Oman SNDC Phase-1 PROJECT


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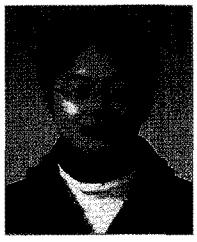
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1. 머리말

본 프로젝트는 오만의 수도 무스캇에서 남쪽으로 약350km 지점 오만의 중부내륙 사막에 위치한 Saih Nihayda에 Sur Oman LNG Plant 및 Saih Rawl 중앙 처리시설에 가스와 Condensate를 공급중인 Saih Nihayda 가스전에 Compression Station을 추가로 건설하여 공급압력을 증대함을 목적으로 오만정부가 약60%의 지분을 갖고 있는 PDO(Petroleum Development Oman)에서 발주한 Gas Plant사업이다.

2009년 11월 Proposal을 시작으로 2009년 12월 GS건설이 수주에 성공, 2010년 1월 Kick Off Meeting을 시작하여 2010년 3월부터 국내 종합 엔지니어링사인 대신엔지니어링(주)와 본사가 협력사로 본격적으로 설계에 착수하여 2011년 4월 현재 설계 마무리 단계에 접어들었다.

설비규모는 15MW Gas Compressor3기 및 Air Coolers, Separator등 부대설비와 132kV Sub-station, Over Head Line(약3km), Turbo Expander 1기 및 주변설비가 있으며, 이에 따라 설계에 반영된 구조물은 Piperack(약900m), Shelters, Sunshades, Equipment supports와 Access platform structure등이 있고, 건물로는 132kV Substation Control Building, Field Auxiliary Room등이 있다.

2. 구조설계 개요

2.1 대지조건 (Site Condition)

- 대지위치 : SAIH NIHAYDA, OMAN
- 기온 : 최대 50℃, 최저 5℃
- 상대습도 : 최대 90%, 최저 30%
- 바람 : 26m/sec @ 10m height
- 강우 : 25mm/h
- 지진 : Do not consider

2.2 적용기준 (Code and Standard)

Project Specification, BS Code를 적용하였으며, 기타구조설계 관련 사항은 발주사와 협의에 의해 결정하였다.

- Project Specification
  - SP-1275 – Civil & Building Works (Design Criteria Manual)
  - SP-1276 – Standard Control Buildings (Design Requirements and Standard Drawings)
- British Standard Code
  - BS 5950 – Structural Use of Steelwork in Buildings
  - BS 8004 – Code of Practice for Foundations

- BS 6399 – Loading for Buildings
- BS 8110 – Structural Use of Concrete
- BS 4190 & 3692 – Hexagon bolts, screws and nuts
- BS EN 10025 – Hot rolled products of structural steels
- BS 648 – Schedule of weights of building materials
- BS 197 – Cement. Composition, specifications and conformity criteria for common cements
- BS 5328 – Concrete. Guide to specifying concrete
- BS 4449 – Specification for carbon steel bars for the reinforcement of concrete

2.3 사용재료 (Material)

■ 콘크리트 : – Grade C35 (28 days cylinder test.)
■ 철근(BS 규격) : Fy=460MPa
■ 철골(BS 규격) : Fy=275MPa (Grade S275JR)

2.4 허용변위

부재	Pipe 지지	Pipe 비지지
수직부재	1/250(height)	1/200(height)
수평부재	1/500(span)	1/360(span)

2.5 구조해석 및 설계프로그램

- STAAD-PRO V8i _ 골조해석
- AFES (GS 기계기초설계 프로그램) _ 기초설계
- MIDAS SET _ 부재설계

3. 주요구조물 구조설계

약 900m 정도 길이의 Piperack은 EXPANSION JOINT 설치로 인해 각각의 Piperack(40~50m)으로 나누어졌으며 지면관계상 일부구간만 소개하기로 한다.

또한 Turbo Expander Equipment를 감싸고 있는 대표적인 구조물 한 동을 소개하기로 한다.

3.1 Piperack

Moment resisting frame과 Braced frame으로 된 철골구조이며 Gas Plant특성상 변위(1/500)를 중요시 하므로 변위제어에 초점을 두고 설계하였다.

3.1.1 구조개요

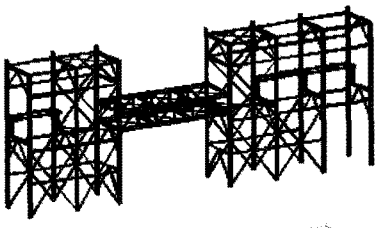
- 구조형식 : 철골구조
- 기초형식 : 독립지내력기초
- 규 모 : 5m(스팬) , 6m (간격), 17.2m(높이)
- 허용지내력 : 300KN/m²
- 적용하중 : Dead Load, Operating Load ,Test Load, Anchor Force –Information 참조
  Friction Force –Operating Load의 15%를 수평력으로 작용
  Wind Load
- 안전성검토 : 전도, 활동, 수직 · 수평변위

3.1.2 설계시 고려사항

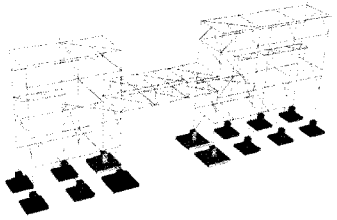
1) 철골구조 시스템
For strong axis (Trans. Direction) : Moment resisting frame
For weak axis (Longi. Direction) : Braced frame

2) 철골구조 시스템의 support condition
Main structure : 강축방향 Fixed, 약축방향 Pinned
Local platform : Pinned

3) 추후 변경 등에 대비하기 위하여, 부재 허용응력에 대해 작용응력의 비는 다음 값 이하가 되도록 설계
– Structure
Column : 0.75 ~ 0.85
Girder : 0.80 ~ 0.90
Beam : 0.85 ~ 0.95
– Structure Foundation : 0.80 미만
– Equipment Foundation : 0.85 미만



〈상부구조물 해석모델〉



〈기초 해석모델〉

3.1.3 설계하중

1) Dead Load

- 5% of additional material weight is considered.
- Platform for operation : 1kN/m²

2) Pipe & Tray Loads

- Empty piping wt. :

  60% of operating pipe load is applied.

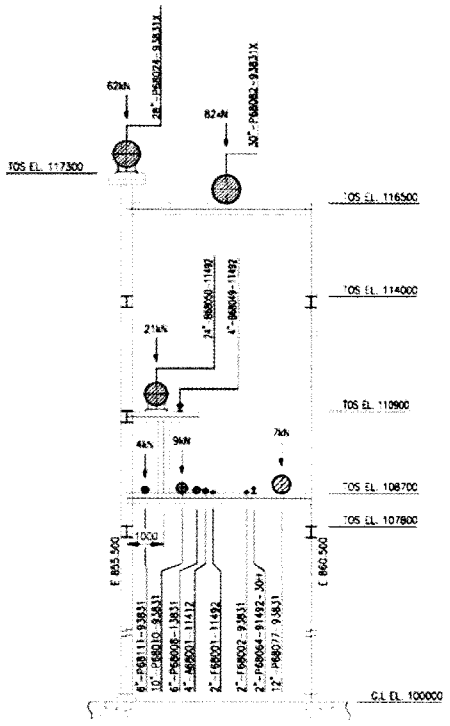
- Operation Loads :

  지름12" 이상은 집중하중 적용

  지름12" 미만은 기본등분포하중 2kPa 적용

GRID LINE	ELEVATION	Con. Load (kN)	Uniform Load(kN/m)
B55	EL 108700	9	11.27
	EL 110700	12	7.43
	EL 116500	96	10.17
	EL 117100	33	-
B56	EL 108700	8	10.80
	EL 110700	5	7.12
	EL 116500	45	9.75
	EL 117200	15	-

〈Input Operating Load〉



〈Operating Information〉

GRID LINE	ELEVATION	Loading Inform. (kN)	Input Load (kN)	Input/ Inform
B55	EL 108700	20.0	54.9	274%
	EL 110700	21.0	35.3	168%
	EL 116500	82.0	164.6	201%
	EL 117100	62.0	62.0	100%

〈Piping load information VS Input Operation Loads〉

GRID LINE	ELEVATION	Con. Load (kN)	Uniform Load(kN/m)
B55	EL 108700	11	11.27
	EL 110700	28	7.43
	EL 116500	71	10.17
	EL 117100	49	-
B56	EL 108700	10	10.80
	EL 110700	11	7.12
	EL 116500	63	9.75
	EL 117200	21	-

〈Test Load〉

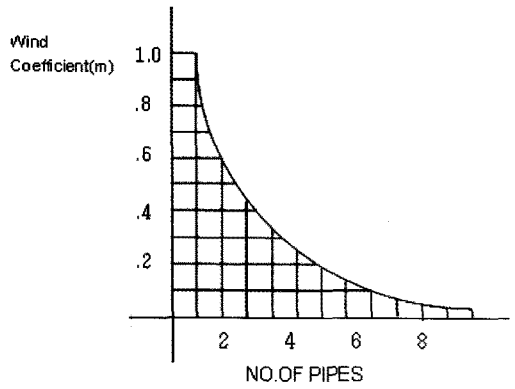
GRID LINE	ELEVATION	Con. Load (kN)	Uniform Load(kN/m)
B55	EL 108700	1.35	1.69
	EL 110700	1.80	1.11
	EL 116500	14.4	1.53
	EL 117100	4.95	-
B56	EL 108700	1.20	1.62
	EL 110700	0.75	1.07
	EL 116500	6.75	1.46
	EL 117200	2.250	-

〈Friction Load〉

GRID LINE	ELEVATION	Con. Load (kN)			Uniform Load(kN/m)
		(N-S)		(E-W)	
B55	EL 108700	-	-	6	-
	EL 110700	-	-	-	-
	EL 116500	-	-	-	-
	EL 117100	-	-	8	-
B56	EL 108700	12	-	-	-
	EL 110700	-	-	3	-
	EL 116500	-	-	-	-
	EL 117200	-	-	-	-

〈Anchor Force Load〉

3) Wind Load for PIPE



NO. OF PIPES	m	Σm
1	1.00	1.00
2	.70	1.70
3	.49	2.19
4	.34	2.53
5	.24	2.77
6	.17	2.94
7	.12	3.06
8	.08	3.14
9	.06	3.20
10	.04	3.24
11	.03	3.27
12	.02	3.29

$Wp = C_D \cdot q \cdot d \cdot \Sigma m = 0.8 \cdot p \cdot d \cdot Sm$

(Total wind load on pipes, kg/m)

C_D = Drag coefficient

q = Velocity pressure = p /1.3 kg/m²

p = Design wind pressure on flat surface, kg/m²

d = Average pipe diameter, m including insulation

Σm = Function of number of pipes considered with average diameter.

EL.p	(Kgf/m²)	Lt (m)	Ap (m)	Sm	Wind Force(KN)
EL 108700	95.3	5.75	0.216	2.53	2.994
		6.00			3.124
		9.75			5.076
		10.0			5.206

〈Acting wind force on Pipe〉

4) Live Load

- Platform for operation : 5kN/m²
- Platform for Walkway : 2.5kN/m²

5) Earthquake load

- Not applicable

3.1.4 하중조합

1) Basic load condition

	Description
Structure (Ds)	Structural Dead Load
Operating (Do)	Operating Load
Erection (Df)	Equipment Erection Load
Empty (De)	Empty Load
Test (Dt)	Test Load
Live (L)	Live Load
Structure (Ts)	Thermal Expansion Load of Structure
Anchor Force (Af)	Pipe Anchor Load
Friction Force (Ff)	Friction Load
Longi. Direction (W1)	Wind Load
Trans. Direction (W2)	Wind Load

2) Deflection check

#	CASE	Ds	Do	De	Dt	L	Ts	Af	Ff	w1	w2
101	Operation w/ Wind	1	1			1	1	1	1	1	
102	Operation w/ Wind	1	1			1	1	-1	1	-1	
103	Operation w/ Wind	1	1			1	1	1	1		1
104	Operation w/ Wind	1	1			1	1	-1	1		-1
120	Empty w/ Wind	1		1						1	
121	Empty w/ Wind	1		1						-1	
122	Empty w/ Wind	1		1							1
123	Empty w/ Wind	1		1							-1
140	Test w/ Wind	1			1	1				0.5	
141	Test w/ Wind	1			1	1				-0.5	
142	Test w/ Wind	1			1	1					0.5
143	Test w/ Wind	1			1	1					-0.5

3) Safety check

#	CASE	Ds	Do	De	Dt	L	Ts	Af	Ff	w1	w2
201	Normal Operation	1.4	1.4			1.6	1.4	1.4	1.4		
202	Oper. (except live)	1.4	1.4				1.4	1.4	1.4	1.4	
203	Oper. (except live)	1.4	1.4				1.4	-1.4	1.4	-1.4	
204	Oper. (except live)	1.4	1.4				1.4	1.4	1.4		1.4
205	Oper. (except live)	1.4	1.4				1.4	-1.4	1.4		-1.4
206	Oper. w/ Wind	1.2	1.2			1.2	1.2	1.2	1.2	1.2	
207	Oper. w/ Wind	1.2	1.2			1.2	1.2	-1.2	1.2	-1.2	
208	Oper. w/ Wind	1.2	1.2			1.2	1.2	1.2	1.2		1.2
209	Oper. w/ Wind	1.2	1.2			1.2	1.2	-1.2	1.2		-1.2
210	Oper. w/ Wind(uplift)	1	1				1	1	1	1.4	
211	Oper. w/ Wind(uplift)	1	1				1	1	1	-1.4	
212	Oper. w/ Wind(uplift)	1	1				1	1	1		1.4
213	Oper. w/ Wind(uplift)	1	1				1	1	1		-1.4
220	Empty w/ Wind	1.4		1.4						1.4	
221	Empty w/ Wind	1.4		1.4						-1.4	
222	Empty w/ Wind	1.4		1.4							1.4
223	Empty w/ Wind	1.4		1.4							-1.4
224	Empty w/ Wind(uplift)	1		1						1.4	
225	Empty w/ Wind(uplift)	1		1						-1.4	
226	Empty w/ Wind(uplift)	1		1							1.4
227	Empty w/ Wind(uplift)	1		1							-1.4
240	Test	1.4			1.4	1.6					
241	Test (except live)	1.4			1.4					0.7	
242	Test (except live)	1.4			1.4					-0.7	
243	Test (except live)	1.4			1.4						0.7
244	Test (except live)	1.4			1.4						-0.7
245	Test w/ Wind	1.2			1.2	1.2				0.6	
246	Test w/ Wind	1.2			1.2	1.2				-0.6	
247	Test w/ Wind	1.2			1.2	1.2					0.6
248	Test w/ Wind	1.2			1.2	1.2					-0.6

4) Soil stability check

#	CASE	Ds	Do	De	Dt	L	Ts	Af	Ff	w1	w2
301	Operation w/ Wind	1	1			1	1	1		1	
302	Operation w/ Wind	1	1			1	1	-1		-1	
303	Operation w/ Wind	1	1			1	1	1			1
304	Operation w/ Wind	1	1			1	1	-1			-1
320	Empty w/ Wind	1		1						1	
321	Empty w/ Wind	1		1						-1	
322	Empty w/ Wind	1		1							1
323	Empty w/ Wind	1		1							-1
340	Test w/ Wind	1			1	1				0.5	
341	Test w/ Wind	1			1	1				-0.5	
342	Test w/ Wind	1			1	1					0.5
343	Test w/ Wind	1			1	1					-0.5

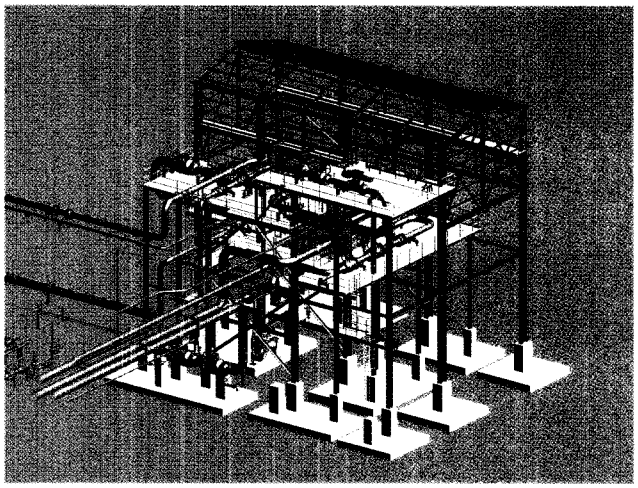
5) Foundation design

#	CASE	Ds	Do	De	Dt	L	Ts	Af	Ff	w1	w2
401	Normal Operation	1.4	1.4			1.6	1.4	1.4			
402	Oper. (except live)	1.4	1.4				1.4	1.4		1.4	
403	Oper. (except live)	1.4	1.4				1.4	-1.4		-1.4	
404	Oper. (except live)	1.4	1.4				1.4	1.4			1.4
405	Oper. (except live)	1.4	1.4				1.4	-1.4			-1.4
406	Oper. w/ Wind	1.2	1.2			1.2	1.2	1.2		1.2	
407	Oper. w/ Wind	1.2	1.2			1.2	1.2	-1.2		-1.2	
408	Oper. w/ Wind	1.2	1.2			1.2	1.2	1.2			1.2
409	Oper. w/ Wind	1.2	1.2			1.2	1.2	-1.2			-1.2
410	Oper. w/ Wind(uplift)	1	1				1	1		1.4	
411	Oper. w/ Wind(uplift)	1	1				1	1		-1.4	
412	Oper. w/ Wind(uplift)	1	1				1	1			1.4
413	Oper. w/ Wind(uplift)	1	1				1	1			-1.4
420	Empty w/ Wind	1.4		1.4						1.4	
421	Empty w/ Wind	1.4		1.4						-1.4	
422	Empty w/ Wind	1.4		1.4							1.4
423	Empty w/ Wind	1.4		1.4							-1.4
424	Empty w/ Wind(uplift)	1		1						1.4	
425	Empty w/ Wind(uplift)	1		1						-1.4	
426	Empty w/ Wind(uplift)	1		1							1.4
427	Empty w/ Wind(uplift)	1		1							-1.4
440	Test	1.4			1.4	1.6					
441	Test (except live)	1.4			1.4					0.7	
442	Test (except live)	1.4			1.4					-0.7	
443	Test (except live)	1.4			1.4						0.7
444	Test (except live)	1.4			1.4						-0.7
445	Test w/ Wind	1.2			1.2	1.2				0.6	
446	Test w/ Wind	1.2			1.2	1.2				-0.6	
447	Test w/ Wind	1.2			1.2	1.2					0.6
448	Test w/ Wind	1.2			1.2	1.2					-0.6

3.2 Turbo Expander Shelter

Turbo expander Equipment를 감싸고 있는 구조물로 Platform에 부분적으로 Pipe Load가 적재되어있고 5.0ton Crane이 설치된다.

Moment resisting frame과 Braced frame으로 된 철골 구조로 설계하였다.



〈3D MODEL〉

3.2.1 구조개요

- 구조형식 : 철골구조
- 기초형식 : 독립+복합지내력기초
- 규　모 : 15.3m(폭) , 20.6m (길이), 19.35m(높이)
- 허용지내력 : 300KN/㎡
- 적용하중 : Dead Load, Operating Load, Test Load
  Friction Force, Anchor Force
  Wind Load, Crane Load
- 안전성검토 : 전도, 활동, 수직 · 수평변위

3.2.2 설계시 고려사항

1) 철골구조 시스템

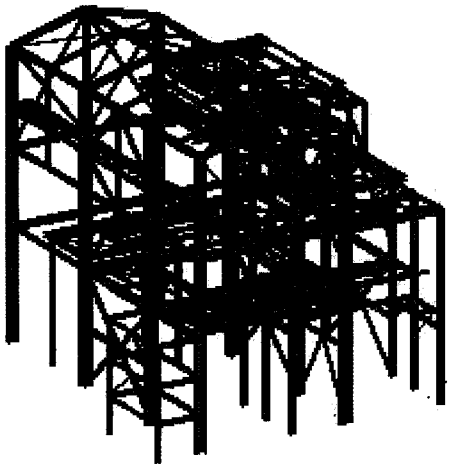
For strong axis : Moment resisting frame

For weak axis : Braced frame

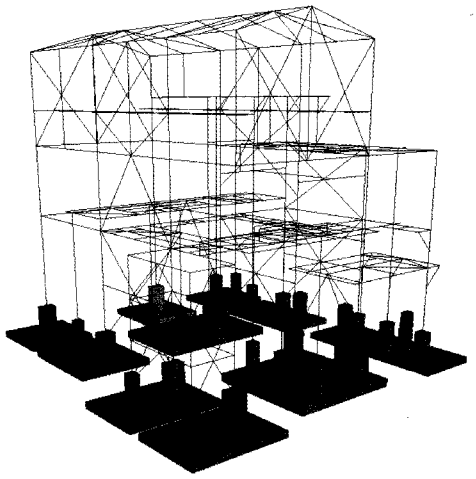
2) 철골구조 시스템의 support condition

Main structure : 강축방향 Fixed, 약축방향 Pinned

Local platform : Pinned



〈상부구조물 해석모델〉



〈기초 해석모델〉

3.2.3 설계하중

1) Dead Load

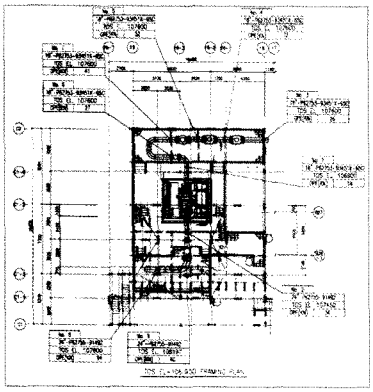
- 5% of additional material weight is considered.
- Platform for operation : 1kN/㎡
- Roof Purlin self weight : 0.1kN/㎡

2) Pipe & Tray Loads

- Empty piping wt. : 60% of operating pipe load is applied.
- Operation Loads : 지름12" 이상은 집중하중 적용
  지름12" 미만은 기본등분포하중 2kPa 적용

ELEVATION	Grid Line	Con. Load (kN)
EL 104600	F8 / C1	87
	F8-1 / C1	77
	F8-2 / C1	195
EL 106900	F8-3 / C1-3	14
EL 107450	F8-3 / C1-2	34

〈Input Operating Load〉



〈Operating Information〉

No.	ELEVATION	Loading Inform.(kN)	Input Load(kN)	Input/ Inform
1	EL 106900	14	14	100%
2	EL 107450	34	34	100%
3	EL 107600	26	26	100%
4	EL 107600	72	72	100%

〈Piping load information VS Input Operation Loads〉

ELEVATION	Grid Line	Con. Load (kN)
EL 104600	F8 / C1	83
	F8-1 / C1	64
	F8-2 / C1	94
EL 106900	F8-3 / C1-3	11
EL 107450	F8-3 / C1-2	50

〈Test Load〉

ELEVATION	Grid Line	Con. Load (kN)
EL 104600	F8 / C1	13.05
	F8-1 / C1	11.55
	F8-2 / C1	29.25
EL 106900	F8-3 / C1-3	2.1
EL 107450	F8-3 / C1-2	5.1

〈Friction Load〉

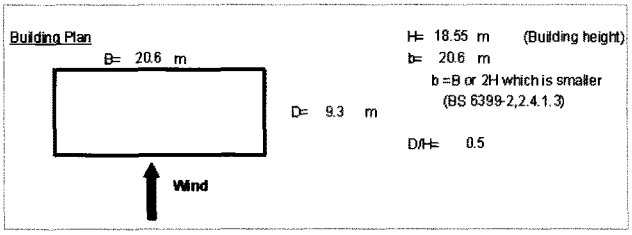
ELEVATION	Grid Line	Con. Load (kN)	
		(N-S)	(E-W)
EL 104600	F8 / C1	-	-
	F8-1 / C1	38	-
	F8-2 / C1	-	44
EL 106900	F8-3 / C1-3	-	-
EL 107450	F8-3 / C1-2	-	-

〈Anchor Force Load〉

3) Wind Load

- Wind Load : x-direction

• Cpe and Cpi for vertical wall and roof



• Cpe for vertical wall

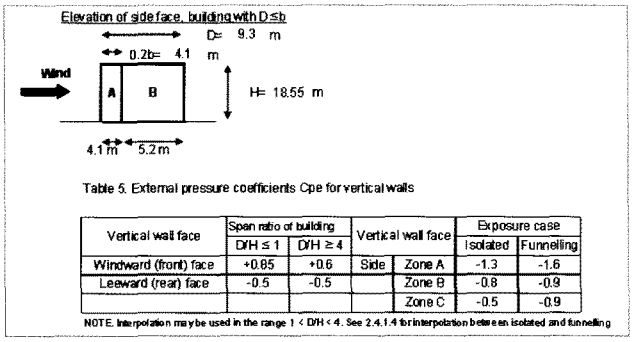


Table 5. External pressure coefficients Cpe for vertical walls

Vertical wall face	Span ratio of building		Vertical wall face		Exposure case	
	D/H ≤ 1	D/H ≥ 4			Isolated	Funnelling
Windward (front) face	+0.85	+0.6	Side	Zone A	-1.3	-1.6
Leeward (rear) face	-0.5	-0.5		Zone B	-0.8	-0.9
				Zone C	-0.5	-0.9

NOTE. Interpolation may be used in the range 1 < D/H < 4. See 2.4.1.4 for interpolation between isolated and funnelling

• Cpe for duopitch roof

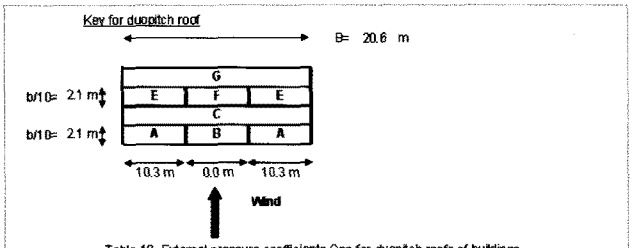


Table 10. External pressure coefficients Cpe for duopitch roofs of buildings

Pitch angle α	Zone for θ = 90°					
	A	B	C	E	F	G
+15°	-1.1	-0.8	-0.4	-1.3	-0.9	-0.5
	+0.2	+0.2	+0.2	-1.3	-0.9	-0.5

NOTE 1. At θ = 0° the pressure changes rapidly between positive and negative values in the range of pitch angles +5° ≤ α ≤ +45°. Two sets of values are given at these pitch angles and they should be treated as separate load cases.

NOTE 2. Interpolation for intermediate pitch angles may be used between values with the same sign. Between pitch angles +5° and -5° interpolation is not permitted and the data for flat roofs in 2.5.1 should be used instead.

• Cpi for enclosed building

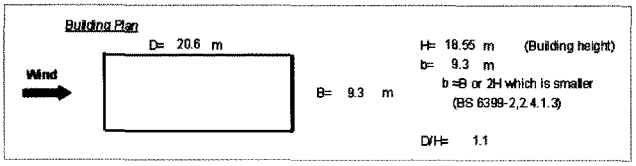
Cpi should be taken as either −0.3 or +0.2, whichever gives the larger net pressure coefficient across the wall.

• Vertical wall and roof

LOCATION		qs (N/m²)	Cpe	Cpi	pe	pi	p (kN/m²)
Wall	Windward	1343	0.85	−0.3	1.14	−0.4	1.54
	Leeward	1343	−0.5	0.2	−0.67	0.27	−0.94
	Zone A	1343	−1.3	0.2	−1.75	0.27	−2.01
	Zone B	1343	−0.8	0.2	−1.07	0.27	−1.34
	Zone C	1343	−0.5	0.2	−0.67	0.27	−0.94
Roof	Zone A	1343	−1.1	0.2	−1.48	0.27	−1.74
	Zone B	1343	−0.8	0.2	−1.07	0.27	−1.34
	Zone C	1343	−0.4	0.2	−0.54	0.27	−0.80
	Zone D	1343	−1.3	0.2	−1.75	0.27	−2.01
	Zone E	1343	−0.9	0.2	−1.21	0.27	−1.47
	Zone F	1343	−0.5	0.2	−0.67	0.27	−0.94

– Wind Load : Z-direction

• Cpe and Cpi for vertical wall and roof



• Cpe for vertical wall

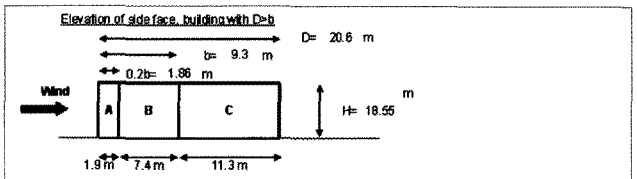


Table 5. External pressure coefficients Cpe for vertical walls

Vertical wall face	Span ratio of building D/H ≤ 1	D/H =1.1	D/H ≥ 4	Vertical wall face		Exposure case Isolated	Funnelling
Windward (front) face	+0.85	0.84	+0.6	Side	Zone A	-1.3	-1.6
Leeward (rear) face	-0.5	-0.5	-0.5		Zone B	-0.8	-0.9
					Zone C	-0.5	-0.9

NOTE. Interpolation may be used in the range 1 < D/H < 4. See 2.4.1.4 for interpolation between isolated and funnelling

• Cpe for duopitch roof

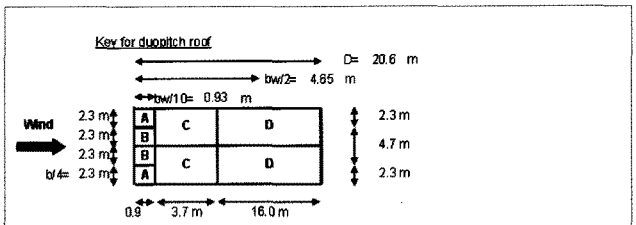


Table 10. External pressure coefficients Cpe for duopitch roofs of buildings

Pitch angle α	Zone for θ = 90° A	B	C	D
+15°	-1.6	-1.5	-0.6	-0.4

NOTE 1. AT θ = 0° the pressure changes rapidly between positive and negative values in the range of pitch angles +b°<α<+b°. Two sets of values are given at these pitch angles and they should be treated as separate load cases.

NOTE 2. Interpolation for intermediate pitch angles may be used between values with the same sign. Between pitch angles +5° and -5° interpolation is not permitted and the data for flat roofs in 2.5.1 should be used instead.

• Cpi for enclosed building

Cpi should be taken as either −0.3 or +0.2, whichever gives the larger net pressure coefficient across the wall.

• Vertical wall and roof

LOCATION		qs (N/m²)	Cpe	Cpi	pe	pi	p (kN/m²)
Wall	Windward	1343	0.84	−0.3	1.13	−0.4	1.53
	Leeward	1343	−0.5	0.2	−0.67	0.27	−0.94
	Zone A	1343	−1.3	0.2	−1.75	0.27	−2.01
	Zone B	1343	−0.8	0.2	−1.07	0.27	−1.34
	Zone C	1343	−0.5	0.2	−0.67	0.27	−0.94
Roof	Zone A	1343	−1.6	0.2	−2.15	0.27	−2.41
	Zone B	1343	−1.5	0.2	−2.01	0.27	−2.28
	Zone C	1343	−0.6	0.2	−0.81	0.27	−1.07
	Zone D	1343	−0.4	0.2	−0.54	0.27	−0.8

4. 맺음말-A

설계(Engineering)와 자재조달(Procurement), 시공(Construction)까지 종합으로 수주된 프로젝트를 3단계(For Information, For Review, For Construction)에 걸쳐 설계 작업을 수행하다보니 정해진 시간내에 끝내야 한다는 강박관념과 타부서(건축, 배관 등)와의 유기적인 협력관계에 많은 어려움이 뒤따랐으나 그동안 쉽게 접하지 못했던 Gas Plant에 대한 많은 정보와 기술력을 축적한게 큰 보람이었던 프로젝트였다.