P1,P2,P9,P10)
R/A-5 Al Muladdah	Inverted T-type	Rigid frame with two columns (P3～P8) T shaped (P1,P2,P9,P10)
R/A-8 Al Khaburah	Inverted T-type	Rigid frame with two columns (P3～P8) T shaped (P1,P2,P9,P10)
R/A-10 Saham	Inverted T-type	T shaped
R/A-12 Sohar	Inverted T-type	Rigid frame with two columns
R/A-14 Falaj Al Qabail	Inverted T-type	Rigid frame with two columns
R/A-18 Aqr	Inverted T-type	Two columns rigid frame with PC beam (PA5, PA7, PB6～PB8) T shaped (Others)

Usage to combine the structural types is shown follows:

Within R/A : Rigid frame with two columns
Out of R/A : T shaped

Structural dimension for each type is shown in Figure 3.16.

(3) Soil Conditions

1) Bearing layers

Dense sand layer with more than 30 of S.P.T value was adopted as a bearing layer. The distribution of bearing layer at each roundabout is summarized in Figures 5.5(a) to 5.8(b).

2) Design Constants of Soil

- Unit weight : $\gamma = 1.90$ tf/m^3
- Modulus of deformation of soil : E2 ; result of Pressio Metric Test shown in Appendix III.
- Cohesion of Soil : C = 0.625*N (tf/m^2)
- Internal friction angle : $\theta = 15 + \sqrt{15 * N}$ (degree)

Where N value is the result of standard penetration test.

3) Ground water

No influence by ground water is considered for this detailed design since its elevation is judged to be sufficiently low by the soil investigation in Appendix III.

(4) Structural Height and Foundation Types

Being based on the study in Clause 3.2.3 Type of Bridges and depth of bearing layers determined above, adopted structural height and foundation type for each substructure is shown in Tables 5.9 (a) to 5.10(b).

GEOLOGICAL PROFILE

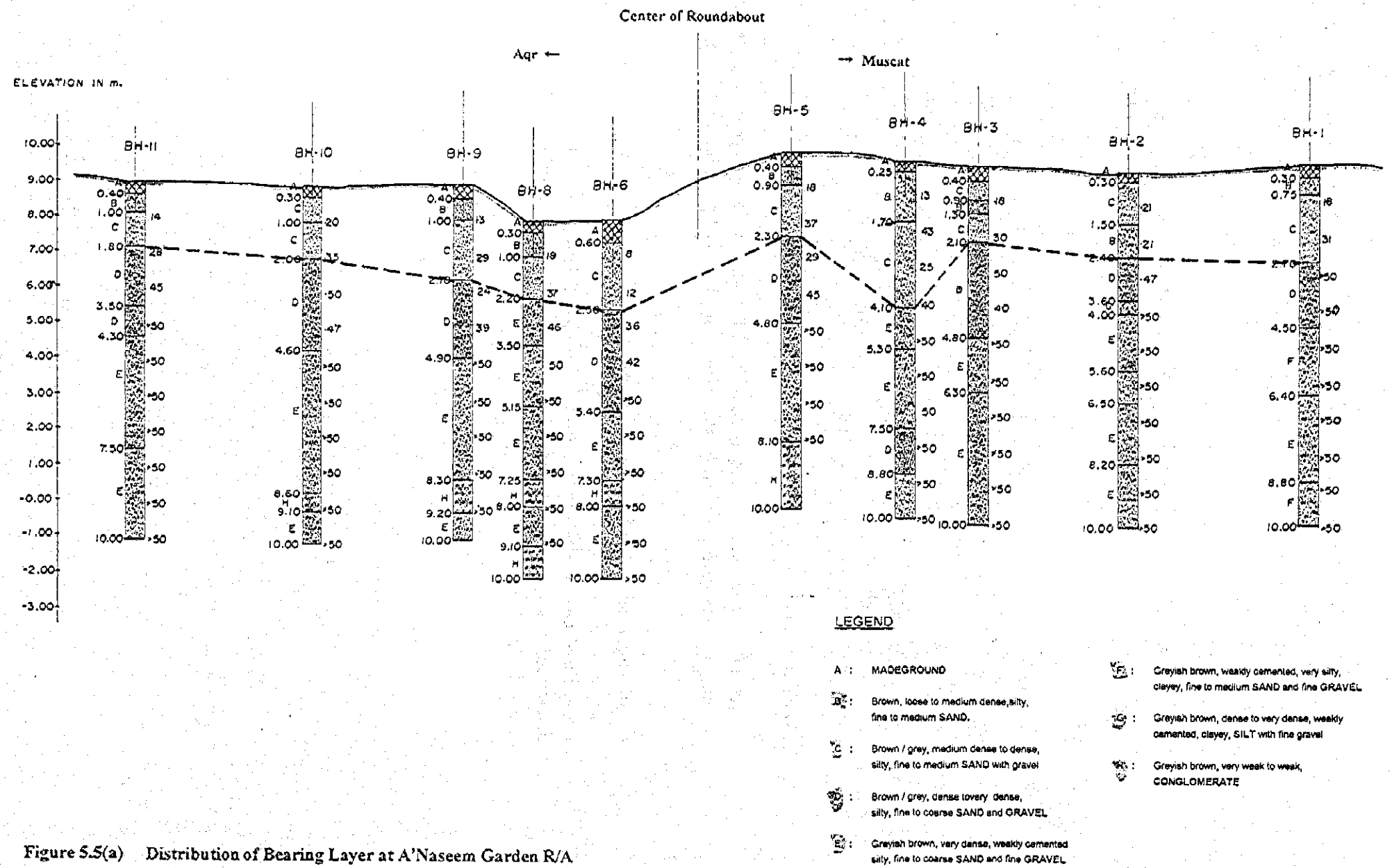


Figure 5.5(a) Distribution of Bearing Layer at A'Naseem Garden R/A

GEOLOGICAL PROFILE

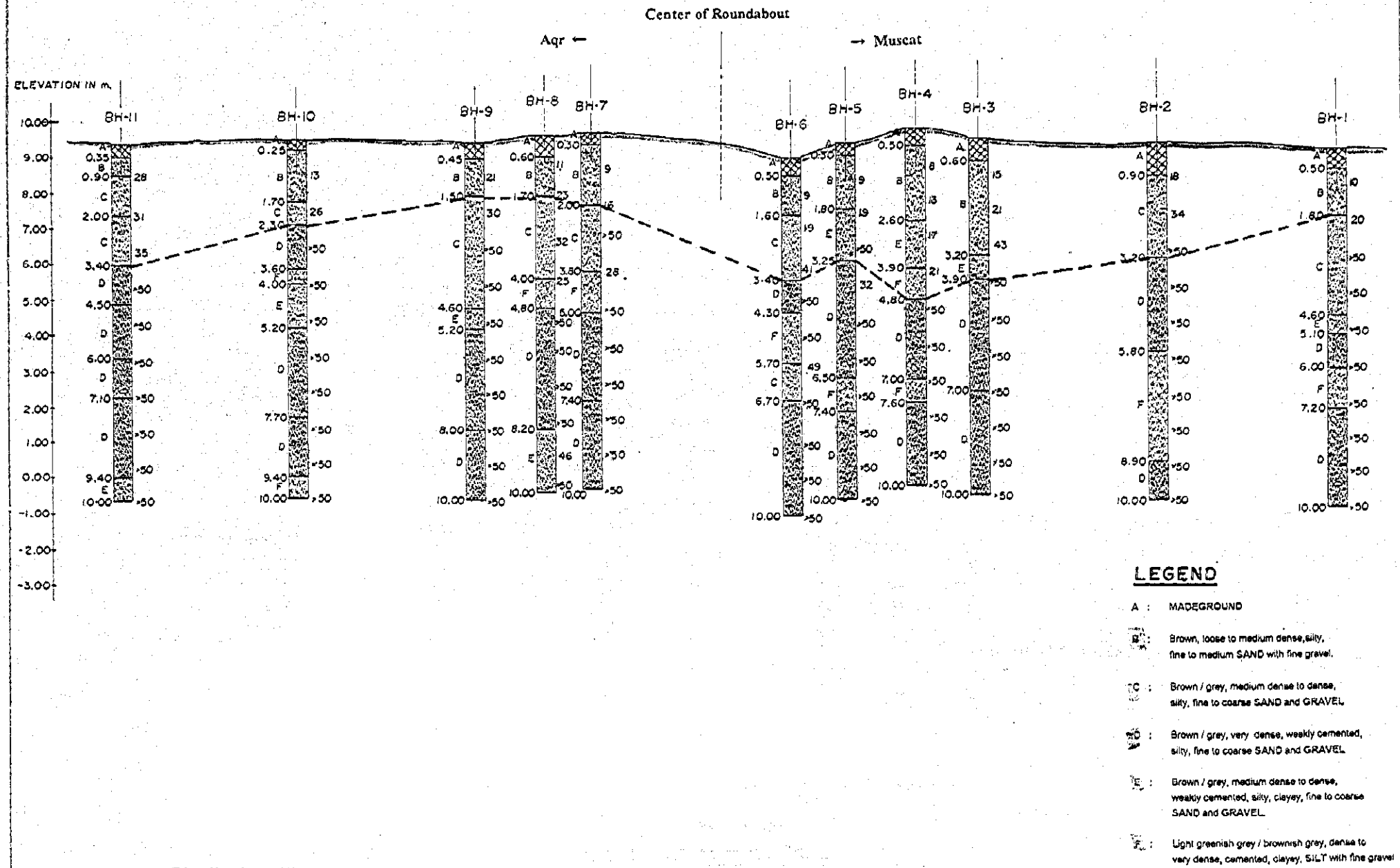


Figure 5.5(b) Distribution of Bearing Layer at Barka R/A

GEOLOGICAL PROFILE

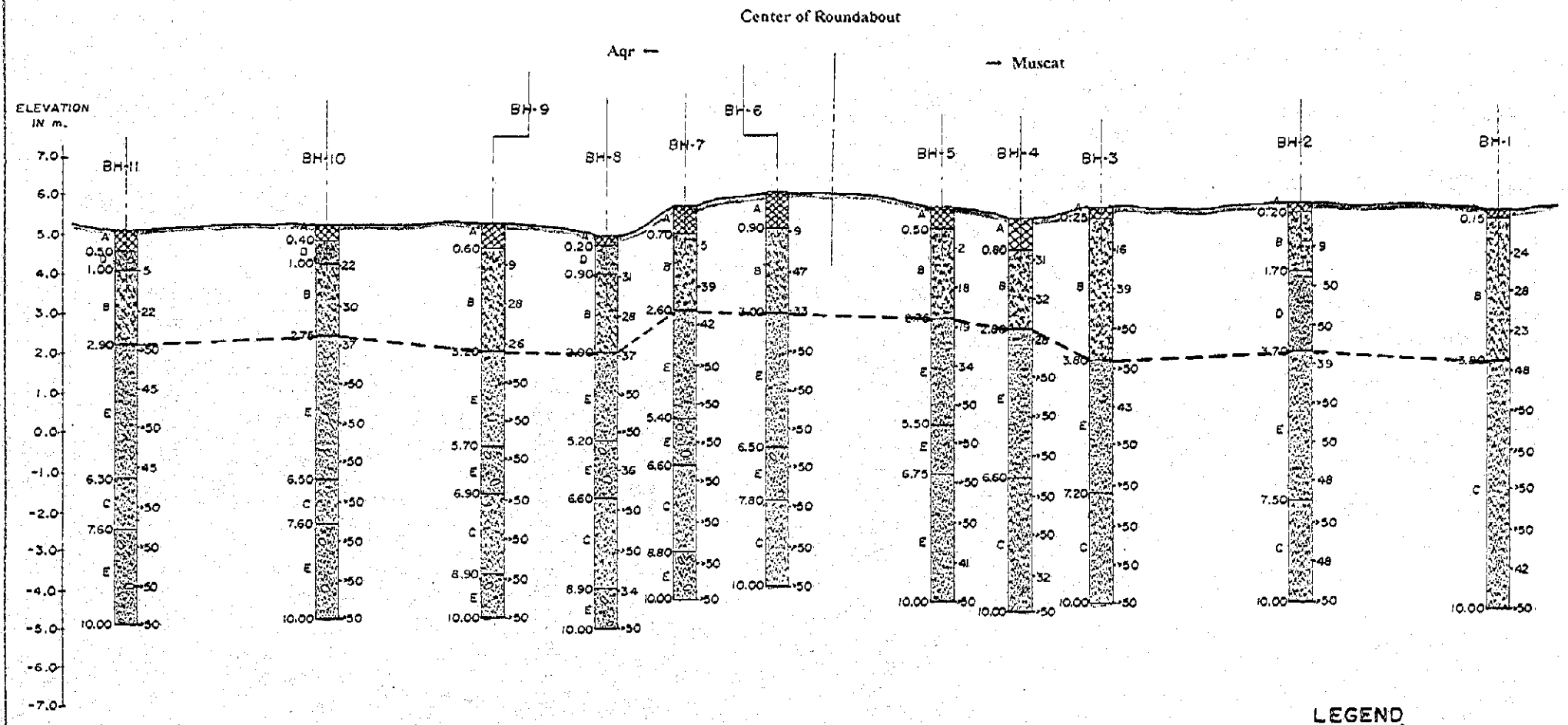
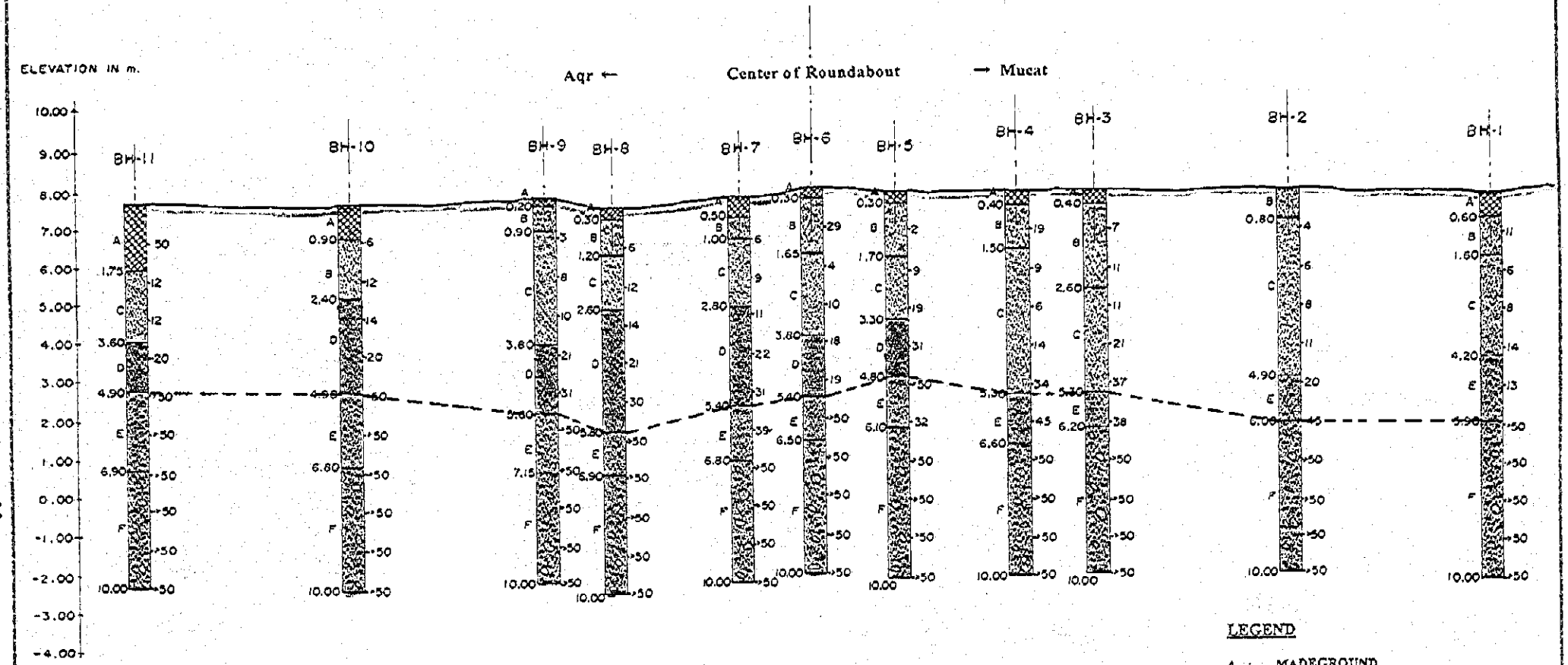


Figure 5.6(a) Distribution of Bearing Layer at Al Muladdah R/A

GEOLOGICAL PROFILE

AL KHABURAH R/A-8



SECTION - A.A

LEGEND

A : MADEGROUND

B : Brown, loose, to medium dense, very silty, fine SAND

C : Brown, loose to medium dense, fine SAND and clayey SILT

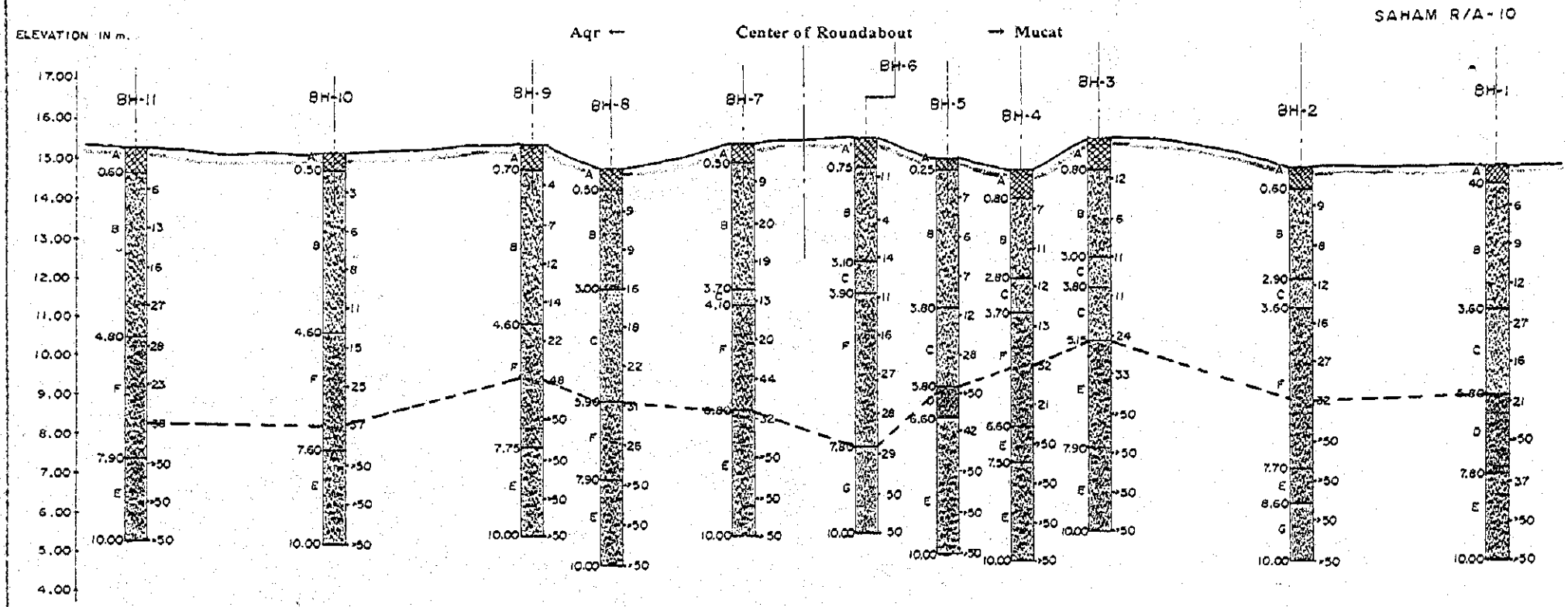
D : Brown, medium dense to dense, clayey, SILT and fine SAND.

E : Brownish grey, medium dense, very silty, fine SAND with some gravel.

F : Brown, grey, very dense, slighty silty, fine to coarse SAND and GRAVEL with sub -rounded to rounded cobbles and occasional boulders.

Figure 5.6(b) Distribution of Bearing Layer at Al Khaburah R/A

GEOLOGICAL PROFILE



SECTION - A.A

LEGEND

- A : MADEGROUND
- B : Brown, loose, fine SAND and clayey SILT
- C : Brown, medium dense, very silty, fine SAND
- D : Brown medium dense to dense, silty, fine SAND with gravel.
- E : Brownish grey, dense to very dense, weakly cemented, fine to coarse SAND and GRAVEL.
- F : Brown, medium dense to dense, weakly cemented, fine SAND and clayey SILT with gravel.
- G : Brown, very dense, weakly cemented to cemented, very silty, fine to medium SAND.

Figure 5.7(a) Distribution of Bearing Layer at Saham R/A

GEOLOGICAL PROFILE

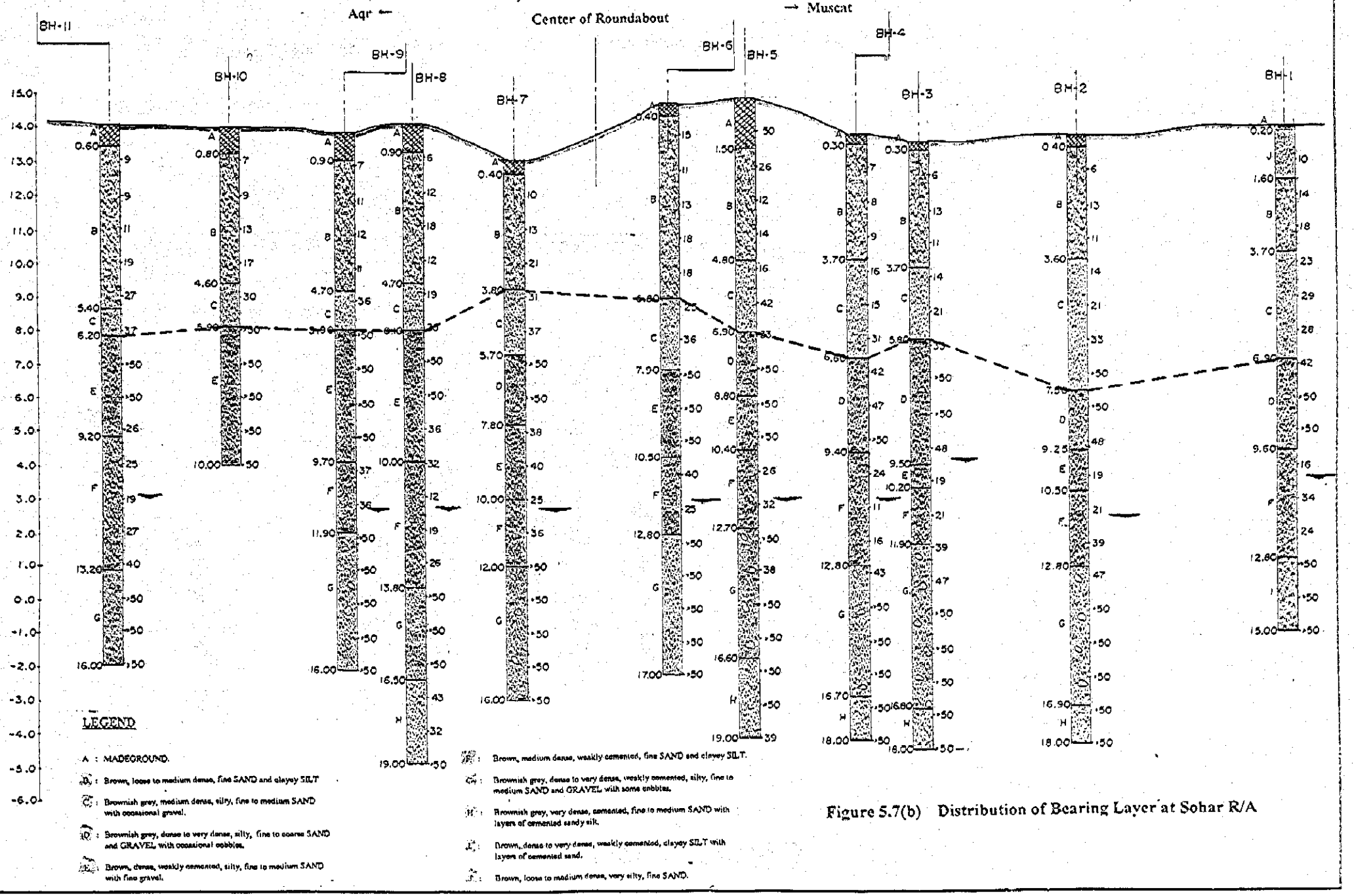
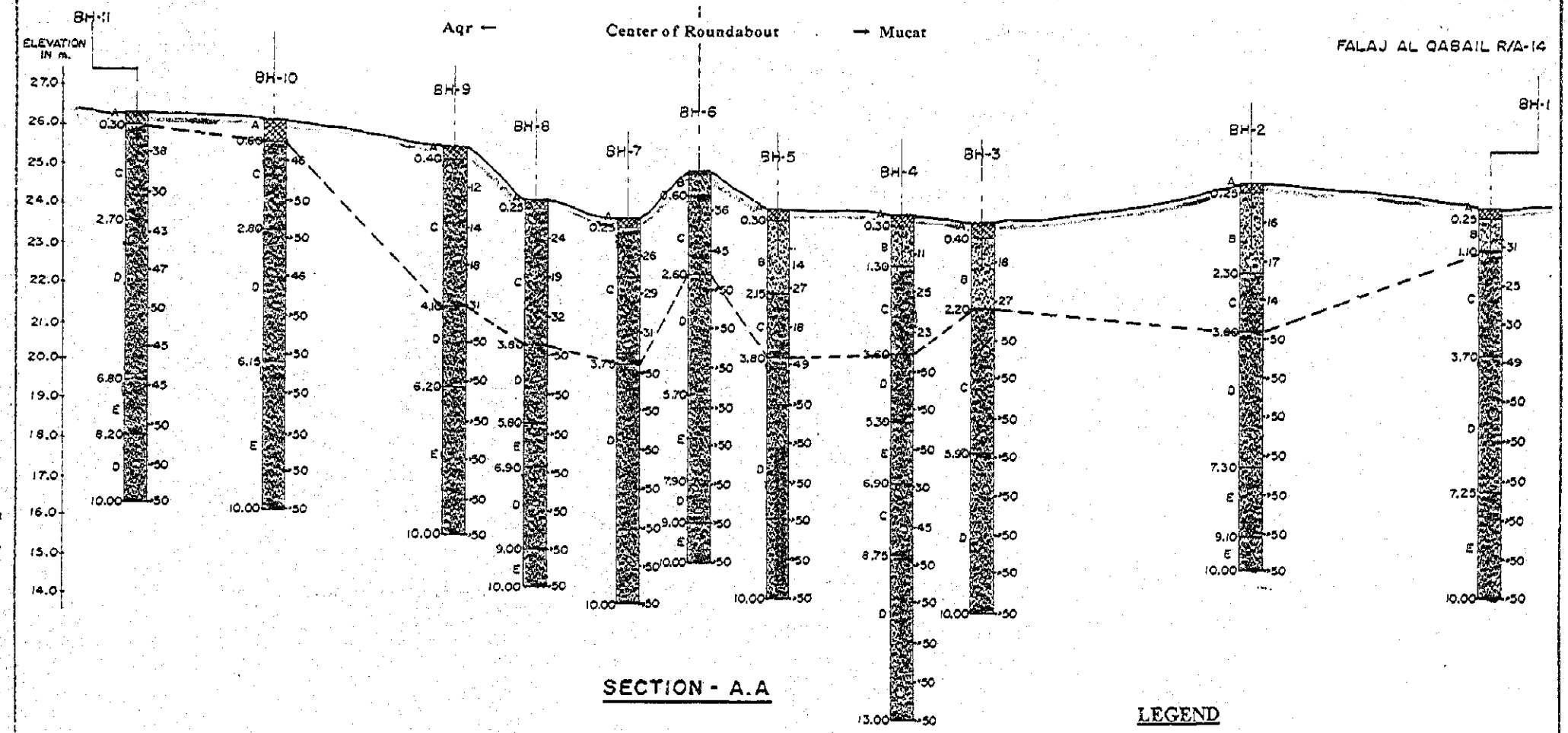


Figure 5.7(b) Distribution of Bearing Layer at Sohar R/A

GEOLOGICAL PROFILE



SECTION - A.A

LEGEND

A : MADEGROUND

: Brown, medium dense, silty, fine SAND with some gravel.

: Brown & grey, medium dense to dense, silty, fine to coarse SAND & GRAVEL with sub rounded to rounded cobbles and layers of very silty sand.

: Brownish grey, dense to very dense, silty, fine to coarse SAND and GRAVEL with sub rounded to rounded cobbles and occasional boulders.

: Brown, very dense, cemented to well cemented, silty, fine to medium SAND with fine gravel.

Figure 5.8(a) Distribution of Bearing Layer at Falaj Al Qabail R/A

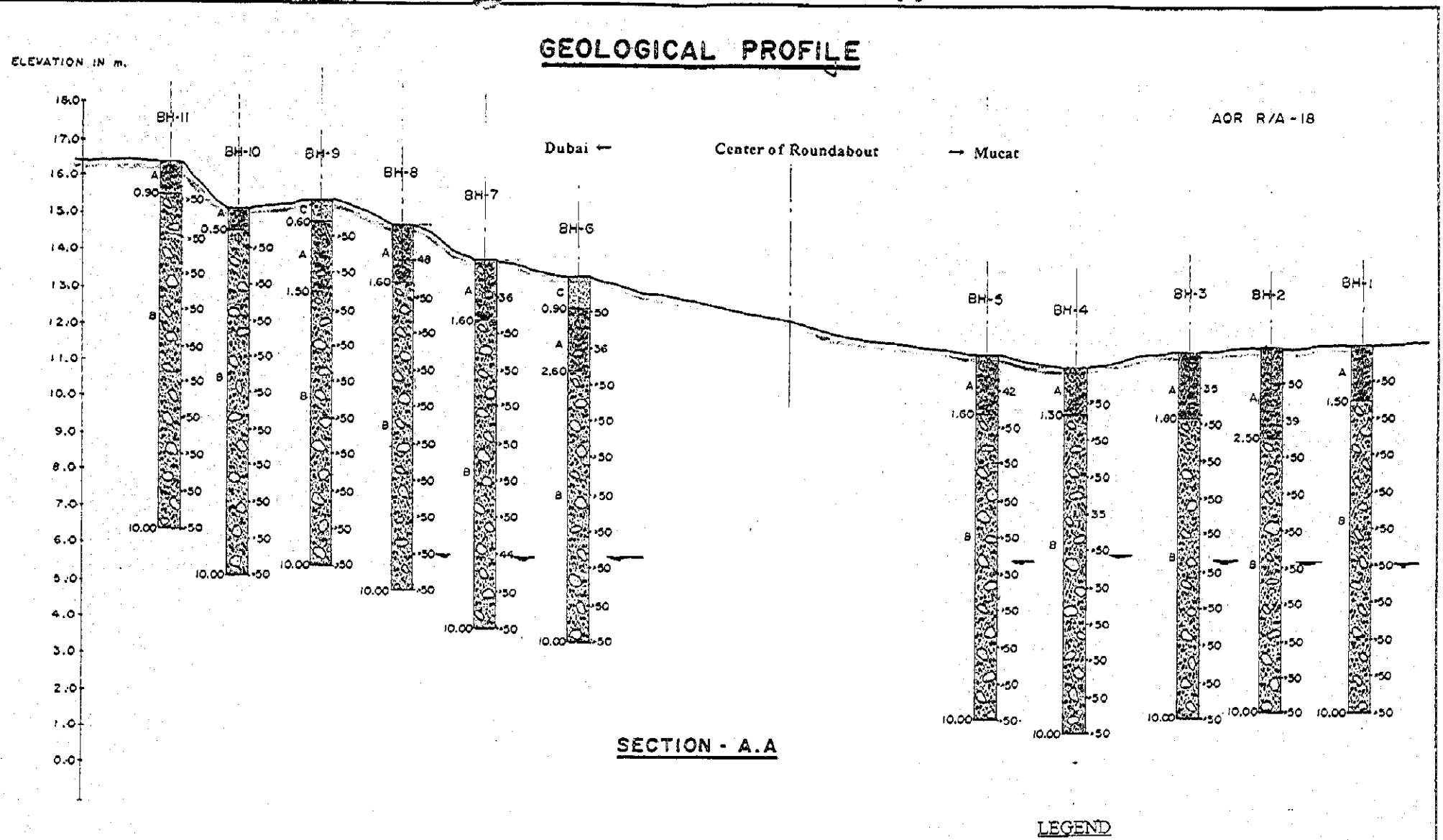


Figure 5.8(b) Distribution of Bearing Layer at Aqr R/A

Table 5.9(a) Structural Height amd Foundation Type(1) (A'Naseem Garden & Barka)

A'Naseem Garden R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	A2
F.H	17.134	17.537	17.844	18.049	18.151	18.151	18.049	17.844	17.537	17.143
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700
Crossfall	0.000	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	15.334	15.675	15.982	16.187	16.289	16.289	16.187	15.982	15.675	15.281
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	15.191	15.522	15.829	16.034	16.136	16.136	16.034	15.829	15.522	15.138
Body Height	7.764	9.600	9.600	9.600	9.600	9.600	9.600	9.600	9.600	7.711
Elevation of Upper footing	7.427	5.922	6.229	6.434	6.536	6.536	6.434	6.229	5.922	7.427
Ground Surface	10.404	10.377	10.349	10.500	10.700	10.900	10.150	10.244	10.207	10.169
Elevation of Bearing Layer	6.220	4.790	4.790	4.790	4.790	4.790	4.790	4.790	4.790	6.220
Elevation of Footing bottom	6.127	4.122	4.429	4.634	4.736	4.736	4.634	4.429	4.122	6.127
Height of above ground	4.787	5.145	5.480	5.534	5.436	5.236	5.884	5.585	5.315	4.969
Cover1(GL-BL)	4.184	5.587	5.559	5.710	5.910	6.110	5.360	5.454	5.417	3.949
Cover2(top-GL)	4.277	6.255	5.920	5.866	5.964	6.164	5.516	5.815	6.085	4.042
Foundation Type	Spread Foundation									

Barka R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	21.453	21.785	22.055	22.258	22.393	22.461	22.461	22.393	22.258	22.055	21.785	21.453
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.000	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	20.053	20.323	20.593	20.796	20.931	20.999	20.999	20.931	20.796	20.593	20.323	19.991
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	19.928	20.188	20.458	20.661	20.796	20.864	20.864	20.796	20.661	20.458	20.188	19.866
Body Height	7.581	9.601	9.600	9.600	10.000	10.001	10.001	10.000	9.600	9.600	9.601	7.519
Elevation of Upper footing	12.347	10.587	10.858	11.061	10.796	10.863	10.863	10.796	11.061	10.858	10.587	12.347
Ground Surface	14.806	14.804	14.803	14.802	15.100	15.900	15.950	15.100	14.782	14.752	14.722	14.692
Elevation of Bearing Layer	11.210	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	11.210
Elevation of Footing bottom	11.147	8.787	9.058	9.261	9.196	9.263	9.263	9.196	9.261	9.058	8.787	11.147
Height of above ground	5.122	5.384	5.655	5.859	5.696	4.964	4.914	5.696	5.879	5.706	5.466	5.174
Cover1	3.596	5.484	5.483	5.482	5.780	6.580	6.630	5.780	5.462	5.432	5.402	3.482
Cover2	3.659	6.017	5.745	5.541	5.904	6.637	6.687	5.904	5.521	5.694	5.935	3.545
Foundation Type	Spread Foundation											

A'Naseem Garden R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	A2
F.H	17.134	17.537	17.844	18.049	18.151	18.151	18.049	17.844	17.537	17.134
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700
Crossfall	0.000	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.000
Elevation of carriageway center	15.334	15.675	15.982	16.187	16.289	16.289	16.187	15.982	15.675	15.334
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	15.191	15.522	15.829	16.034	16.136	16.136	16.034	15.829	15.522	15.191
Body Height	7.764	9.600	9.600	9.600	9.600	9.600	9.600	9.600	9.600	7.764
Elevation of Upper footing	7.427	5.922	6.229	6.434	6.536	6.536	6.434	6.229	5.922	7.427
Ground Surface	10.492	10.472	10.452	10.500	10.700	10.900	10.150	10.302	10.260	10.219
Elevation of Bearing Layer	6.220	4.790	4.790	4.790	4.790	4.790	4.790	4.790	4.790	6.220
Elevation of Footing bottom	6.127	4.122	4.429	4.634	4.736	4.736	4.634	4.429	4.122	6.127
Height of above ground	4.699	5.050	5.377	5.534	5.436	5.236	5.884	5.527	5.262	4.972
Cover1(GL-BL)	4.272	5.682	5.662	5.710	5.910	6.110	5.360	5.512	5.470	3.999
Cover2	4.365	6.350	6.023	5.866	5.964	6.164	5.516	5.873	6.138	4.092
Foundation Type	Spread Foundation									

Barka R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	21.453	21.785	22.055	22.258	22.393	22.461	22.461	22.393	22.258	22.055	21.785	21.453
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.000	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	20.053	20.323	20.593	20.796	20.931	20.999	20.999	20.931	20.796	20.593	20.323	19.991
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	19.928	20.188	20.458	20.661	20.796	20.864	20.864	20.796	20.661	20.458	20.188	19.866
Body Height	7.581	9.601	9.600	9.600	10.000	10.001	10.001	10.000	9.600	9.600	9.601	7.519
Elevation of Upper footing	12.347	10.587	10.858	11.061	10.796	10.863	10.863	10.796	11.061	10.858	10.587	12.347
Ground Surface	14.806	14.804	14.803	14.802	15.100	15.900	15.950	15.100	14.780	14.765	14.751	14.737
Elevation of Bearing Layer	11.210	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	9.320	11.210
Elevation of Footing bottom	11.147	8.787	9.058	9.261	9.196	9.263	9.263	9.196	9.261	9.058	8.787	11.147
Height of above ground	5.122	5.384	5.655	5.859	5.696	4.964	4.914	5.696	5.881	5.693	5.437	5.129
Cover1	3.596	5.484	5.483	5.482	5.780	6.580	6.630	5.780	5.460	5.445	5.431	3.527
Cover2	3.659	6.017	5.745	5.541	5.904	6.637	6.687	5.904	5.519	5.707	5.964	3.590
Foundation Type	Spread Foundation											

Table 5.9(b) Structural Height and Foundation Type(2) Type (Al Muladdah & Sohar)

Al Muladdah R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	13.730	14.062	14.332	14.535	14.670	14.738	14.738	14.670	14.535	14.332	14.062	13.730
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall		0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	12.330	12.600	12.870	13.073	13.208	13.276	13.276	13.208	13.073	12.870	12.600	12.268
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	12.205	12.465	12.735	12.938	13.073	13.141	13.141	13.073	12.938	12.735	12.465	12.143
Body Height	8.881	9.600	9.600	10.200	10.200	10.200	10.200	10.200	10.200	9.600	9.600	7.319
Elevation of Upper footing	3.324	2.865	3.135	2.738	2.873	2.941	2.941	2.873	2.738	3.135	2.865	4.824
Ground Surface	7.024	7.041	7.057	7.215	7.215	7.215	7.215	7.215	7.215	7.430	7.404	7.378
Elevation of Bearing Layer	2.070	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	3.690
Elevation of Footing bottom	2.024	1.065	1.335	1.138	1.273	1.341	1.341	1.273	1.138	1.335	1.065	3.624
Height of above ground	5.181	5.424	5.678	5.723	5.858	5.926	5.926	5.858	5.723	5.305	5.061	4.765
Cover1	4.954	5.661	5.677	5.835	5.835	5.835	5.835	5.835	5.835	6.050	6.024	3.668
Cover2	5.000	5.976	5.722	6.077	5.942	5.874	5.874	5.942	6.077	6.095	6.339	3.754
Foundation Type	Spread Foundation											

Sohar R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	A2
F.H	21.225	21.707	22.074	22.319	22.442	22.442	22.319	22.074	21.707	21.225
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899
Crossfall	-0.145	-0.145	-0.145	-0.145	-0.145	-0.145	-0.145	-0.145	-0.145	-0.145
Elevation of carriageway center	19.371	19.853	20.220	20.465	20.588	20.588	20.465	20.220	19.853	19.371
Adjustment	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Bearing Pad	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Adjusting Mortar	0.040	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.040
Top Elevation of Structure	19.218	19.690	20.057	20.302	20.425	20.425	20.302	20.057	19.690	19.218
Body Height	5.156	6.400	6.400	6.400	6.400	6.400	6.400	6.400	6.400	5.156
Elevation of Upper footing	14.062	13.290	13.657	13.902	14.025	14.025	13.902	13.657	13.290	14.062
Ground Surface	14.624	14.593	14.562	14.490	14.490	14.490	14.490	14.564	14.604	14.645
Elevation of Bearing Layer	8.070	8.400	8.400	8.400	8.400	8.400	8.400	8.400	8.400	7.550
Elevation of Footing bottom	12.662	10.990	11.357	11.602	11.725	11.725	11.602	11.357	10.990	12.662
Height of above ground	4.594	5.097	5.495	5.812	5.935	5.935	5.812	5.493	5.086	4.573
Cover1	6.554	6.193	6.162	6.090	6.090	6.090	6.090	6.164	6.204	7.095
Cover2	1.962	3.603	3.205	2.888	2.765	2.765	2.888	3.207	3.614	1.983
Foundation Type	Pile Foundation									

Al Muladdah R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	13.724	14.062	14.332	14.535	14.670	14.738	14.738	14.670	14.535	14.332	14.062	13.724
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	12.262	12.600	12.870	13.073	13.208	13.276	13.276	13.208	13.073	12.870	12.600	12.262
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	12.137	12.465	12.735	12.938	13.073	13.141	13.141	13.073	12.938	12.735	12.465	12.137
Body Height	8.813	9.600	9.600	10.200	10.200	10.200	10.200	10.200	10.200	9.600	9.600	7.313
Elevation of Upper footing	3.324	2.865	3.135	2.738	2.873	2.941	2.941	2.873	2.738	3.135	2.865	4.824
Ground Surface	7.024	7.041	7.057	7.215	7.215	7.215	7.215	7.215	7.215	7.430	7.461	7.373
Elevation of Bearing Layer	2.070	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.380	3.690
Elevation of Footing bottom	2.024	1.065	1.335	1.138	1.273	1.341	1.341	1.273	1.138	1.335	1.065	3.624
Height of above ground	5.113	5.424	5.678	5.723	5.858	5.926	5.926	5.858	5.723	5.305	5.004	4.764
Cover1	4.954	5.661	5.677	5.835	5.835	5.835	5.835	5.835	5.835	6.050	6.081	3.683
Cover2	5.000	5.976	5.722	6.077	5.942	5.874	5.874	5.942	6.077	6.095	6.396	3.749
Foundation Type	Spread Foundation											

Sohar R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	A2
F.H	21.458	21.940	22.307	22.552	22.675	22.675	22.552	22.307	21.940	21.458
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899	1.899
Crossfall	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Elevation of carriageway center	19.334	19.816	20.183	20.428	20.551	20.551	20.428	20.183	19.816	19.334
Adjustment	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Bearing Pad	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Adjusting Mortar	0.040	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.040
Top Elevation of Structure	19.181	19.653	20.020	20.265	20.388	20.388	20.265	20.020	19.653	19.181
Body Height	5.156	6.400	6.399	6.399	6.400	6.400	6.399	6.399	6.400	5.156
Elevation of Upper footing	14.025	13.253	13.621	13.866	13.988	13.988	13.866	13.621	13.253	14.025
Ground Surface	14.645	14.605	14.566	14.490	14.490	14.490	14.490	14.564	14.593	14.623
Elevation of Bearing Layer	8.070	8.400	8.400	8.400	8.400	8.400	8.400	8.400	8.400	7.550
Elevation of Footing bottom	12.625	10.953	11.321	11.566	11.688	11.688	11.566	11.321	10.953	12.625
Height of above ground	4.536	5.048	5.454	5.775	5.898	5.898	5.775	5.456	5.060	4.558
Cover1	6.575	6.205	6.166	6.090	6.090	6.090	6.090	6.164	6.193	7.073
Cover2	2.020	3.652	3.245	2.924	2.802	2.802	2.924	3.243	3.640	1.998
Foundation Type	Pile Foundation									

Table 5.10(a) Structural Height and Foundation Type (Al Khaburah & Saham)

Al Khaburah R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	14.725	15.063	15.333	15.536	15.671	15.739	15.739	15.671	15.536	15.333	15.063	14.725
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Elevation of carriageway center	13.263	13.601	13.871	14.074	14 209	14.277	14.277	14.209	14.074	13.871	13.601	13 263
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0 035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	13.138	13.466	13.736	13.939	14.074	14.142	14.142	14.074	13.939	13.736	13.466	13.138
Body Height	5 313	9.801	9.800	9.800	10 200	10 201	10.201	10.200	9.800	9.800	9 801	5.313
Elevation of Upper footing	7.825	3.665	3.936	4.139	3.874	3.941	3.941	3 874	4.139	3.936	3.665	7.825
Ground Surface	8.348	8.393	8.437	8.481	8 270	8 270	8.270	8.270	8.491	8.495	8.499	8.502
Elevation of Bearing Layer	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2 630
Elevation of Footing bottom	6 525	1.865	2.136	2 339	2 274	2 341	2 341	2 274	2 339	2.136	1.865	6.525
Height of above ground	4.790	5.073	5 299	5.458	5 804	5 872	5.872	5 804	5.448	5 241	4.967	4.636
Cover1	5.938	5.983	6 027	6.071	5.860	5.860	5.860	5 860	6.081	6 085	6.089	5.872
Cover2	1.823	6.528	6.301	6.142	5.996	5.929	5.929	5.996	6.152	6.359	6.634	1.977
Foundation Type	Pile	Spread Foundation										Pile

Saham R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	22 263	22 601	22 871	23 074	23 209	23 277	23 277	23 209	23 074	22 871	22 601	22 263
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0 062	0.062	0.062	0.062	0.062	0.062	0 062	0 062	0.062	0.062	0.062	0.062
Elevation of carriageway center	20.801	21.139	21.409	21.612	21.747	21.815	21.815	21.747	21.612	21.409	21.139	20.801
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0 010	0 010	0.010	0.010	0 010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0 080	0.080	0 080	0 080	0.080	0.080	0 080
Adjusting Mortar	0.035	0 045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	20.676	21.004	21.274	21.477	21.612	21.680	21.680	21.612	21.477	21.274	21.004	20.676
Body Height	5.313	6.401	6.397	6.400	6.400	6.401	6.401	6.400	6.400	6.400	6.401	5.313
Elevation of Upper footing	15.363	14.603	14.877	15.077	15 212	15 279	15.279	15 212	15.077	14.874	14.603	15.363
Ground Surface	15.934	15.973	16.013	16.052	15.840	15.840	15.840	15.840	16.054	16.023	15.991	15.960
Elevation of Bearing Layer	9.410	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	9.510
Elevation of Footing bottom	14.063	12.603	12 877	13.077	13.212	13.279	13 279	13.212	13.077	12 874	12.603	14.063
Height of above ground	4.742	5.031	5.261	5.425	5.772	5.840	5.840	5.772	5.423	5 251	5.013	4.716
Cover1	6.524	7.833	7.873	7.912	7.700	7.700	7.700	7.700	7.914	7.883	7.851	6.450
Cover2	1.871	3.370	3.136	2 975	2.628	2.561	2.561	2 628	2.977	3.149	3.388	1.897
Foundation Type	Pile Foundation											

Al Khaburah R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	14.725	15.063	15 333	15.536	15.671	15.739	15.739	15.671	15.536	15.333	15.063	14.725
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.062	0.062	0.062	0.062	0 062	0 062	0.062	0 062	0.062	0.062	0 062	0.062
Elevation of carriageway center	13.263	13.601	13.871	14.074	14 209	14 277	14 277	14 209	14.074	13.871	13.601	13.263
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0 080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.035
Top Elevation of Structure	13.138	13.466	13.736	13.939	14.074	14.142	14.142	14 074	13.939	13.736	13.466	13.138
Body Height	5 313	9 801	9 800	9.800	10 200	10.201	10 201	10.200	9 800	9.800	9.801	5.313
Elevation of Upper footing	7.825	3.665	3.936	4.139	3.874	3.941	3.941	3.874	4.139	3.936	3.665	7.825
Ground Surface	8.419	8.441	8.463	8.486	8 270	8 270	8 270	8.270	8.489	8.484	8.479	8.473
Elevation of Bearing Layer	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.630
Elevation of Footing bottom	6.525	1.865	2.136	2.339	2 274	2 341	2 341	2 274	2 339	2.136	1.865	6.525
Height of above ground	4.719	5.025	5 273	5.453	5.804	5.872	5 872	5.804	5.450	5 252	4.987	4.665
Cover1	6.009	6.031	6.053	6.076	5 860	5 860	5.860	5.860	6 079	6.074	6.069	5.843
Cover2	1.894	6 576	6.327	6.147	5.996	5.929	5.929	5.996	6.150	6.348	6.614	1.948
Foundation Type	Pile	Spread Foundation										Pile

Saham R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	22.151	22.489	22.759	22.962	23.097	23.165	23.165	23.097	22.962	22.759	22.489	22.151
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0 062	-0.062	-0.062
Elevation of carriageway center	20.813	21.151	21.421	21.624	21.759	21.827	21.827	21.759	21.624	21.421	21.151	20.813
Adjustment	0.010	0.010	0.010	0.010	0 010	0.010	0.010	0.010	0 010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0 080	0.080	0.080	0.080
Adjusting Mortar	0.035	0.045	0.045	0.045	0.045	0.045	0.045	0 045	0.045	0.045	0.045	0.035
Top Elevation of Structure	20.688	21.016	21.286	21.489	21.624	21.692	21.692	21.624	21.489	21.286	21.016	20.688
Body Height	5.437	6.400	6.400	6.400	6.400	6.400	6.400	6.400	6.400	6.400	6.400	5.437
Elevation of Upper footing	15 251	14.616	14.886	15.089	15 224	15 292	15 292	15.224	15.089	14.886	14.616	15.251
Ground Surface	16.049	16 052	16.056	16.059	15.840	15 840	15.840	15.840	16.062	16.070	16.078	16.087
Elevation of Bearing Layer	9.410	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	8.140	9.510
Elevation of Footing bottom	13.951	12.616	12 886	13.089	13 224	13 292	13.292	13.224	13.089	12 886	12.616	13.951
Height of above ground	4.639	4.964	5 230	5.430	5.784	5.852	5.852	5.784	5.427	5 216	4.938	4.601
Cover1	6.639	7.912	7.916	7.919	7.700	7.700	7.700	7.700	7.922	7.930	7.938	6 577
Cover2	2 098	3.436	3.170	2.970	2 616	2.548	2.548	2 616	2.973	3.184	3.462	2.136
Foundation Type	Pile Foundation											

Table 5.10(b) Structural Height and Foundation Type (Falaj Al Qabail & Aqr)

Falaj Al Qabail R/A A-line (for Aqr)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	33.233	33.478	33.661	33.782	33.841	33.838	33.773	33.646	33.457	33.206	32.893	32.518
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166
Elevation of carriageway center	31.667	31.912	32.095	32.216	32.275	32.272	32.207	32.080	31.891	31.640	31.327	30.952
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.045	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.045
Top Elevation of Structure	31.532	31.767	31.950	32.071	32.130	32.127	32.062	31.935	31.746	31.495	31.182	30.817
Body Height	7.965	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	7.365
Elevation of Upper footing	23.567	22.262	22.445	22.566	22.625	22.622	22.557	22.430	22.241	21.990	21.677	23.452
Ground Surface	27.130	26.839	26.547	26.256	25.980	25.980	25.980	25.980	26.174	26.038	25.902	25.766
Elevation of Bearing Layer	22.380	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	22.370
Elevation of Footing bottom	22.267	20.662	20.845	20.966	21.025	21.022	20.957	20.830	20.641	20.390	20.077	22.252
Height of above ground	4.402	4.929	5.403	5.815	6.150	6.147	6.082	5.955	5.572	5.457	5.280	5.051
Cover1	4.750	5.768	5.477	5.186	4.910	4.910	4.910	4.910	5.104	4.968	4.832	3.396
Cover2	4.863	6.176	5.702	5.290	4.955	4.958	5.023	5.150	5.533	5.648	5.825	3.514
Foundation Type	Spread Foundation											

Aqr R/A A-line (for Dubai)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	A2
F.H	19.239	20.705	21.932	22.887	23.569	23.978	24.114	23.978	23.569	22.887	21.932	20.705	19.239
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700
Crossfall	-0.072	-0.075	-0.075	-0.075	-0.075	-0.075	-0.075	-0.142	-0.071	-0.007	0.057	0.075	0.075
Elevation of carriageway center	17.511	18.980	20.207	21.162	21.844	22.253	22.389	22.320	21.840	21.094	20.075	18.830	17.364
Adjustment	0.025	0.030	0.030	0.045	0.030	0.030	0.045	0.030	0.030	0.045	0.030	0.030	0.025
Bearing Pad	0.125	0.135	0.135	0.125	0.135	0.135	0.125	0.135	0.135	0.125	0.135	0.135	0.125
Adjusting Mortar	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Top Elevation of Structure	17.321	18.775	20.002	20.952	21.639	22.048	22.179	22.115	21.635	20.884	19.870	18.625	17.174
Body Height	6.182	7.600	9.900	10.900	11.200	11.000	10.900	11.000	11.200	10.900	9.900	7.600	4.835
Elevation of Upper footing	11.139	11.175	10.102	10.052	10.439	11.048	11.279	11.115	10.435	9.984	9.970	11.025	12.339
Ground Surface	11.910	12.030	11.930	11.785	11.770	11.785	11.800	11.665	11.520	11.500	11.670	12.375	12.920
Elevation of Bearing Layer	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500	11.500
Elevation of Footing bottom	10.139	9.575	8.502	8.452	8.839	9.048	9.679	9.115	8.835	8.384	8.370	9.425	11.339
Height of above ground	5.411	6.745	8.072	9.167	9.869	10.263	10.379	10.450	10.115	9.384	8.200	6.250	4.254
Cover1	0.410	0.530	0.430	0.285	0.270	0.285	0.300	0.165	0.020	0.000	0.170	0.875	1.420
Cover2	1.771	2.455	3.428	3.333	2.931	2.737	2.121	2.550	2.685	3.116	3.300	2.950	1.581
Foundation Type	Spread Foundation												

Falaj Al Qabail R/A B-line (for Muscat)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	A2
F.H	32.923	33.168	33.351	33.472	33.531	33.528	33.463	33.336	33.147	32.896	32.583	32.208
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Crossfall	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166	-0.166
Elevation of carriageway center	31.689	31.934	32.117	32.238	32.297	32.294	32.229	32.102	31.913	31.662	31.349	30.974
Adjustment	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bearing Pad	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Adjusting Mortar	0.045	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.045
Top Elevation of Structure	31.554	31.789	31.972	32.093	32.152	32.149	32.084	31.957	31.768	31.517	31.204	30.839
Body Height	7.965	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	9.505	7.365
Elevation of Upper footing	23.589	22.284	22.467	22.588	22.647	22.644	22.579	22.452	22.263	22.012	21.699	23.474
Ground Surface	27.777	27.283	26.789	26.295	25.980	25.980	25.980	25.980	26.178	26.064	25.950	25.836
Elevation of Bearing Layer	22.380	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	21.070	22.370
Elevation of Footing bottom	22.289	20.684	20.867	20.988	21.047	21.044	20.979	20.852	20.663	20.412	20.099	22.274
Height of above ground	3.777	4.506	5.183	5.798	6.172	6.169	6.104	5.977	5.590	5.453	5.254	5.003
Cover1	5.397	6.213	5.719	5.225	4.910	4.910	4.910	4.910	5.108	4.994	4.880	3.466
Cover2	5.488	6.599	5.922	5.307	4.933	4.936	5.001	5.128	5.515	5.652	5.851	3.562
Foundation Type	Spread Foundation											

Aqr R/A B-line (for Dubai)

	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	A2
F.H	24.632	25.817	26.792	27.497	27.932	28.097	27.992	27.617	26.972	26.057	24.872	23.432	21.932
Pavement Thickness	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Girder Height	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700
Crossfall	-0.075	-0.075	-0.075	-0.075	-0.075	-0.075	-0.054	-0.075	-0.163	-0.075	-0.068	-0.003	0.045
Elevation of carriageway center	22.907	24.092	25.067	25.772	26.207	26.372	26.246	25.892	25.335	24.332	23.140	21.635	20.087
Adjustment	0.025	0.030	0.030	0.045	0.030	0.030	0.045	0.030	0.030	0.045	0.030	0.030	0.025
Bearing Pad	0.125	0.135	0.135	0.125	0.135	0.135	0.125	0.135	0.135	0.125	0.135	0.135	0.125
Adjusting Mortar	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Top Elevation of Structure	22.717	23.887	24.862	25.562	26.002	26.167	26.036	25.687	25.130	24.122	22.935	21.430	19.897
Body Height	6.185	7.600	9.900	10.900	11.200	11.200	11.300	11.200	11.000	10.900	9.900	7.600	6.065
Elevation of Upper footing	16.532	16.287	14.962	14.662	14.802	14.967	14.736	14.487	14.130	13.222	13.035	13.830	13.832
Ground Surface	17.370	17.140	15.500	15.350	15.930	15.540	15.330	15.200	15.315	14.670	14.200	14.330	14.385
Elevation of Bearing Layer	17.500	17.500	14.200	14.200	14.200	14.200	14.200	14.200	14.200	14.200	14.200	14.200	14.200
Elevation of Footing bottom	15.532	14.687	13.362	13.062	13.202	13.367	12.736	12.887	12.130	11.622	11.435	12.230	12.832
Height of above ground	5.347	6.747	9.362	10.212	10.072	10.627	10.706	10.487	9.815	9.452	8.735	7.100	5.512
Cover1	-0.130	-0.360	1.300	1.150	1.730	1.340	1.130	1.000	1.115	0.470	0.000	0.130	0.185
Cover2	1.838	2.453	2.138	2.288	2.728	2.173	2.594	2.313	3.185	3.048	2.765	2.100	1.553
Foundation Type	Spread Foundation												

(5) Calculation Method

(a) Procedure for design work

General design procedure for substructure is shown on next page.

(b) Frame Analysis

Rigid frame line for structural analysis is set through the center of structural body.
Rigid area around connection point of frame lines is taken into consideration to calculate the member forces.
Assumption of rigid area is shown in Figure 5.9 .

(c) Spread Foundation

Stability calculation of spread foundation consists of the safety against ground reaction, sliding, over-turning, bearing capacity.

1) Ground reaction

Calculated ground reaction at the bottom of footing will be less than allowable ground reaction.

$$\frac{Q\,max}{Q\,min} = \frac{V}{L \times B} \pm \frac{6 \times M}{L \times B^2} \leq Qa = 40.0 \quad (tf/m^2)$$

where:

Qmax	:	Calculated maximum ground reaction (tf/m^2)
Qmin	:	Calculated minimum ground reaction (tf/m^2)
Qa	:	Allowable ground reaction (tf/m^2)
L	:	Length of footing (m)
B	:	Width of footing (m)

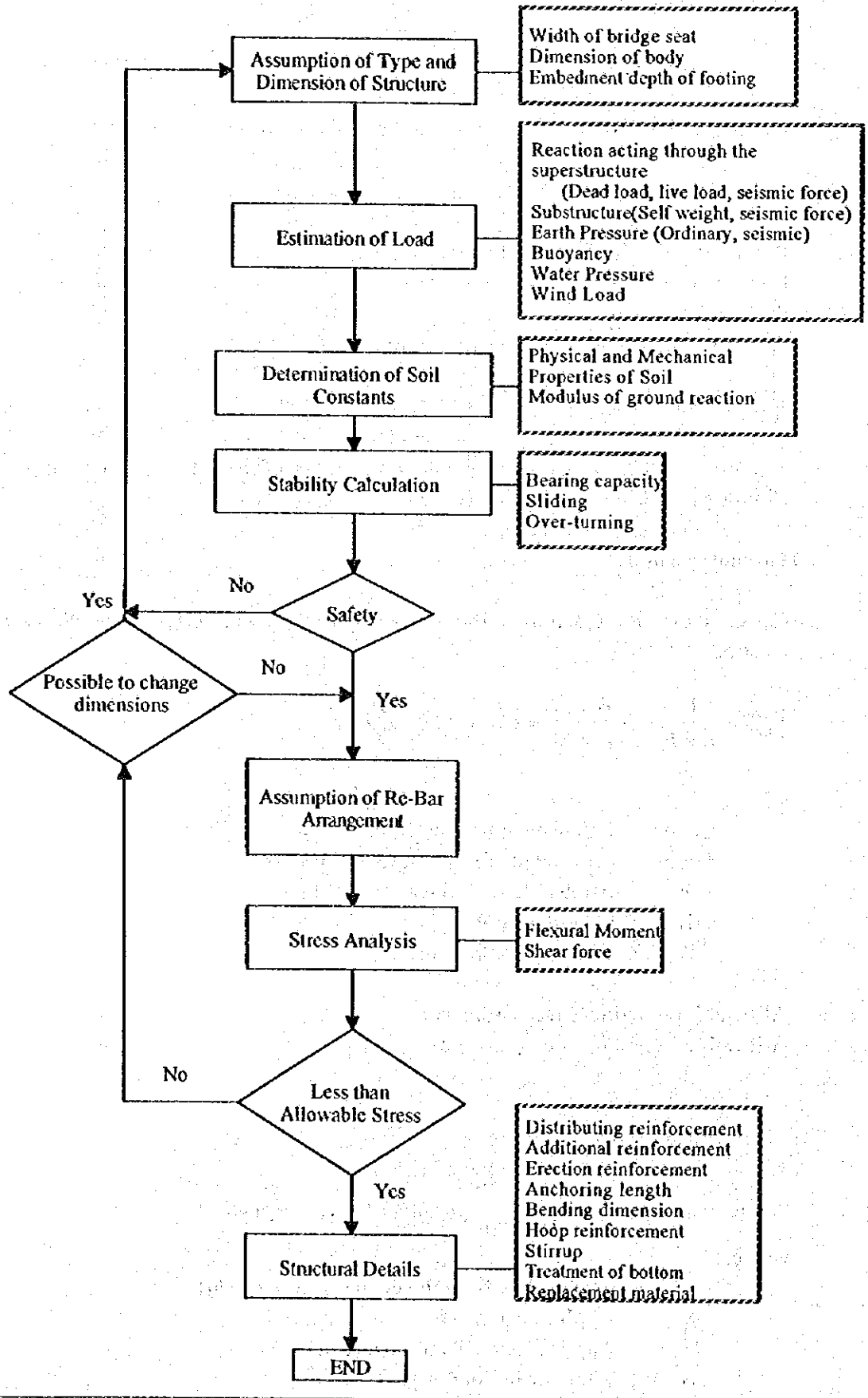
Allowable ground reaction (ordinary)	Qa =	40	tf/m^2
Allowable ground reaction (seismic)	Qae =	60	tf/m^2

2) Stability against over-turning

Safety condition : $e = \frac{M}{V} \leq \frac{B}{6}(ordinary) \quad or \quad \frac{B}{3}(seismic)$

where:

e	:	Eccentricity from the center of footing (m)
V	:	Applied external force in vertical (tf)
M	:	Applied external moment (tfm)
B	:	Width of footing (m)


Assumption of Type and Dimension of Structure
Width of bridge seat
Dimension of body
Embedment depth of footing
Estimation of Load
Reaction acting through the superstructure
(Dead load, live load, seismic force)
Substructure(Self weight, seismic force)
Earth Pressure (Ordinary, seismic)
Buoyancy
Water Pressure
Wind Load
Determination of Soil Constants
Physical and Mechanical Properties of Soil
Modulus of ground reaction
Stability Calculation
Bearing capacity
Sliding
Over-turning
Safety
No
Yes
Possible to change dimensions
No
Yes
Assumption of Re-Bar Arrangement
Stress Analysis
Flexural Moment
Shear force
Less than Allowable Stress
No
Yes
Structural Details
Distributing reinforcement
Additional reinforcement
Erection reinforcement
Anchoring length
Bending dimension
Hoop reinforcement
Stirrup
Treatment of bottom
Replacement material
END

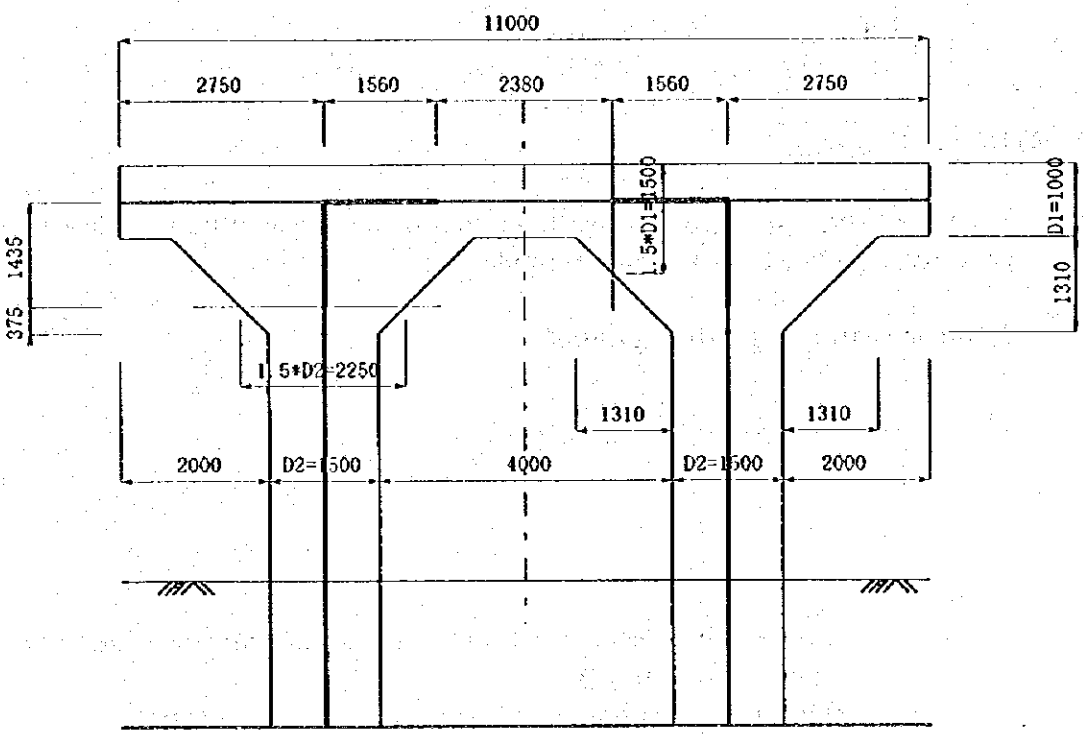


Figure 5.9 Assumption of Rigid Area for Frame Analysis

3) Stability against sliding

Shear resistance at the bottom of footing : $Hu = C \cdot B + V \cdot \tan \phi_b = V \cdot 0.6$

The safety factor against sliding: $Fs = \frac{Hu}{H} \rangle 1.5 \quad or \quad 1.2$

where:

Fs : Safety factor against sliding
ordinary : 1.5
seismic : 1.2
Hu : Shear resistance (tf)
H : Applied external force in horizontal (tf)

4) Bearing Capacity

For the safety, applied force on the bottom of footing will be less than the bearing capacity of ground form Terzagi's formula.

Ultimate bearing capacity of ground

$$Qu = A' \times (\alpha\kappa cNc + \kappa qNq + \frac{\gamma_1 \beta B' N\gamma}{2})$$

$$Qa = \frac{Qu}{n}$$

where:

Qu : Ultimate bearing capacity of ground with considering eccentric inclined load (tf)
c : Cohesion of soil (tf/m^2)
q : Weight of soil over bottom of footing (tf/m^2) : $q = \gamma_2 * Df$
A' : Effective loading area (m^2)
γ_1 : Unit weight of bearing layer (tf/m^3)
γ_2 : Unit weight of embedding layer (tf/m^3)
B' : Effective loading width of footing with considering eccentric load (m)
$B' = B - 2e_B$
B : Width of footing (m)
e_B : eccentric distance of load (m)
Df : Effective embed depth of footing (m)
κ : Rate of increase by embedding effect of footing
$\kappa = 1 + 0.3 * (Df/B')$
Df' : Embedded depth of footing to the bearing layer
Nc, Nq, N_γ : Coefficient of bearing capacity (Refer to Figure 5.)
Qa : Allowable bearing capacity of ground (tf)
n : Safety factor (ordinary=3, seismic=2)

α , β : Coefficient of footing shape

Coefficient	Belt	Square or Circle	Rectangle, Ellipse, Oval
α	1.0	1.3	1+0.3*(B'/L')
β	1.0	0.6	1-0.4*(B'/L')

(d) Pile Foundation

Pile condition
Pile Type : Cast-in-place concrete pile
Pile diameter : ϕ 1000 mm

1) Calculation of bearing capacity

Allowable bearing capacity per pile is estimated by following formulae:

$$Ra = \frac{\gamma}{n} \times (Ru - Ws) + Ws - W$$

$$Ru = qd * A + \Sigma li * fi$$

Ra : Allowable bearing capacity per pile at pile head (tf)
n : Safety factor listed as below
γ : Revising rate to consider the difference of estimation method of ultimate bearing capacity

Safety Factor : n

	Bearing Pile	Frictional Pile
Ordinary	3	4
Seismic	2	3

Revising rate : γ

Estimation method of ultimate bearing capacity	Revising rate
Using estimation formula	1.0
Based on result of vertical loading test	1.2

A : Area of pile top (m^2)
qd : Ultimate bearing capacity per unit area at pile top (tf/m^2)
U : Circumferential length of pile (m)
li : Stratum depth with the skin friction taken into consideration (m)
fi : Maximum skin friction of stratum with the skin friction taken into consideration (tf/m^2)
Ws : Effective weight of soil to be replaced with a pile (tf)
W : Effective weight of pile and soil in it (tf)

qd for cast-in-place pile

Classification of soil	Ultimate bearing capacity at pile top (tf/m^2)
Sandy gravel and sand (N≧30)	300
Hard cohesive soil	3qu

*qu is uni-axial compressive strength

Estimation of maximum skin friction

	Cast-in-place pile	Driven pile
Sandy soil	0.5*N (≦20)	0.2*N (≦10)
Cohesive soil	C or N (≦15)	C or N(≦15)

2) Stability calculation

The pile reaction and the amount of displacement will generally be calculated by a method taking displacement into account. (The displacement method)

However, in case a whole pile foundation is relatively rigid, a simplified displacement method may be used .(Simplified method)

- Bearing capacity

  For pile foundation, maximum reaction per pile calculated by the displacement method will be less than bearing capacity per pile.

- Displacement

  Allowable displacement at a pile head is 15mm.

- Stress in the pile

  Stress in a pile caused by flexural moment, axial force and shear force shall be less than allowable stress determined by material property of pile.

(6) Calculation of Load for Substructure Design

(a) Reaction acting through Superstructure to Substructure

Reactions acting through superstructure to substructure for this detailed design are listed in the below Tables:

Table 5.11 Vertical Reaction

Unit : tf

		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
A'Naseem Garden	Dead	125.0	123.6	123.4	123.0	123.0	123.0	123.0	123.0	123.4	123.6	125.0
	Live1	69.6	63.4	57.0	50.6	44.2	37.8	31.6	25.2	19.0	12.8	6.8
	Live2	37.4	37.6	38.0	38.2	38.4	38.4	38.4	38.2	38.0	37.6	37.4
Barka AlMuladdah AlKhaburah Saham	Dead	86.2	84.6	84.0	83.6	83.4	83.2	83.4	83.6	84.0	84.6	86.2
	Live1	33.0	32.2	31.4	30.6	29.6	28.6	27.6	26.6	25.6	24.6	23.6
	Live2	28.2	28.4	28.4	28.6	28.6	28.6	28.6	28.6	28.4	28.4	28.2
	Live3	54.4	50.0	45.4	40.8	36.2	31.6	27.2	22.8	28.4	14.2	10.0
	Live4	30.8	31.4	31.8	32.4	32.6	32.8	32.6	32.4	31.8	31.4	30.8
Sohar	Dead	146.6	145.6	145.4	145.2	144.6	145.0	144.6	145.2	145.4	145.6	146.6
	Live1	77.2	69.8	62.6	55.8	48.2	41.0	33.8	26.6	19.4	12.2	5.2
	Live2	40.6	40.8	41.0	41.2	41.4	41.4	41.4	41.2	41.0	40.8	40.6

Table 5.12 Horizontal Inertia Force by Dead Load at Seismic Time (kh=0.1)

Unit : tf

		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
A'Naseem G	Dead	12.6	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.6
Barka Al Muladdah Al Khaburah Saham	Dead	8.6	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.6
Sohar	Dead	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6

Table 5.13 Horizontal Inertia Moment by Dead Load at Seismic Time (kh=0.1) (Transverse)

Unit : tfm

		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
A'Naseem G	Dead	20.6	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.6
Barka Al Muladdah Al Khaburah Saham	Dead	11.8	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.8
Sohar	Dead	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8

Table 5.14 Horizontal Inertia Moment by Dead Load at Seismic Time (kh=0.1) (Longitudinal)

Unit : tfm

		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
A'Naseem G	Dead	6.4	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.4
Barka Al Muladdah Al Khaburah Saham	Dead	4.4	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.4
Sohar	Dead	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4

Table 5.15 Longitudinal Force acting through superstructure to substructure

		LF(L) (tf)	MLF(L)(tfm)	LF(R)(tf)	MLF(R)(tfm)
A'Naseem Farden	Rigid frame	10.5	5.3	10.5	5.3
Barka	Rigid frame	8.8	3.5	8.8	3.5
Al Muladdah Al Khaburah	T shaped	17.6	7.0	-	-
Saham	T shaped	17.6	7.0	-	-
Sohar	Rigid frame	11.3	5.7	11.3	5.7
Falaj Al Qabail	Rigid frame	8.8	3.5	8.8	3.5

(b) Calculation of earth pressure acting on abutment wall

$$Phi = K_A \times (q + Z_0 \cdot \gamma)$$

K_A : Coefficient of Coulomb's active earth pressure = 0.333

q : Surcharge live load = 1.90 tf/m^2

γ : Unit weight of soil = 1.90 tf/m^3

Z_0 : Depth at calculating point (m)

(c) Loading diagram

Diagrams to explain the loading condition for pier types and directions are shown in Figures 5.10 to 5.12.

(7) Design of Rigid Framed Pier with PC Beam at Aqr

Piers at Aqr, which is located over the service road, are rigid framed pier with beam in span 16m. When the beam is reinforced concrete structure, its dimension will be 3.0m wide and 3.5m high. And the diameter of columns shall become lager.
It is to be desirable that the substructure is relatively small scale at Aqr from the aesthetic viewpoint because the Aqr roundabout is located as the gateway to the sultanate of Oman from Dubai.

Therefore, it is determined the beam is prestressed concrete structure with 2.0m wide and 1.7m to 2.2m high

Design condition of rigid framed piers with PC beam at Aqr

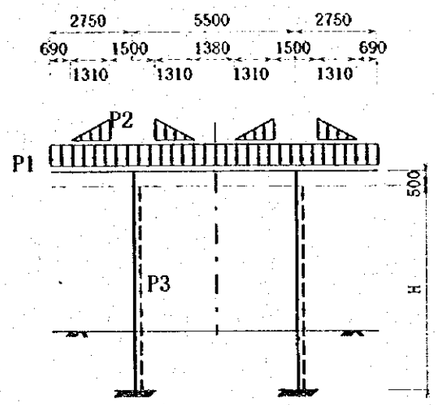
Specific design strength of Concrete	
For columns	σ ck= 240 kgf/cm^2
For Beams	σ ck= 400 kgf/cm^2
PC tendons for beam	12T15.2 Strand
Anchoring system	Freyssinet multi strand system

General view of a rigid framed pier at Aqr is shown on next page.

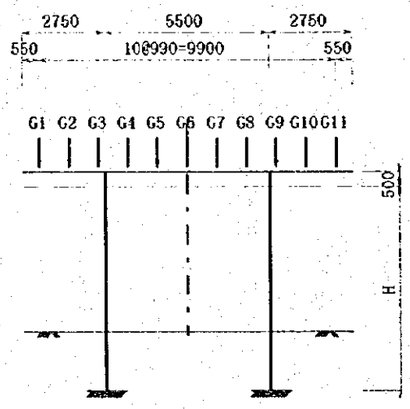
(8) Design Summary of Substructures

Design summary of substructures for flyovers are shown in Tables 5.16(a) to 5. 19(b).

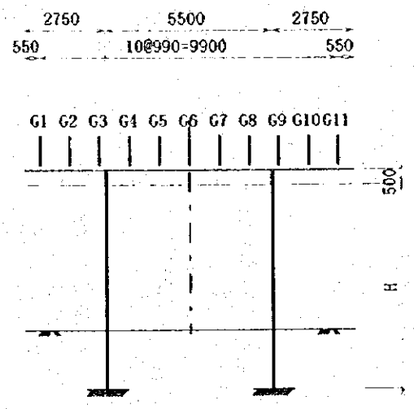
CASE-1 (Self Weight)



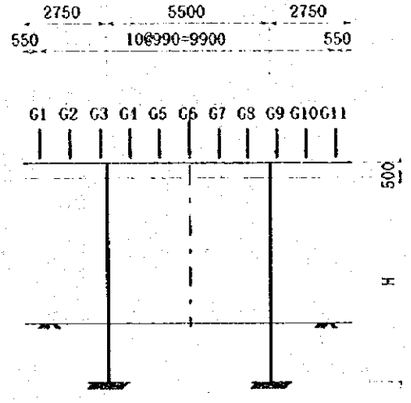
CASE-2 (Dead Load Reaction)



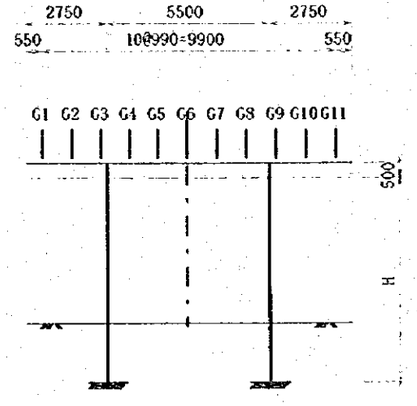
CASE-3 (Superstructure Live Load Case-1)



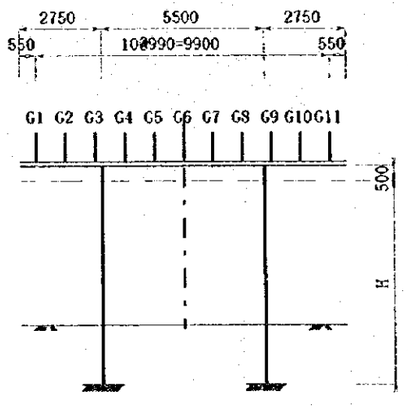
CASE-4 (Superstructure Live Load Case-2)



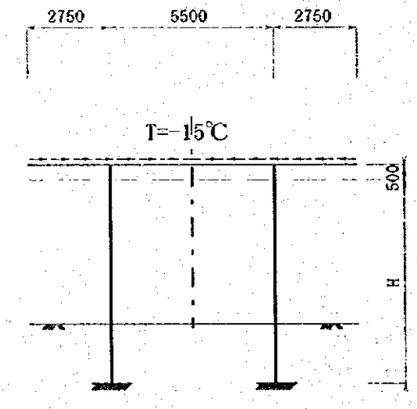
CASE-5 (Superstructure Live Load Case-3)



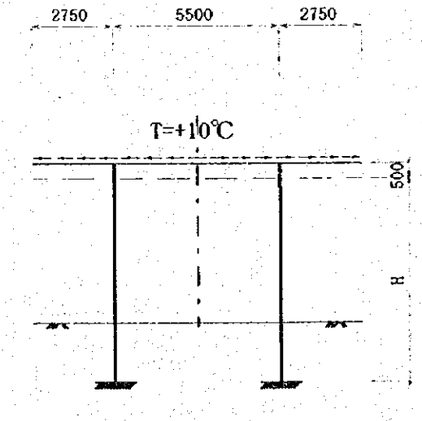
CASE-6 (SUPERSTRUCTURE LIVE LOAD CASE4)



CASE-7 (Shrinkage corresponding to T=-15°)



CASE-8 (Temperature Change T=+10°)



CASE-9 (Seismic Force)

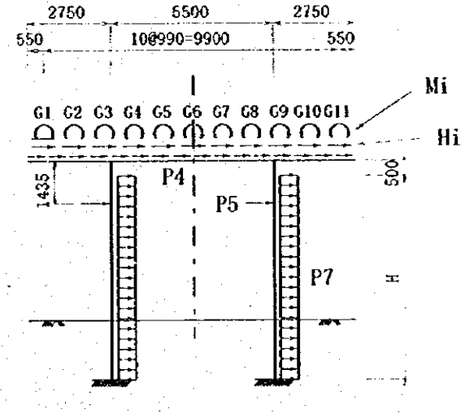


Figure 5.10 General Loading Diagram for Rigid Framed Pier in Transversal Direction

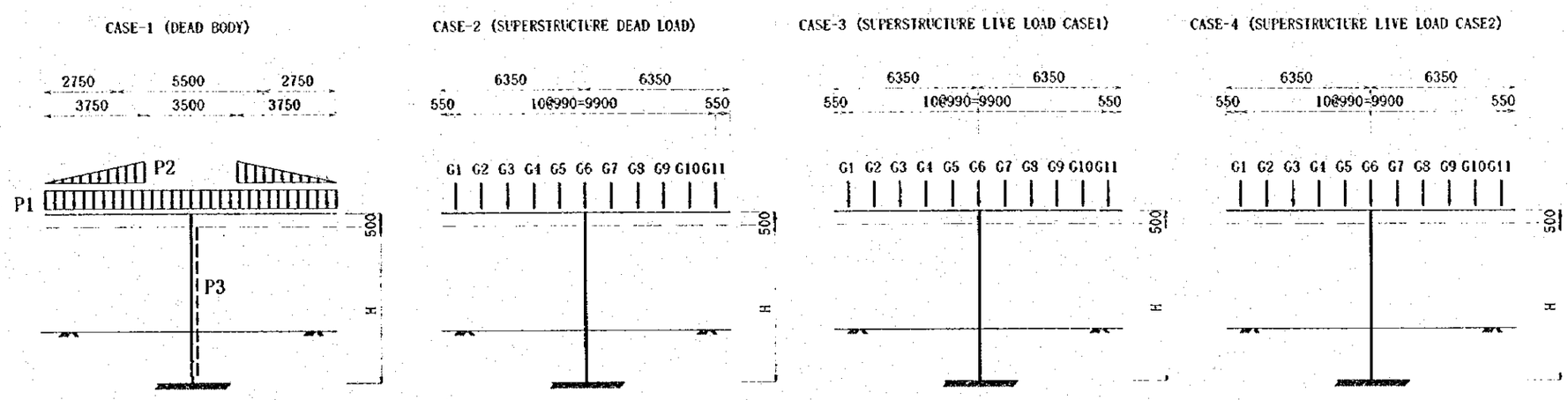


Figure 5.11 Gemeral Loading Diagram for T Shaped Pier in Transverse Direction

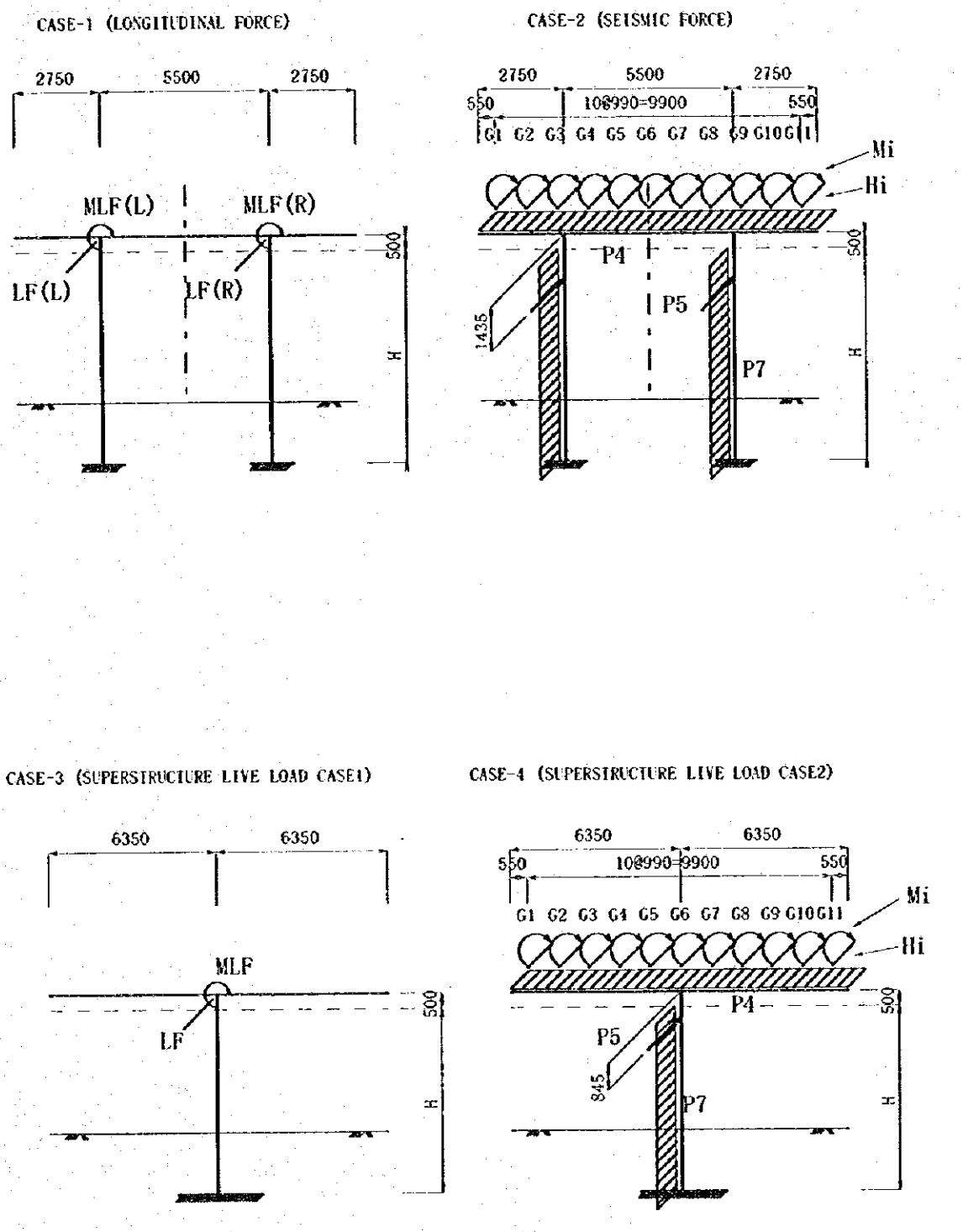


Figure 5.12 Genaral Loading Diagram in Longitudinal Direction

Table 5.16(a) Design Summary of Pier at A'Naseem Garden (Spread Foundation)

Result of Stability Caluculation

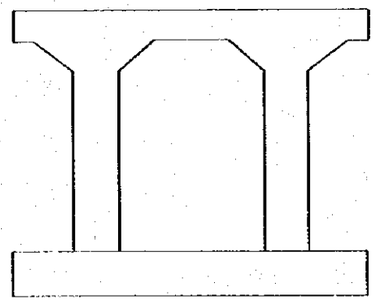
Name of pier	P1～P8							
Structural Type	Rigid Frame							
Case	Ordinary		Seismic					
Decisible direction	Transverse		Longitudinal					
	Result	Allowable	Result	Allowable				
Eccentricity (m)	1.33	0.08	2.67	0.67				
Safety Factor against Sliding	86.30	1.50	8.16	1.20				
Maximum Ground Reaction (tf/m²)	36.40	40.00	44.40	60.00				

Reaction acting through the superstructure

Case		P1～P8	
Vertical (tf)	Ordinary	1777	
	Seismic	1359	
Horizontal seismic force (tf)	Longitudinal	136	
	Transverse	136	

Member Stresses

General Diagram



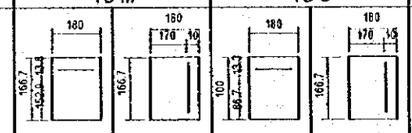
Name of Pier				P1～P8 (Rigid Frame)											
Member				Beam				Column				Footing			
Loading Direction				Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Longi.	Transverse	Longi	Tmsverse	Longi	Tmsverse
Loading Condition				Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.				T8-M		T8-S		TC-1		TC-2		TF-M		TF-S	
Section															
Force	M		tfm/m	342.00	25.00	-	-	714.00	354.00	535.00	126.00	1241.00	797.00	-	-
	N		tf/m	-	-	-	-	775.00	600.00	759.00	938.00	-	-	-	-
	S		tf/m	-	-	239.00	26.00	78.00	83.00	77.00	72.00	-	-	567.00	231.00
Reinforcing Bar	Required		㎠												
	Minimum		㎠			Diagonal									
	Design		㎠	172.00	13.10	4 Nos.	-	278.60	93.90	180.30	61.20	516.00	41.00	-	-
	Dia.		mm	D32	D16	D22	-	D32	D32,D19	D32	D32,D19	D29	D32	-	-
	Interval		mm	125	125	150	-	125	125	125	125	125	125	-	-
	Cover		mm	138	100	133	-	70	70	70	70	100	100	-	-
Stress	Designed	σ c	kgf/㎠	53.0	10.0	-	-	107.0	85.0	90.0	51.0	37.0	41.0	-	-
		σ s	kgf/㎠	1526.0	1165.0	-	-	1417.0	1093.0	1212.0	72.5	1548.0	1506.0	-	-
		τ m	kgf/㎠	-	-	17.20	0.90	3.10	3.30	3.00	2.70	-	-	2.90	1.70
	Allowable	σ ca	kgf/㎠	80	120	-	-	120	120	120	120	80	80	-	-
		σ sa	kgf/㎠	1800	2700	-	-	2700	2700	2700	2700	1600	1600	-	-
		τ a	kgf/㎠	-	-	3.90	5.85	5.85	5.85	3.90	3.90	-	-	6.10	4.00

Table 5.16(b) Design Summary of Pier at Al Muladdah (Spread Foundation)

Result of Stability Caluculation

Name of pier	P1,P2,P9,P10				P3～P8			
Structural Type	T Shape				Rigid Frame			
Case	Ordinary		Seismic		Ordinary		Seismic	
Decisible direction	Transverse		Longitudinal		Longitudinal		Longitudinal	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Eccentricity (m)	1.58	0.22	2.33	0.67	1.00	0.10	2.00	0.68
Safety Factor against Sliding	6.20	1.50	7.92	1.20	74.80	1.50	8.20	1.20
Maximum Ground Reaction (tf/m²)	38.00	40.00	45.10	60.00	36.40	40.00	47.00	60.00

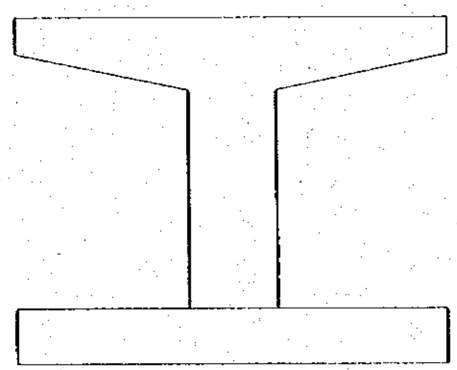
Reaction acting through the superstructure

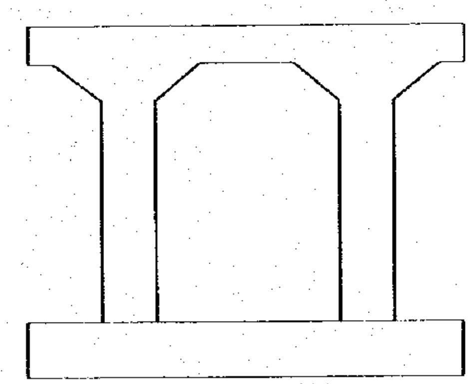
Case		P1,P2 P9,P10	P3～P8
Vertical (tf)	Ordinary	1281	1317
	Seismic	929	929
Horizontal seismic force (tf)	Longitudinal	93	93
	Transverse	93	93

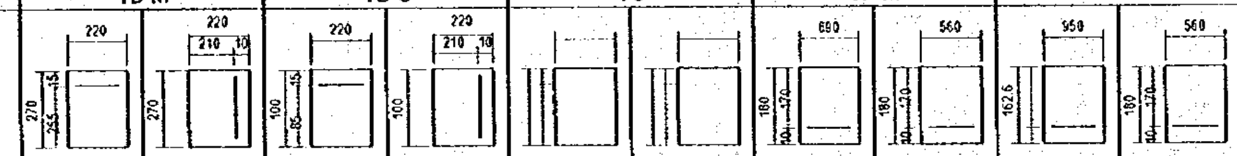
Member Stresses

Calculation Points

General Diagram





Name of Pier			P1,P2,P9,P10 (T-shaped)									
Member			Beam				Column		Footing			
Loading Direction			Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Long.i	Tmsverse	Long.i	Tmsverse
Loading Condition			Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.			TB-M		TB-S		TC		TF-M		TF-S	
Section												
Force	M	tfm/m	978.00	62.00	-	-	1037.00	1129.00	608.00	814.00	-	-
Force	N	tf/m	-	-	-	-	1176.00	1176.00	-	-	-	-
Force	S	tf/m	-	-	287.00	39.00	118.00	118.00	-	-	317.00	379.00
Reinforcing Bar	Required	cm²	-									
Reinforcing Bar	Minimum	cm²			Diagonal							
Reinforcing Bar	Design	cm²	278.00	21.60	6 Nos.	-	108.40	69.70	284.00	369.00	-	-
Reinforcing Bar	Dia.	mm	D32	D19	D25	-	D22	D22	D25	D32	-	-
Reinforcing Bar	Interval	mm	125	125	150	-	100	100	125	125	-	-
Reinforcing Bar	Cover	mm	70	70	100	-	70	70	100	100	-	-
Stress Designed	σ c	kgf/cm²	48.0	11.0	-	-	70.0	43.0	48.0	11.0	-	-
Stress Designed	σ s	kgf/cm²	1547.0	431.0	-	-	1195.0	617.0	1547.0	431.0	-	-
Stress Designed	τ m	kgf/cm²	-	-	15.20	0.70	1.60	1.60	-	-	2.00	3.20
Stress Allowable	σ ca	kgf/cm²	80	120	-	-	120	120	80	80	-	-
Stress Allowable	σ sa	kgf/cm²	1800	2700	-	-	2700	2700	1600	1600	-	-
Stress Allowable	τ a	kgf/cm²	-	-	3.90	5.85	5.85	5.85	-	-	7.70	6.30

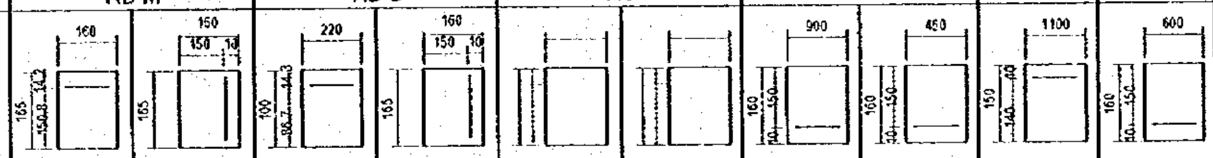
Name of Pier			P3～P8 (Rigid Frame)									
Member			Beam				Column		Footing			
Loading Direction			Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Long.i	Tmsverse	Long.i	Tmsverse
Loading Condition			Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.			RB-M		RB-S		RC		RF-M		RF-S	
Section												
Force	M	tfm/m	287.00	17.10	-	-	532.00	269.00	634.00	589.00	-	-
Force	N	tf/m	-	-	-	-	543.00	428.00	-	-	-	-
Force	S	tf/m	-	-	163.00	8.90	55.00	60.00	-	-	367.00	-
Reinforcing Bar	Required	cm²										
Reinforcing Bar	Minimum	cm²			Diagonal							
Reinforcing Bar	Design	cm²	155.70	14.00	4 Nos.	-	180.30	61.20	377.00	303.00	-	-
Reinforcing Bar	Dia.	mm	D32	D16	D19	-	D32	D32,D19	D25	D32	-	-
Reinforcing Bar	Interval	mm	125	125	150	-	150	150	125	125	-	-
Reinforcing Bar	Cover	mm	142	100	133	-	70	70	100	100	-	-
Stress Designed	σ c	kgf/cm²	51.0	8.0	-	-	110.0	77.0	27.0	42.0	-	-
Stress Designed	σ s	kgf/cm²	1443.0	878.0	-	-	1847.0	1135.0	1224.0	1412.0	-	-
Stress Designed	τ m	kgf/cm²	-	-	11.70	0.40	2.50	2.70	-	-	2.20	-
Stress Allowable	σ ca	kgf/cm²	80	120	-	-	120	120	80	80	-	-
Stress Allowable	σ sa	kgf/cm²	1800	2700	-	-	2700	2700	1600	1600	-	-
Stress Allowable	τ a	kgf/cm²	-	-	3.90	5.85	5.85	5.85	-	-	7.70	-

Table 5.17(a) Design Summary of Pier at Al Khaburah R/A (Spread Foundation)

Result of Stability Caluculation

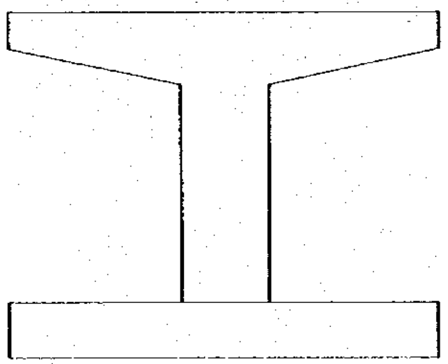
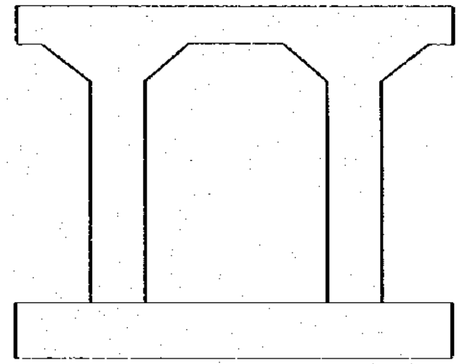
Name of pier	P1~P3, P8~P10				P4~P7			
Structural Type	T Shape				Rigid Frame			
Case	Ordinary		Seismic		Ordinary		Seismic	
Decisible direction	Transverse		Longitudinal		Longitudinal		Longitudinal	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Eccentricity (m)	1.58	0.21	2.50	0.64	1.00	0.10	2.00	0.68
Safety Factor against Sliding	∞	1.50	8.30	1.20	74.80	1.50	8.20	1.20
Maximum Ground Reaction (tf/m^2)	38.00	40.00	43.20	60.00	36.40	40.00	47.00	60.00

Reaction acting through the superstructure

Case		P1,P2,P3 P8,P9,P10	P4~P7
Vertical (tf)	Ordinary	1281	1317
	Seismic	929	929
Horizontal seismic force (tf)	Longitudinal	93	93
	Transverse	93	93

Member Stresses

Calculation Points

General Diagram	P1,P2,P3,P8,P9,P10 (T-shaped)	P4~P7 (Rigid Frame)
		

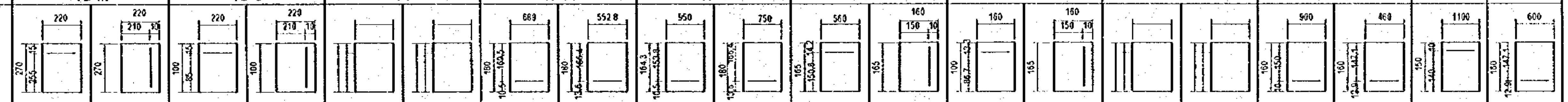
Name of Pier			P1,P2,P3,P8,P9,P10 (T-shaped)										P4~P7 (Rigid Frame)									
Member			Beam				Column		Footing				Beam				Column		Footing			
Loading Direction			Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Long.i	Trnsverse	Long.i	Trnsverse	Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Long.i	Trnsverse	Long.i	Trnsverse
Loading Condition			Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary	Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.			TB-M		TB-S		TC		TF-M		TF-S		RB-M		RB-S		RC		RF-M		RF-S	
Section																						
Force	M	tfm/m	978.00	62.00	-	-	1060.00	1152.00	690.00	812.00	-	-	287.00	17.10	-	-	532.00	269.00	634.00	589.00	-	-
	N	tf/m	-	-	-	-	1180.00	1180.00	-	-	-	-	-	-	-	-	513.00	428.00	-	-	-	-
	S	tf/m	-	-	287.00	39.00	118.00	118.00	-	-	305.00	378.00	-	-	163.00	8.90	55.00	60.00	-	-	367.00	154.00
Reinforcing Bar	Required	cm^2																				
	Minimum	cm^2			Diagonal										Diagonal							
	Design	cm^2	278.00	21.60	6 Nos.	-	108.40	69.70	361.00	369.00	-	-	156.00	14.00	4 Nos.	-	180.30	61.20	377.00	303.00	-	-
	Dia.	mm	D32	D19	D25	-	D22	D22	D29	D32	-	-	D32	D16	D19	-	D32	D32,D19	D25	D32	-	-
	Interval	mm	125	125	150	-	100	100	125	125	-	-	125	125	150	-	150	150	125	125	-	-
	Cover	mm	150	100	150	-	70	70	105	100	-	-	142	100	133	-	70	70	100	100	-	-
Stress Designed	σ c	kgf/cm^2	48.0	11.0	-	-	72.0	44.0	29.0	40.0	-	-	51.0	8.0	-	-	110.0	77.0	27.0	43.0	-	-
	σ s	kgf/cm^2	1547.0	431.0	-	-	1298.0	630.0	1234.0	1466.0	-	-	1443.0	878.0	-	-	1847.0	1135.0	1224.0	1469.0	-	-
	τ m	kgf/cm^2	-	-	16.20	0.70	1.60	1.60	-	-	2.10	3.00	-	-	11.70	0.40	2.50	2.70	-	-	2.20	1.70
Stress Allowable	σ ca	kgf/cm^2	80	120	-	-	120	120	80	80	-	-	80	120	-	-	120	120	80	80	-	-
	σ sa	kgf/cm^2	1800	2700	-	-	2700	2700	1600	1600	-	-	1800	2700	-	-	2700	2700	1600	1600	-	-
	τ a	kgf/cm^2	-	-	3.90	5.85	7.00	7.60	-	-	7.10	6.20	-	-	3.90	5.85	5.85	5.85	-	-	7.70	3.90

Table 5.17(b) Design Summary of Pier at Saham R/A (Pile Foundation)

Result of Stability Caluculation

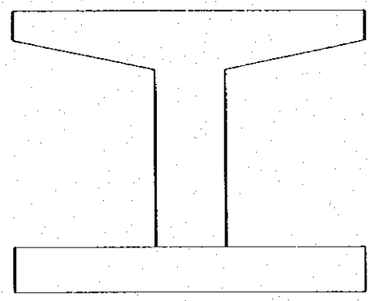
Name of pier	P1~P10							
Structural Type	T Shape							
Number of Piles	12 nos.							
Case	Ordinary		Seismic					
Decisible direction	Transverse		Longitudinal					
	Result	Allowable	Result	Allowable				
Bearing Capacity (tf/pile)	171.00	175.00	168.00	265.00				
Displacement at Pile head (cm)	0.03	1.50	0.15	1.50				

Reaction acting through the superstructure

Case		P1~P10	
Vertical (tf)	Ordinary	1281	
	Seismic	929	
Horizontal seismic force (tf)	Longitudinal	93	
	Transverse	93	

Member Stresses

General Diagram — Calculation Points



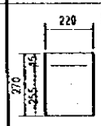
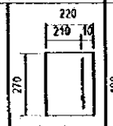
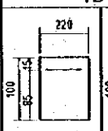
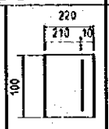
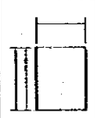
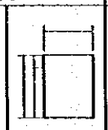
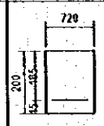
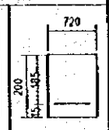
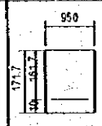
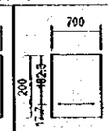
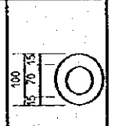
Name of Pier			P1~P10 (T-shaped)										
Member			Beam				Column		Footing				Pile
Loading Direction			Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Long.i	Tmsverse	Long.i	Tmsverse	
Loading Condition			Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary	Seismic
Section No.			TB-M		TB-S		TC		TF-M		TF-S		PL
Section													
Force	M	tfm/m	978.00	62.00	-	-	670.00	743.00	706.00	885.00	-	-	16.00
	N	tf/m	-	-	-	-	1115.00	1115.00	-	-	-	-	167.70
	S	tf/m	-	-	287.00	39.00	112.00	112.00	-	-	558.00	432.00	11.80
Reinforcing Bar	Required	cm²											
	Minimum	cm²			Diagonal								
	Design	cm²	278.00	21.60	6 Nos.	-	108.40	69.70	296.00	385.00	-	-	
	Dia.	mm	D32	D19	D25	-	D22	D22	D25	D32	-	-	D22
	Interval	mm	125	125	150	-	100	100	125	125	-	-	10 nos.
	Cover	mm	150	100	150	-	70	70	150	150	-	-	150
Stress	Designed σc	kgf/cm²	48.0	11.0	-	-	40.0	30.0	27.0	31.0	-	-	35.0
	Designed σs	kgf/cm²	1547.0	1431.0	-	-	557.0	441.0	1396.0	1327.0	-	-	420.0
	Designed τm	kgf/cm²	-	-	15.20	0.70	1.50	1.50	-	-	3.60	3.40	1.5
	Allowable σca	kgf/cm²	80	120	-	-	120	120	80	80	-	-	120
	Allowable σsa	kgf/cm²	1800	2700	-	-	2700	2700	1600	1600	-	-	2700
	Allowable τa	kgf/cm²	-	-	3.90	5.85	7.60	8.40	-	-	7.80	6.90	5.85

Table 5.18(a) Design Summary of Pier at Sohar (Pile Foundation)

Result of Stability Caluculation

Name of pier	P1～P8							
Structural Type	Rigid Frame							
Number of Piles	20 nos.							
Case	Ordinary		Seismic					
Decisible direction	Transverse		Longitudinal					
	Result	Allowable	Result	Allowable				
Bearing Capacity (tf/pile)	161.00	163.00	164.00	245.00				
Displacement at Pile head (cm)	0.12	1.50	0.13	1.50				

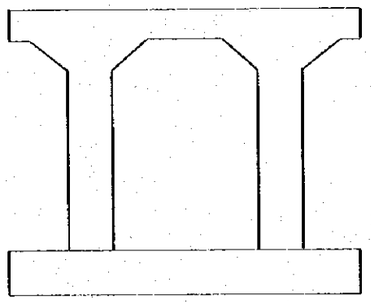
Reaction acting through the superstructure

Case		P1～P8	
Vertical (tf)	Ordinary	2052	
	Seismic	1600	
Horizontal seismic force (tf)	Longitudinal	160	
	Transverse	160	

Member Stresses

Calculation Points

General Diagram



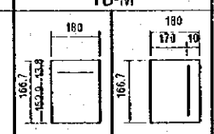
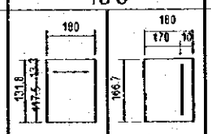
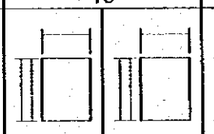
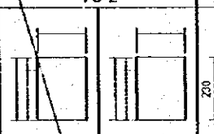
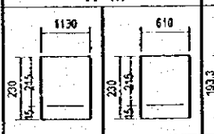
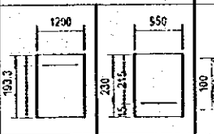
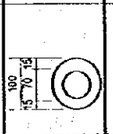
Name of Pier				P1～P8 (Rigid Frame)												
Member				Beam				Column				Footing				Pile
Loading Direction				Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Longi.	Transverse	Longi	Tmsverse	Longi	Tmsverse	
Loading Condition				Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary	Seismic
Section No.				TB-M		TB-S		TC		TC-2		TF-M		TF-S		PL
Section																
Force	M	tfm/m		379.00	29.00	-	-	551.00	279.00			1854.00	1180.00	-	-	12.60
	N	tf/m		-	-	-	-	873.00	718.00			-	-	-	-	163.00
	S	tf/m		-	-	229.00	37.00	89.00	104.00			-	-	683.00	561.00	11.80
Reinforcing Bar	Required	cm²														
	Minimum	cm²				Diagonal										
	Design	cm²		172.00	12.00	4 Nos.	-	100.60	51.20			746.00	402.00	-	-	
	Dia.	mm		D32	D16	D22	-	D22	D22			D32	D32	-	-	D22
	Interval	mm		125	125	150	-	125	125			125	125	-	-	10 nos.
	Cover	mm		138	100	133	-	70	70			150	150	-	-	150
Stress	Designed	σ c	kgf/cm²	58.0	12.0	-	-	105.0	68.0			30.0	35.0	-	-	72.0
		σ s	kgf/cm²	1690.0	1458.0	-	-	1423.0	932.0			1267.0	1500.0	-	-	419.0
		τ m	kgf/cm²	-	-	10.70	1.30	3.50	4.10			-	-	3.10	2.70	1.5
	Allowable	σ ca	kgf/cm²	80	120	-	-	120	120			80	80	-	-	120
		σ sa	kgf/cm²	1800	2700	-	-	2700	2700			1600	1600	-	-	2700
		τ a	kgf/cm²	-	-	3.90	5.85	5.85	5.85			-	-	6.30	5.20	5.85

Table 5.18(b) Design Summary of Abutment at Sohar (Pile Foundation)

Result of Stability Caluculation

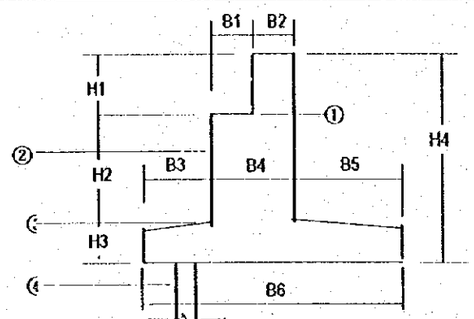
Name of Abutment / Number of Piles	A1 - 18 nos.				A2 - 18 nos.			
Structural Type	Inverted-T Type				Inverted-T Type			
Case	Ordinary		Seismic		Ordinary		Seismic	
Decisible direction	Longitudinal		Longitudinal		Longitudinal		Longitudinal	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Bearing Capacity (tf/pile)	139.00	146.00	168.00	221.00	136.00	146.00	151.00	221.00
Pull-out Capacity (tf/pile)								
Displacement at Pile head (cm)	0.23	1.50	0.36	1.50	0.22	1.50	0.28	1.50

Reaction acting through the superstructure

Case		A1	A2
Vertical (tf)	Ordinary	987	987
	Seismic	800	800
Horizontal seismic force (tf)	Longitudinal	160	80
	Transverse	-	-

Member Stresses

General Diagram



	A1	A2
B1	1.00	1.00
B2	0.50	0.50
B3	2.75	2.75
B4	1.00	1.00
B5	3.25	3.25
B6	7.00	7.00
H1	2.14	2.14
H2	5.16	5.16
H3	1.40	1.40
H4	8.70	8.70

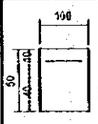
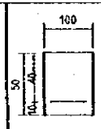
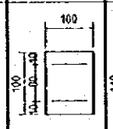
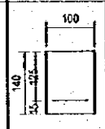
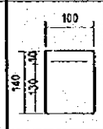
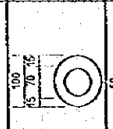
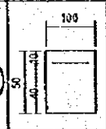
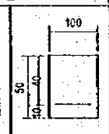
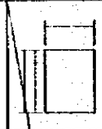
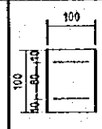
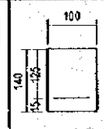
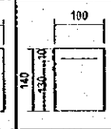
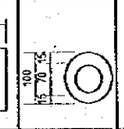
Name of Pier				A1							A2						
Member				Parapet		Wall		Footing		Pile	Parapet		Wall		Footing		Pile
				Back	Front			Front	Back		Front	Back					
Loading Condition				Ordinary	Seismic		Seismic	Ordinary	Seismic	Seismic	Ordinary	Seismic	Ordinary	Ordinary	Seismic	Seismic	Ordinary
Section No.				①		②	③	④	⑤	⑥	①		②	③	④	⑤	⑥
Section																	
Force	M	tfm/m		17.60	2.10		119.60	97.70	46.00	33.00	17.60	2.10		61.90	97.70	46.00	31.70
	N	tf/m		-	-		80.10	-	-	52.10	-	-		94.90	-	-	130.20
	S	tf/m		-	-		39.00	56.30	24.30	32.80	-	-		22.10	56.30	24.30	17.80
Reinforcing Bar	Required	cm²															
	Minimum	cm²															
	Design	cm²															
	Dia.	mm		D22	D16		D29	D32	D22	D22	D22	D16		D22	D32	D19	D22
	Interval	mm		125	250		125	125	250	10 nos.	125	250		125	125	250	10 nos.
	Cover	mm		100	100		100	150	100	150	100	100		100	150	100	150
Stress	Designed	σ c	kgf/cm²	67.0	13.0		105	44.0	34.0	72.0	67.0	13.0		64	42.0	23.0	57.0
		σ s	kgf/cm²	1631.0	707.0		2242.0	1378.0	2426.0	1604.0	1631.0	707.0		1159.0	1341.0	1978.0	647.0
		τ m	kgf/cm²	-	0.5		3.80	4.50	1.90	4.2	-	0.5		2.50	4.40	1.30	2.3
	Allowable	σ ca	kgf/cm²	80	120		120	80	120	120	80	120		80	80	120	80
		σ sa	kgf/cm²	1800	2700		2700	1600	2700	2700	1800	2700		1600	1600	2700	1600
		τ a	kgf/cm²	-	11.70		6.20	5.30	6.10	5.85	-	11.70		4.40	5.30	6.10	3.90

Table 5.19(a) Design Summary of Pier at Falaj Al Qabail R/A (Spread Foundation)

Result of Stability Caluculation

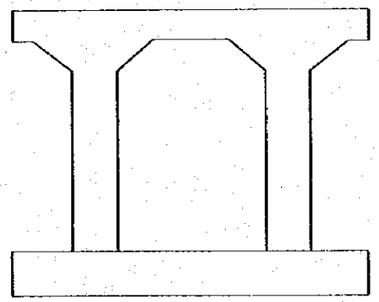
Name of pier	P1～P10							
Structural Type	Rigid Frame							
Case	Ordinary		Seismic					
Decisible direction	Longitudinal		Longitudinal					
	Result	Allowable	Result	Allowable				
Eccentricity (m)	1.00	0.09	2.00	0.64				
Safety Factor against Sliding	74.70	1.50	8.23	1.20				
Maximum Ground Reaction (tf/m²)	36.10	40.00	45.70	60.00				

Reaction acting through the superstructure

Case		P1～P8	
Vertical (tf)	Ordinary	1777	
	Seismic	1359	
Horizontal seismic force (tf)	Longitudinal	136	
	Transverse	136	

Member Stresses

General Diagram



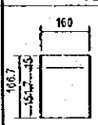
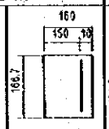
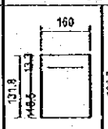
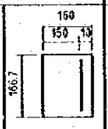
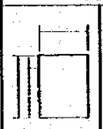
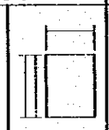
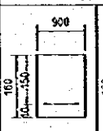
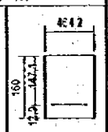
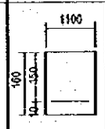
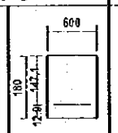
Name of Pier				P1～P10 (Rigid Frame)											
Member				Beam				Column				Footing			
Loading Direction				Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Longi.	Transverse	Longi	Trnsverse	Longi	Trnsverse
Loading Condition				Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.				TB-M		TB-S		TC-1		TC-2		TF-M		TF-S	
Section															
Force	M	tf/m/m		246.00	17.10	-	-	491.00	244.00			629.00	797.00	-	-
	N	tf/m		-	-	-	-	548.00	434.00			-	-	-	-
	S	tf/m		-	-	147.00	9.00	55.00	60.00			-	-	338.00	181.00
Reinforcing Bar	Required	cm²		-											
	Minimum	cm²				Diagonal									
	Design	cm²		123.00	11.60	4 Nos.	-	142.00	54.20			377.00	303.00	-	-
	Dia.	mm		D29	D16	D19	-	D29	D29,D19			D25	D32	-	-
	Interval	mm		125	125	150	-	125	125			125	125	-	-
	Cover	mm		150	100	133	-	70	70			100	129	-	-
Stress	Designed	σ c	kgf/cm²	46.0	9.0	-	-	111.0	70.0			27.0	43.0	-	-
		σ s	kgf/cm²	1529.0	1030.0	-	-	1884.0	855.0			1214.0	1476.0	-	-
		τ m	kgf/cm²	-	-	7.70	0.40	2.50	2.70			-	-	2.20	2.10
	Allowable	σ ca	kgf/cm²	80	120	-	-	120	120			80	80	-	-
		σ sa	kgf/cm²	1800	2700	-	-	2700	2700			1600	1600	-	-
		τ a	kgf/cm²	-	-	3.90	5.85	5.85	5.85			-	-	7.70	3.90

Table 5.19(b) Design Summary of Pier at Aqr R/A (Spread Foundation)

Result of Stability Caluculation

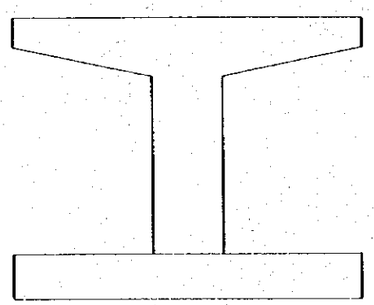
Name of pier	P1,P2,P10,P11(Intermadiate)				P3,P6,P9 (End)			
Structural Type	T Shaped				T Shaped			
Case	Ordinary		Seismic		Ordinary		Seismic	
Decisible direction	Transverse		Longitudinal		Transverse		Longitudinal	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Eccentricity (m)	1.33	0.08	2.67	0.67	1.33	0.08	2.67	0.67
Safety Factor against Sliding	86.30	1.50	8.16	1.20	86.30	1.50	8.16	1.20
Maximum Ground Reaction (tf/m²)	36.40	40.00	44.40	60.00	36.40	40.00	44.40	60.00

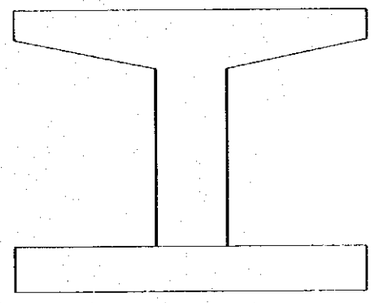
Reaction acting through the superstructure

Case		P1,P2 P10,P11	P1,P6 P9
Vertical (tf)	Ordinary	1281	1281
	Seismic	929	929
Horizontal seismic force (tf)	Longitudinal	93	93
	Transverse	93	93

Member Stresses

General Diagram





Calculation Points

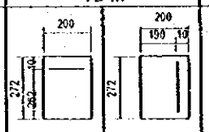
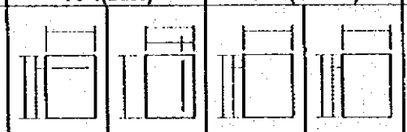
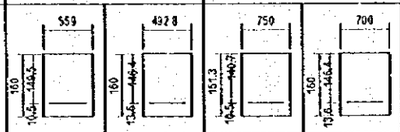
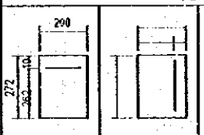
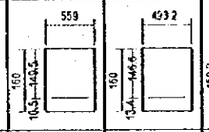
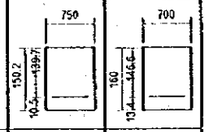
Name of Pier				P1,P2,P10,P11 (T-shaped)								P3,P6,P9, (T-shaped)									
Member				Beam		Column				Footing				Beam				Column		Footing			
Loading Direction				Vertical	Horizontal	Longi.	Transverse	Longi.	Transverse	Longi.	Trnsverse	Longi.	Trnsverse	Vertical	Horizontal	Vertical	Horizontal	Longi.	Transverse	Longi.	Trnsverse	Longi.	Trnsverse
Loading Condition				Ordinary	Seismic	Seismic	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary	Ordinary	Seismic	Ordinary	Seismic	Seismic	Seismic	Ordinary	Ordinary	Ordinary	Ordinary
Section No.				TB-M		TC-1(Base)		TC-2(h=3.4m)		TF-M		TF-S		TB-M				TC		TF-M		TF-S	
Section																							
Force	M	tfm/m		-		1239.00	892.00	983.00	735.00	670.00	501.00	-	-	-				936.00	814.00	552.00	471.00	-	-
	N	tf/m		-		867.00	867.00	810.00	810.00	-	-	-	-	-				768.00	768.00	-	-	-	-
	S	tf/m		-		132.00	87.00	129.00	81.00	-	-	336.00	275.00	-				93.00	77.00	-	-	293.00	259.00
Reinforcing Bar	Required	cm²		-																			
	Minimum	cm²				Diagonal	Diagonal											Diagonal	Diagonal				
	Design	cm²		-		4 Nos.	3 Nos.	361.30	361.30	369.00	258.00	-	-	77.40				3 Nos.	2 Nos.	290.00	258.00	-	-
	Dia.	mm		D32		D19	D19	D29	D29	D32	D29	-	-	D32				D19	D19	D29	D29	-	-
	Interval	mm		150		150	150	125	125	125	125	-	-	150				150	150	125	125	-	-
	Cover	mm		100		100	100	100	100	105	136	-	-	100				100	100	105	131	-	-
Stress	Designed	σ c	kgf/cm²	-		112.0	59.0	102.0	52.0	39.0	38.0	-	-	-				105.0	66.0	36.0	35.0	-	-
		σ s	kgf/cm²	-		2142.0	588.0	1918.0	421.0	1352.0	1462.0	-	-	1587.0				2292.0	881.0	1379.0	1371.0	-	-
		τ m	kgf/cm²	-		2.60	1.70	2.50	1.60	-	-	3.20	2.70	-				1.80	1.50	-	-	2.80	2.70
	Allowable	σ ca	kgf/cm²	80		120	120	120	120	80	80	-	-	80				120	120	80	80	-	-
		σ sa	kgf/cm²	1800		2700	2700	2700	2700	1600	1600	-	-	1800				2700	2700	1600	1600	-	-
		τ a	kgf/cm²	-		3.90	5.85	4.40	4.80	-	-	6.90	6.90	-				6.50	6.90	-	-	7.50	6.90

Table 5.19(c) Design Summary of Pier at Aqr R/A(Rigid Frame) (Spread Foundation)

Type of Pier	Rigid Frame Pier			Bridge Length	L=	360.000	m	Horizontal Alignment	900m	Bevel	90 degree	Bridge	Total Width	ΣW=	10.000	m	Design	Longitudinal direction	kh=
Structural Type	Rigid frame with prestressed concrete beam			Beam Length	l=	18.500	m	Span Arrangement	4*(29.5m+30.0m+29.5m)			Width	Effective Width	W=	8.000	m	Seismic Coefficien	Transverse direction	kh=

Main Girder	Number	Nos.	Girder Height	1.70 to 2.20 m	Maximum Deflection by Live Loading	δ L=	mm (1/)
	Interval	m	Ratio of Girder Height to Span	(at Center of Span) H/L= 1/ 10.9		(at Support) H/L= 1/ 8.4	
Cross Beam	Number	Nos.	Interval of Cross Beam	m	Height of Cross Beam	m	

Design of Slab

Type of Deck Slab	RC Slab	Type of PC Tendon		Interval of Transyerse Prestressing	mm		
Specified Design Strength	σ ck=	kgf/cm²	Rate of Increase	k=			
Cantilever Section	Bending Moment	Slab Thickness	Flexural Stress (kgf/cm²)				
Cantilever Section	6.49 tfm/m	500 mm	σ s	1011 kgf/cm2			
Center of Span	6.02 tfm/m	300 mm	σ s	1251 kgf/cm2			
Intermediate Support	5.30 tfm/m	500 mm	σ s	826 kgf/cm2			

Applied Design Theory	Beam theory	Type of PC Tendon	12T-15.2B
Method of PC Beam Erection	All Staging Method		

Design of Main Girder

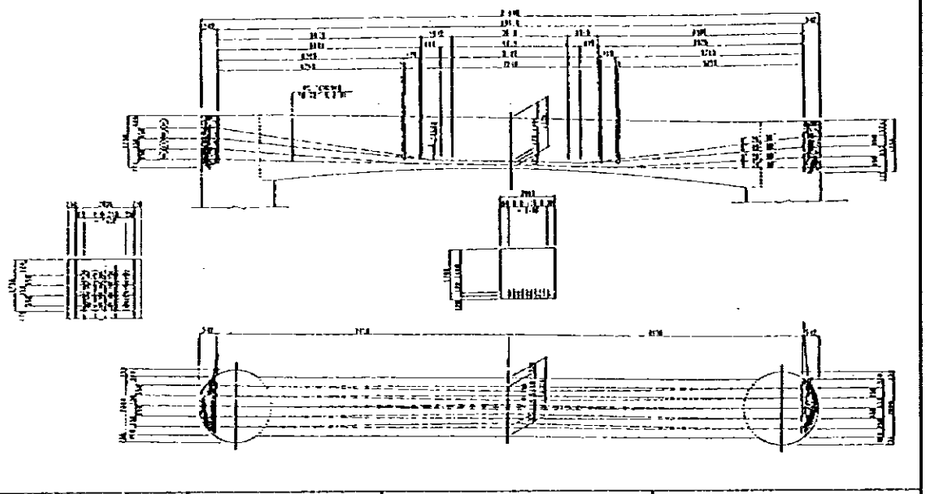
	Bending Moment (tf • m)	Location	Conbined Flexural Stress (tf/cm²)		Allowable Stress (kgf/cm²)	
			Immediate after Prestressing	At Design Load	Immediate after Prestressing	At Design LOad
Design Section		Upper				
		Lower				
Center of Side Span	Md+l 1705	Upper	-0.5	149.2	-15≦ σ ≦150	-15≦ σ ≦140
	Mpt 1304	Lower	170.9	-7.3	-15≦ σ ≦190	-15≦ σ ≦140
Intermediate	Md+l -1679	Upper	141.2	38.5	-15≦ σ ≦190	0≦ σ ≦140
Support	Mpt 1288	Lower	-14.7	74.4	-15≦ σ ≦150	-15≦ σ ≦140
Center of Main Span		Upper				
		Lower				

Shear Force	at Design Load	at Ultimate state	Diagonal Tension Stress	Stirrup		Vertical PC Tendon		
End Support	807.0 tf	1397.0 tf	-4.8 kgf/cm²	D22 (3sets)	ctc 150			
Intermediate Support	tf	tf	kgf/cm²					

Reaction

Reaction	P5(A),P7(A),P8(B) (Fixed)
Reaction by Dead Load : Rd	695.0
Reaction by Live Load : RL	331.0
Total Reaction : R	1026.0
Reaction for Bearing Pad	319.0 (Rubber bearing)

Cross Section Diagram



Main Materials

Item		Unit	Specification	Quantity	Quantity per 1 m³ of concrete
Concrete		m³	σ ck= 240(400) kgf/cm²	248.1(110 3) m³	
Form	Externa	m²		374.1 m²	
	Internal	m²			
Reinforcing Bar		t		43.1 t	
Tendon	Longitudinal	t			
	Transverse	t			
	Vertical	t			
	Total	t			

Maximum Stress in Tendon	118.7 kgf/mm²	σ pa=	133 kgf/mm²
Means for Transmission of Horizontal Force			

Remarks :Result of Stability calculation

Loading case	Ordinary		Sesmic		Ordinary		Sesmic	
Decisible direction(m)	Transverse		Longitudinal		Transverse		Longitudinal	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Eccentricity (m)	1.17	0.73	2.17	1.38	1.17	0.73	1.83	0.88
Safety factor against Sliding	3.4	1.5	4.3	1.2	3.4	1.5	6.0	1.2
Max Ground reaction(tf/m²)	35.9	40.0	49.6	60.0	37.8	40.0	38.7	60.0