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Your ref: Docket No. 52-006
Our ref: DCP/NRC2253

September 5, 2008

Subject: AP1000 Response to Request for Additional Information (SRP3.8.4)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3.8.4. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

A revised response is provided for RAI-SRP3.8.4-SEB1-01. This response completes all requests received to date for SRP Section 3.8.4. A response for RAI-SRP3.8.4-SEB1-01 was provided under DCP/NRC2189 dated July 3, 2008.

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk

Robert Sisk, Manager
Licensing and Customer Interface
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/Enclosure

1. Response to Request for Additional Information on SRP Section 3.8.4

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3.8.4

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.8.4-SEB1-01
Revision: 1

Question:

The shield building in AP1000 Rev.15 was a 100% reinforced concrete structure. The shield building has been revised in Rev.16. The revision involves a portion of the shield building cylinder wall and the shield building roof. The excerpts from the Rev. 16 are provided below:

3H.5.1.5 Shield Building Cylinder at Elevation 180'-0"

[*The thickness of the cylindrical portion of the shield building wall is 3 feet. Above the roof level, the wall consists of high strength concrete contained within ½-inch think steel liner plates on both faces. The liner plates, tied to concrete with shear connectors, behave as reinforcement bars. Vertical angle stiffeners are provided to support the wet concrete load.*

The wall is designed for the applicable loads described in subsection 3H.3-3. A finite element analysis is performed to determine the design forces.

The design of the shield building roof is described in 3H.5.6.]*

3H.5.6 Shield Building Roof

[*The shield building roof is a reinforced concrete shell supporting the passive containment cooling system tank and air diffuser. The structural configuration is shown on sheets 7, 8, and 9 of Figure 3.7.2-12. Air intakes are located at the top of the cylindrical portion of the shield building. The conical roof supports the passive containment cooling system tank. The conical roof is constructed as a structural steel module and lifted into place during construction. Steel beams provide permanent structural support for steel liner and concrete. The concrete is cast in place. Connection between concrete and steel liner are made using shear studs.*]*

Section 2.2.2.1.5 of Technical Report (TR) 57 states that the shield building cylinder in the air inlet region is 4.5' thick, and the cylinder thickness above and below the air inlet region is 3'-0".

The staff requests the following information:

1. Provide the geometries, typical cross-sections, and dimensions of the revised portion of the shield building wall and the boundary lines, in the horizontal (circumferential) and vertical (meridional) directions, between the revised portion and the non-revised portion of the shield building.
2. Provide anchorage details, in the horizontal (circumferential) and vertical (meridional) directions, between the revised portion and the non-revised portion of the shield building.

Provide calculations to demonstrate that the anchorage details have sufficient capacity to transfer all types of loads, such as bending moment, shear force and axial force. Describe the method that was used for the calculations, and state whether the method was derived from, or substantiated by, test data. If yes, provide the test data. If not, provide the basis for using the method.

3. Provide the size (diameter), length, and spacing of shear connectors, and state whether they are welded to the entire plate or not. If not, specify the regions of the plate that contain shear connectors.
4. Section 3H.5.1.5 states that "*A finite element analysis is performed to determine the design forces",* but fails to state the method that was used to design the concrete-filled steel cylinder to resist *the design forces*. Therefore, identify the critical regions (elements) of the revised portion of the shield building that are subjected to the largest load combination effects of *the design forces* (bending moment, axial force, and shear force) from your finite element analysis. Describe your design method and state whether the method was derived from, or verified by, test data. If yes, provide the test data. If not, provide the basis for using the design method. Is your design method influenced by the size, length, and spacing of shear connectors? If yes, state the influence of each item. If not, state the reason for no influence. Provide numerical examples, with at least one involves positive bending moment and the other negative bending moment, to illustrate your design method and demonstrate that the critical regions of the revised portion of the shield building can resist *the design forces*.
5. Based on the description of the last two sentences in Section 3H.5.6, Shield Building Roof, the staff assumes that steel plates (liners) with studs are welded to the top of the steel beams and concrete is then poured over the steel plates as exteriors of the roof. Provide drawings that indicate the thickness of the steel and the type, size, length, and spacing of welds that are used to attach the steel plates to steel beams and the size, length, and spacing of the studs. Identify the location of the most critical section (the largest load combination effect of bending moment, shear force, and axial force) in the shield building roof and provide numerical examples, with at least one involves positive bending moment and the other negative bending moment, to illustrate how the sections are designed to resist those forces.
6. Voids or honeycombs in reinforced concrete structures have been observed, after the removal of forms, and then repaired. Some structural members were found so deficient, after the removal of forms, that they were demolished and re-poured. Since the steel forms of the revised portion of the shield building walls are not to be removed, provide the method that you would use to inspect or detect concrete voids/honeycombs and other major defects.
7. In concrete construction, after the removal of forms, water in the concrete migrates continuously toward the faces of a concrete member and evaporates into the air, and the concrete dries out. With the steel forms remained in place, water will accumulate at the inside face of the steel forms and cannot escape. This water accumulation problem may cause the long-term steel plate corrosion problem. Therefore, provide your solution to this potential corrosion problem.

Westinghouse Response:

1. Typical details related to the geometries, cross-sections, and dimensions of the shield building wall, and the roof, are shown in Figure 2.2-18 (7 sheets) of Technical Report 57, APP-GW-GLR-045, Rev 2. ~~The additional details and calculations are available for NRC audit.~~

For the enhanced shield building design, the design of the shield building roof and the airinlet region has changed. The changes are shown in sheets 1 thru 5 of TR57 Figure 2.2-18. The design changes for the cylindrical part are shown in sheets 6 and 7.

A design summary is included herewith as Attachment 'A'. It includes some additional roadmap type information about the design methodology.

Detailed design calculations are available for the NRC audit.

2. As stated above, typical details related to the geometries, cross-sections, and dimensions of the shield building wall, and the roof, are shown in Figure 2.2-18 (7 sheets) of Technical Report 57, APP-GW-GLR-045, Rev 2.

Typical details for the transition of the shield building cylinder design, from surface plates to rebars design, is shown in TR57 Figure 2.2-10.

The design calculations and the drawings are available for NRC audit.

The design methodology for the shield building roof and the airinlet region is summarized in the attached file.

As indicated in TR57 Figure 2.2-18 (sheets 6 and 7), segments of the cylindrical concrete wall have surface plates (with shear connectors) to provide the reinforcement. The AP1000 certified design, for hard rock sites, included modules walls with surface plate reinforcement. Similar design methodology is used here.

3. Typical shear connectors' size and spacing ~~design~~ information is shown in Technical Report 57, APP-GW-GLR-045, Revision 2 figure 2.2-18 Sheets 2, 3 and 4. A summary of the typical desing of the shear connectors is provided below:

- On top flanges of W36x393 sloped beams: 7/8" x 6- 3/16" studs; 6" spacing, two rows. (Region: 69'–1" > radius > 46')
- On top flanges of W36x393 sloped beams: 7/8" x 6- 3/16" studs; 6" spacing, three rows. (Region: 46' > radius > internal end of sloped beam)

- On top flange of W30x90 circular beam: ¾" x 6" studs; 6"spacing, two rows

- On the conical roof, ½" thick liner steel plate: ¾ " x 6" studs (on entire surface area; spacing varies)

- All the shield building wall regions, where the surface plates are used as the wall reinforcement, have shear connectors

The detail design calculations and the drawings are available for audit.

4. Information on regions subjected to the largest load combination effects of the design forces (bending moment, axial force, and shear force) is quite extensive; and it is difficult to summarize it in a RAI response. It is contained in following detailed calculations:

- Enhanced Shield Building Roof Design (APP-1278-CCC-001)
- AP1000 Shield Building Cylindrical Wall Design Report (APP-1200-CCC-119)

However, the design methodology summary for the enhanced shield building roof and the airinlet region is included in Attachment 'A'.

Detailed analyses and design calculations are available for the NRC audit. Answers to specific questions are provided below.

- Finite Element Analysis Method: Detailed analyses were performed using a 3-dimensional ANSYS finite element analysis model.

- Critical Regions: A list of the Auxiliary Building 'Critical Sections' is contained in the DCD Chapter 3 Appendix 3H (also in TR57 section 2.2.1).

- Two 'Critical Sections' were established, by the NRC, associated with the shield building conical roof and cylinder air inlet region. These critical sections are as follows:

(i) Shield building roof / PCCS Tank interface

(ii) Shield building roof / Shield building cylinder interface

These regions were modeled in great detail in the ANSYS 3-D finite element analysis model. The design details are summarized in Technical Report 57, APP-GW-GLR-045, Rev 2, Table 2.2-13 (3 sheets), and are included in Attachment 'A' of this response.

~~- Documents containing the analyses and design calculations are available for NRC audit.~~

5. – It is confirmed that Tthe conical roof structure includes the liner plate, with studs, welded to the top of the steel beams. Concrete slab, with reinforcement, poured on the steel liner plate forms the exterior surface of the roof.

- Sketches showing the typical design features are included in Technical Report 57, APP-GW-GLR-045, Rev 2, Figure 2.2-18 (sheets 1 thru 5). Information on the thickness of the steel plated is included in these drawings.

Calculations and Ddetailed drawings, showing the information requested in the RAI, are available for NRC audit.

- 'Critical Sections': (Please see response to RAI question 4).

6. Concrete module construction technology has been in use for a long time. 'Self Consolidating Concrete', that precludes the possibility of voids or honeycombs, will be used for the modules.

Mock up tests are planned to confirm that the construction technology assures voids and honeycomb free modules

7. The concrete mix is designed to control the heat of hydration, using appropriate water/cement ratio, specified type of cement, and a percentage of fly-ash. The moisture will not accumulate at steel plates. In a sealed environment there is no reason for moisture migration to a free surface. Even if some moisture accumulates at the steel plates, the lack of oxygen condition will prevent the plate corrosion.

As stated above, the concrete module construction technology has been in use for a long time; potential corrosion can be precluded by a proper concrete mix design.

Design Control Document (DCD) Revision:

See Revision 2 of Technical Report 57, APP-GW-GLR-045, for the changes already incorporated in DCD Rev 16; and the changes to be made in DCD Rev 16.

PRA Revision:

None

Technical Report (TR) Revision:

See Revision 2 of Technical Report 57, APP-GW-GLR-045.

Attachment A

AP1000 Shield Building (SB) Design Summary:

Notes:

(1) Please see TR57 (APP-GW-GLR-045) Rev2, Figure 2.2-18 (7 sheets), for the following design description.

(2) Please see TR57 (APP-GW-GLR-045) Rev2, Table 2.2-13 (3 sheets), for the reinforcement design summary and sketches.

The above listed figures and tables have 'Security-Related' information and have not been reproduced in this summary.

1.0 Design Description:

- The design of the shield building roof structure is shown in Figure 2.2-18, sheet 1. The reinforcement design details for the 'critical sections' are shown in Figure 2.2-18, sheets 3 and 5.

  The shield building roof is a conical shell structure, with the integral passive containment cooling system (PCS) water storage tank and air diffuser on the top.

  Figure 2.2-18, sheets 2 and 3, show the air intake structure which is located at the top of the cylindrical portion of the shield building. This structure includes three rows of 16"x16' square structural tubes (provided from El 251'- 6 ½" to EL 266'-6"). The thickness of the shield building cylinder in the 'Air Intake Region' is 4'-6". The conical roof supports the PCS water storage tank (with the air diffuser in the center of the roof).

- The conical roof steel module is composed of the following (Figure 2.2-18, sheets 1 and 5)

  - 32 radial beams W36x393
  - W30x90 and MC8x20 circumferential beams
  - compression ring at the top
  - Steel liner ½" thick.

  This structure is used as the permanent formwork during concrete pouring.

- The conical roof is constructed as a structural steel module; and is lifted in place during construction. Steel beams provide permanent structural support for steel liner and concrete. The concrete is cast in place. The conical concrete slab at the bottom of PCS tank is 2' thick. The lower segment of the conical concrete slab, supporting the steel module, is 3' thick. Shear studs are used to connect concrete and steel liner (typical detail are as shown in Figure 2.2-18, sheets 2, 3 and 4).

- The connection between the conical roof and air inlet is designated as tension ring, and is a 'critical section'. In Figure 2.2-18, sheets 1 and 3, the tension ring region is between El. 267' – 9" and El. 272' – 11/16". Also attached to the air intake region is an 'External Walkway' at El. 250' – 6".

- Below the air inlet region, the shield building cylinder thickness is transitioned to 3'-0". As shown in Figure 2.2-18, sheets 6 and 7, the 3' thickness includes ½" thick steel plate (shown by hatched lines) on each face of the cylinder (connected to concrete by shear connectors). The A572 steel plate is provided up to various elevations (shown in the figures) determined from security considerations.

2.0 Design Loads

The following loads were considered in the analyses and design, and were combined in accordance with the Civil/Structural Design Criteria:

i) Dead weight (D)

ii) Hydrostatic load due to PCS water (H)

iii) Snow load (L)

iv) Wind load (W)

iv) Tornado load (Wt)

v) Seismic load including seismic induced pressure on PCS wall. (Es)

vi) Thermal loads

Seismic Load: An ANSYS analysis was performed to evaluate the seismic forces and moments in the air intake region and in the tension ring. The accelerations shown in the following table (obtained from detailed seismic model) were applied.

Seismic Design Accelerations (g values):

Elevation [ft]	X (North-South)	Y (East-West)	Z (Vertical)
180	1.50	1.61	1.04
240	1.43	1.50	1.06
267	1.53	1.72	1.15
289	1.69	1.98	1.95
327	2.00	1.45	2.01

Load Factors for Load Combinations not Including SSE Load

Comb. # in Ref.[3]	1	2	2	4	4	4	4	7	7	8	8	8	8
Comb. # in this document	1	2	3	4	5	6	7	8	9	10	11	12	13
DEADWEIGHT	1.4	1.4	1.4	1	1	1	1	1.05	1.05	1.05	1.05	1.05	1.05
SNOW	1.7	1.7	1.7	0	0	1	1	1.3	1.3	1.3	1.3	1.3	1.3
WIND SYMMETRIC	0	1.7	1.7	0	0	0	0	0	0	1.3	1.3	1.3	1.3
WIND ASYMMMETRIC	0	1.7	1.7	0	0	0	0	0	0	1.3	-1.3	1.3	-1.3
TORNADO SYMM	0	0	0	1	1	1	1	0	0	0	0	0	0
TORNADO ASYM	0	0	0	1	1	1	1	0	0	0	0	0	0
T_O SUMMER	0	0	0	1	1	0	0	1.2	0	1.2	1.2	0	0
T_O WINTER	0	0	0	0	0	1	1	0	1.2	0	0	1.2	1.2

Load Factors for Load Combinations Including SSE

N°	DW	Snow	EZ	Ex	Ey
1	1	1	+1	+0.4	+0.4
2	1	1	+1	+0.4	-0.4
3	1	1	+1	-0.4	+0.4
4	1	1	+1	-0.4	-0.4
5	1	0	-1	+0.4	+0.4
6	1	0	-1	+0.4	-0.4
7	1	0	-1	-0.4	+0.4
8	1	0	-1	-0.4	-0.4
9	1	1	+0.4	+1	+0.4
10	1	1	+0.4	+1	-0.4
11	1	1	+0.4	-1	+0.4
12	1	1	+0.4	-1	-0.4
13	1	0	-0.4	+1	+0.4
14	1	0	-0.4	+1	-0.4
15	1	0	-0.4	-1	+0.4
16	1	0	-0.4	-1	-0.4
17	1	1	+0.4	+0.4	+1
18	1	1	+0.4	+0.4	-1
19	1	1	+0.4	-0.4	+1
20	1	1	+0.4	-0.4	-1
21	1	0	-0.4	+0.4	+1
22	1	0	-0.4	+0.4	-1
23	1	0	-0.4	-0.4	+1
24	1	0	-0.4	-0.4	-1

The combination of the three SSE components was performed using the 100%-40%-40% rule instead of the SRSS in order to save the sign of stresses. 75% of snow mass was added to structure mass in evaluating seismic stresses. Furthermore, the snow load was added to DW, only in combinations having the vertical component of seismic load in downward direction.

Normal thermal loads were not included in combinations with SSE load according to the design criteria.

3.0 Design Methodology

3.1 The design of the Shield Building roof was performed considering the loads, the load combinations and the load factors specified in "Civil/Structural Design Criteria" (APP-GW-C1-001 Rev.1).

The design criteria of AISC N690-94 and ACI 349-01 codes have been followed for steel and reinforced concrete components respectively.

Two groups of load combinations have been considered:

a) DW (including Snow), Wind, Tornado, Temperatures Winter and Summer
b) DW (including Snow), plus seismic Ex, Ey, Ez

An ANSYS finite element model was used; wherein all main segments of the structure (radial and circumferential roof beams, the liner steel plates, the square tubes lining the air intake openings walls) were idealized in great detail. The model is detailed to such an extent that in the air intake region, each opening is modeled with regular solid elements. The model contains about 115000 elements.

The results of calculations showed that, with the appropriate load factors, the seismic load combinations were the governing in most cases. The seismic evaluation was performed by a static analysis; and in order to preserve the sign of the loads, the 100/40/40 rule for combination for the 3 seismic components was followed. To evaluate the seismic load combination (DW + Ex + Ey + Ez), the following 24 load cases were evaluated:

- DW ± 100 * Ez ± 40 * Ex ± 40 * Ey
- DW ± 40 * Ez ± 100 * Ex ± 40 * Ey
- DW ± 40 * Ez ± 40 * Ex ± 100 * Ey

3.2 The stress evaluation, for items outside the roof and PCS, was performed considering the PCS tank with the maximum water inventory. The impulsive and convective contributions of seismic sloshing loads were considered in the design.

The post processing of ANSYS result files was performed using ANSYS macros. For each of the evaluated SB roof region, and for all load combinations, envelope values of forces and moments were extracted from ANSYS output, and used to size the required reinforcing steel.

The rebar amount was determined for the critical sections of the Shield Building roof reinforced concrete structure.

The sizing of reinforcing steel in the Air Intake Region was evaluated in detail considering this zone as a grid made up of vertical columns and annular beams (See the sketches in Table 2.2-13, sheets 1 and 2), plus two massive concrete zones that bound the regions above and on the underside of the 'Air Intake' region. Governing forces and moments in each component were extracted from ANSYS output, and the required reinforcing steel was evaluated following the procedure described in the document APP-1000-CC-001 Rev.2 "Verification of Design Macro for Reinforcing Concrete Walls and Floors".

The 3/4" thick surface plates in this region, associated with the columns, carry inplane shear, moment (My) and axial load. The surface plates, associated with the beams carry inplane shear, torsion, moment (Mz) and axial load. The shear and axial stress in the surface plates were then combined to generate Von Mises principal stress. In this region, the seismic loads are the governing.

The same procedure was followed to size the reinforcing in the 'Tension Ring' region where the surface plates carry all the member forces except the out- of- plane shear. In this region also, the seismic load governs.

The reinforcing rebars in the 'Conical Roof' were evaluated using forces and moments extracted from ANSYS output for 12 stress lines roughly evenly distributed on the meridional section of the roof on the centerline between the W36 radial beams. The contribution of the ½" liner was accounted to size the required reinforcing steel, following the same procedure as for the 'Air Intake' region. In all the stress lines within the PCS sloping bottom, in the conical roof, the thermal loads govern.

4.0 Reinforcement Design

4.1 Tension Ring / Air Inlet Region

Figures 1 thru 4 in this document show the details of this region. AS stated above, this region was modeled in great detail in the ANSYS model.

The design of reinforcement in the air inlet region is shown in detail in Figure 2.2-18 (sheet 3 of 7) of TR57. The amount of reinforcement required, and the reinforcement provided, is included in Table 2.2-13 (sheets 1 and 2) of TR57. The tension ring reinforcement calculation is included therein.

4.2 PCCS Tank / Inclined Roof Interface

The stress lines shown on Figure 5 are the locations in the ANSYS model. The design forces and moments were extracted from the ANSYS output at these locations. Stress line 8 is at the critical section location. Table 2.2-13 (sheet 3) of TR57 includes the reinforcement for the critical section location.

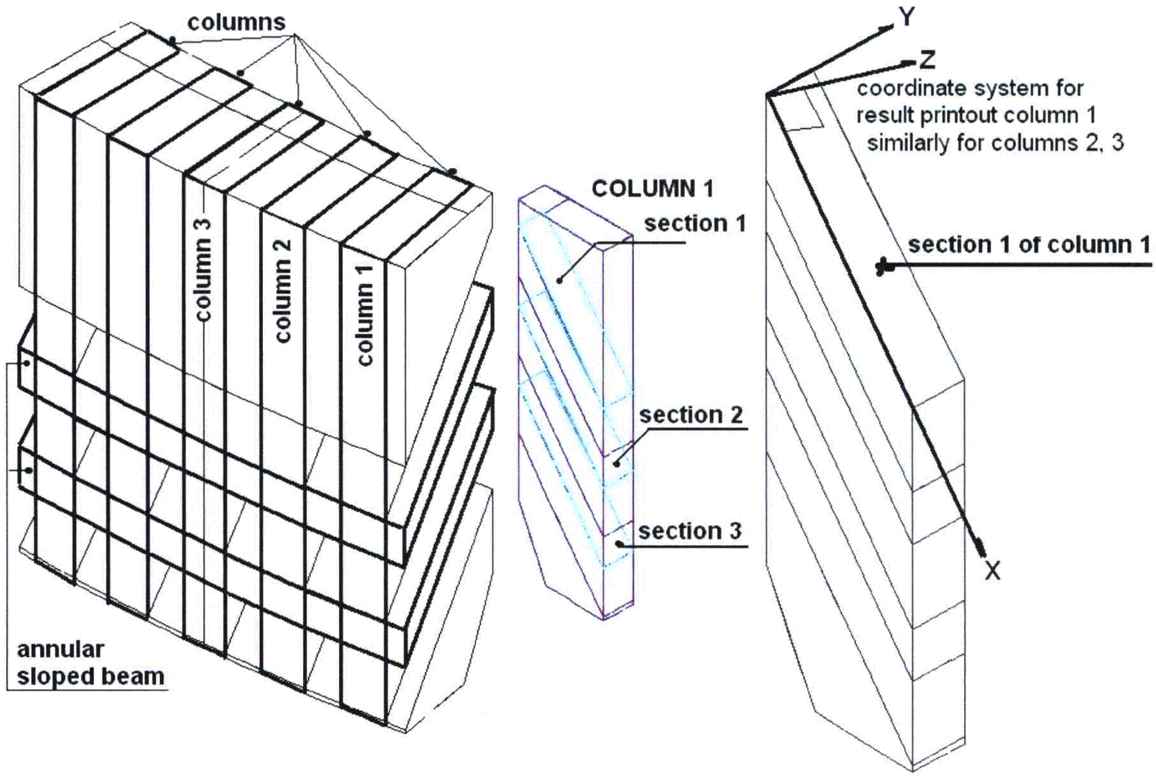

Figure 1

Air Intake Region - Columns: Locations for Design Forces and Moments

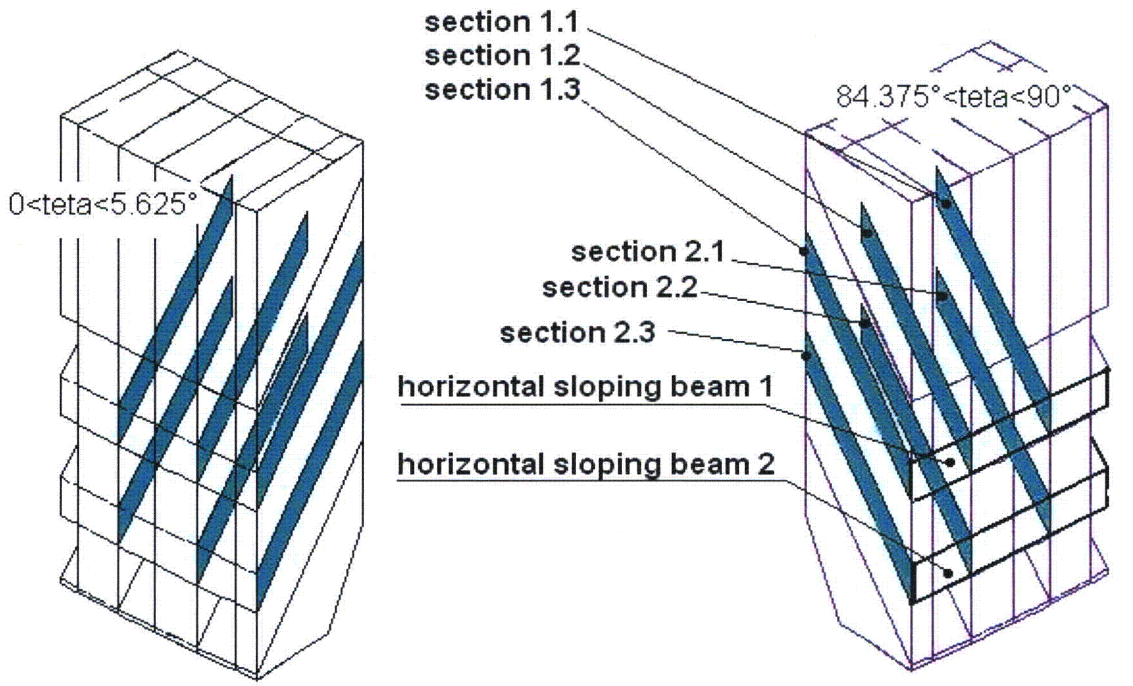

Figure 2

Air Intake Region - Sloping Beams: Locations for Design Forces and Moments

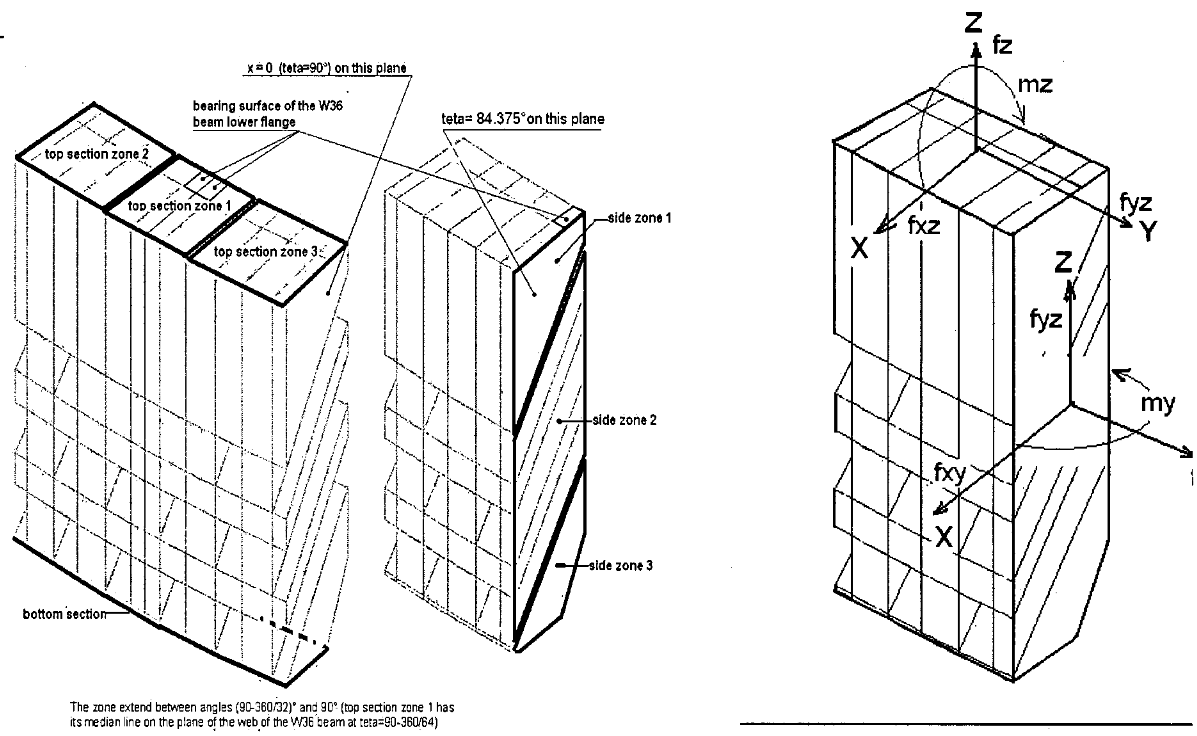

Figure 3

Air Intake Region: Other Locations in Mass Concrete for Design Forces and Moments

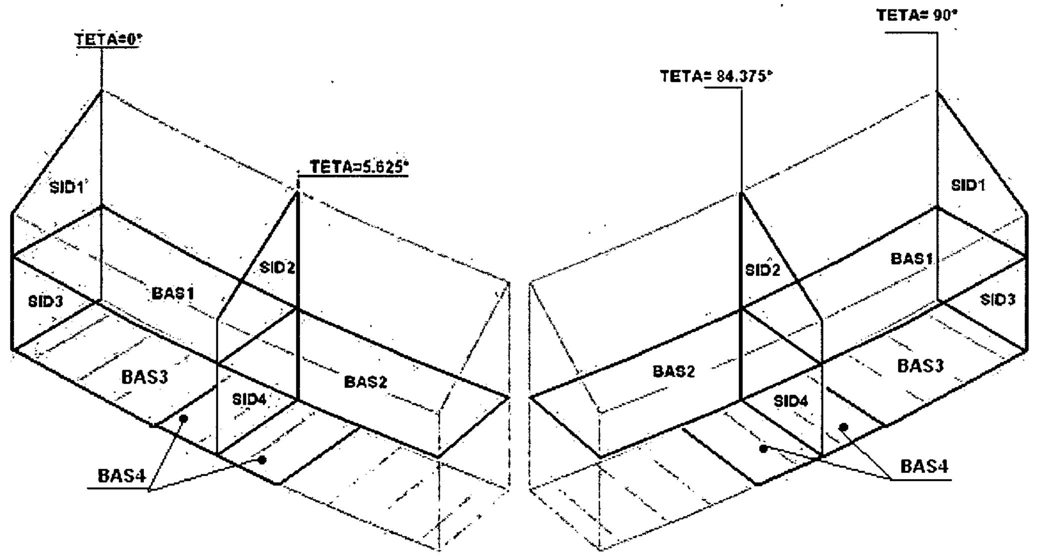

Figure 4

Tension Ring: Locations for Design Forces and Moments

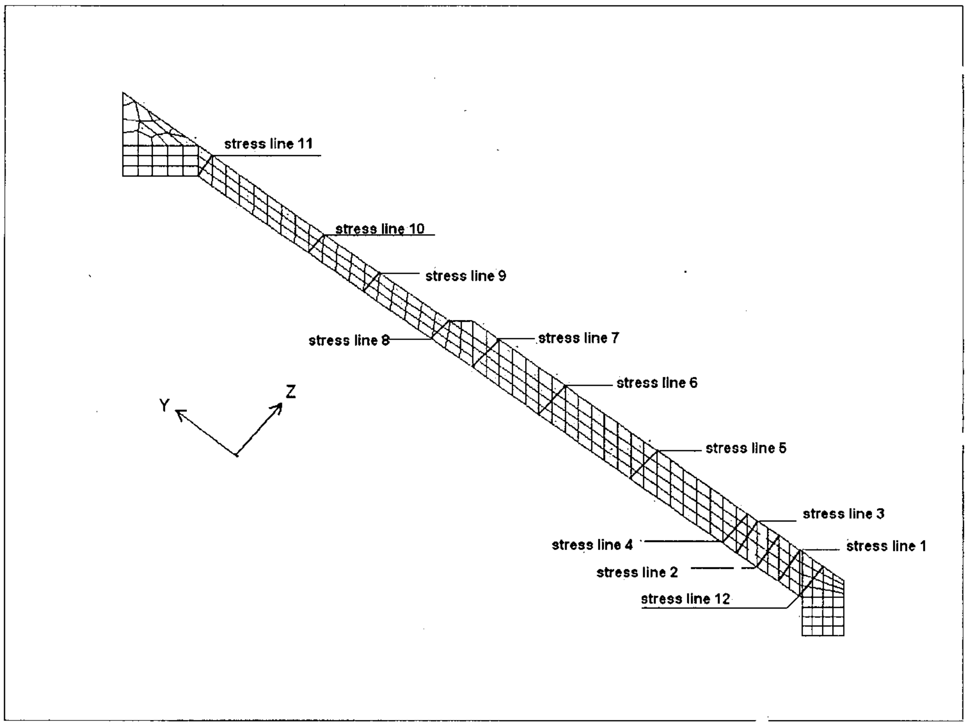

Figure 5

ANSYS Model: Stress Lines Selected on Conical Roof
(Location where design forces and moments were extracted)