BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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This calculation supersedes document 51A-SSC-IH00-00200-000-00A in its entirety

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SEE SECTION 5	220

RECORD OF REVISIONS

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DISCLAIMER

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ACRONYMS AND ABBREVIATIONS

Acronyms

BSC	Bechtel SAIC Company
C.G.	Center of Gravity
CHC	Cask Handling Crane
CTM	Canister Transfer Machine
D/C Ratio	Demand/Capacity Ratio
DBGM-2	Design Basis Ground Motion -2
FEM	Finite Element Model
El	Elevation
HVAC	Heating, Ventilation, Air-Conditioning
ITS	Important To Safety
ITWI	Important To Waste Isolation
PDS	Plant Design System
SRSS	Square Root of the Sum of the Squares
SSC	Structures, Systems, and Components
TAD	Transportation, Aging, and Disposal
WP	Waste Package
3D	Three Dimensional

Abbreviations

IHF	Initial Handling Facility
kcf	kips per cubic foot
ksf	kips per square foot
psf	pounds per square foot

1. PURPOSE

The purpose of this calculation is to develop a finite element model of the Initial Handling Facility (IHF) steel structure with SAP2000 computer program, and to perform a Tier-1 seismic analysis using response spectrum method with DBGM-2 input ground motion. This calculation will also include the preliminary design of the structural steel members subject to prevailing load combination. The results will be used in generating structural steel drawings and also as input to IHF foundation design.

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2.3 DESIGN CONSTRAINTS

There are no design constraints.

2.4 DESIGN OUTPUTS

Design and analysis outputs of this calculation will include the following:

1) Steel member design check including Demand/Capacity ratios.
2) Support reactions for Dead Loads, Live Loads and each earthquake component Ex, Ey and Ez.
3) Maximum displacements and Story Drift considerations.
4) Seismic analysis including modal frequencies and mass participation factors.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Building plan, elevations, and dimensions

Plans and elevations of the IHF building steel structure are shown in Attachment A. These sketches reflect the results of the design and will be incorporated in the steel drawings. They are based on general arrangement (G.A.) drawings (Ref 2.2.7 through 2.2.14), with minor variation in dimensions and/or arrangement of columns. The SAP2000 mathematical model closely represents the steel drawings with respect to some dimensions and location of structural members.

Rationale–The general arrangement drawings were in the process of being changed to reflect the final layout of the IHF structure as shown in the steel drawings including the final arrangement of columns. These minor discrepancies will be addressed during the detail design stage by incorporating all changes into the SAP2000 model of IHF building. Then the steel structure will be reanalyzed to verify that these dimensional and structural variations have no impact on the overall seismic response of the structure and also on the steel member stress levels. This assumption is being tracked in CalcTrac.

Where used: Section 6.4.

3.1.2 Steel structure and concrete structure supported by a common mat foundation.

The IHF building is composed of steel and concrete structures supported on a common mat foundation. However the structures are not connected to each other. The structure-soil-structure interaction will be neglected in the fixed base analysis.

Rationale–The IHF steel structure supports are modeled as pinned connections at the mat, hence there will be no moment transfer to the foundation; however, the translational supports are considered fixed. As such the mat is considered to be rigid. There is also sufficient separation between the two structures as not to interact directly with each other under seismic loads. Therefore, any effect each structure may have on the response of the other structure through structure-soil-structure interaction, will be minimal and can be neglected in this preliminary Tier 1 analysis. This assumption is being tracked in CalcTrac.

Where used: SAP2000 models located in Attachment D/CLC Input and Output files - subfolder

3.1.3 General requirements for consideration of torsion

ASCE 4-98 (Ref 2.2.17) Section 3.1.1.d requires that the model shall represent the actual locations of the center of masses and center of rigidity of elements and equipment. Section 3.1.1 of the ASCE 4-98 also requires that the torsional moments due to accidental eccentricity with respect to the center of rigidity shall be accounted for. In the SAP2000 mathematical model the loads from the crane assemblies have been directly applied along the longitudinal centerline of structural members ignoring any eccentricity. Accidental torsion is not taken into account in the SAP2000 mathematical model for the seismic analysis or steel member selection. However, to account for torsion it was recommended to increase the D/C ratios by 15% at outer columns and 0% at center columns, then linearly interpolate for %increase D/C rations for remaining columns (Refer to Attachment H).

Rationale– Detailed information about the cranes that will be operating in the IHF is not available at this time. This Tier-1 seismic analysis of the IHF is preliminary and its results are used in determining the initial structural member sizes. The finite element model for detailed design will include all eccentricities, and the corresponding calculation will address all issues related to torsion. The 15% maximum increase is based on accidental torsional analysis of other typical structures with a regular layout and represents a reasonable upper bound. This assumption is being tracked in CalcTrac.

Where used: Section 4.3

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Built-up column and girder sectional properties

In the IHF steel structure, built-up column and runway girder sections are used for structural members that support the cranes. For simplicity, in the SAP2000 model tube sections are used with dimensions and wall thicknesses selected in a way to produce similar, and conservative, section properties as built-up sections. See Attachment B for built-up steel section properties calculation.

Rationale–The section properties used in SAP2000 model closely represent the actual built-up column and girder section properties. The small discrepancies in the section properties will not affect the rigidity of the structure nor change the seismic system response in a significant way.

Where used: Section 6.2.

3.2.2 Crane Locations

There are six cranes operating in the IHF building:

1) Canister Transfer Machine Crane (Top of Rail El. 65’-0”).

2) Cask Handling Crane (Top of Rail El. 65’-0”).

3) CTM Maintenance Crane (Top of Rail El.87’-3”).

4) Cask Preparation Crane (Top of Rail El. 87’-3”).

5) WP Closure Room Crane (Top of Rail El. 53’-9”).

6) Remote Handling Crane (Top of Rail El. 44’ - 1”).

There are two variables for the selection of each crane location for the seismic analysis of the IHF steel structure, namely the position of the trolley on the crane bridge and the position of the crane bridge along the runway girder. Seven different crane loadings cases have been selected for analysis. Each Crane Loading Case has all six cranes placed in pre-determined locations as to cause maximum moments and/or maximum shears and/or maximum axial loads and/or maximum displacements in structural members in different parts of the IHF steel structure. Attachment C shows the position on the structure of all 6-cranes for each of the seven Crane Loading Cases analyzed.

Rationale–It will be shown that regardless of which Crane Load Case is used in the analysis, that is, regardless of what position the cranes are placed for analysis, the fundamental frequency of the structure does not change significantly. See Attachment D for fundamental frequencies for each Crane Load Analysis Case. In addition, the frequency band near the maximum accelerations on the input response spectra does not shift any significant amount to affect the seismic response. From member stress consideration point of view the selected crane locations closely envelope all possible combinations of crane positions. Further justification will be provided in the detailed analysis stage.

Where used Section 6.3.1.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref.2.1.1). Section 3.1.2 of the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Ref.2.2.3) classifies the IHF structure as ITS. Therefore the approved record version of this calculation is designated as QA: QA.

4.2 USE OF SOFTWARE

4.2.1 SAP2000 Version 9.1.4

The computer program SAP2000, Version 9.1.4 is used for static and dynamic analysis as well as for the design of structural steel members. SAP2000, Version 9.1.4 is classified as Level 1 software defined in IT-PRO-0011, *Software Management* (Ref. 2.1.2). The SAP2000 Software Validation Report is contained in Ref. 2.2.25. This software is commercially available from Computers and Structures, Inc. (Ref.2.2.21) and is qualified to perform static and dynamic analysis of structural systems. The software is installed on a PC system running the Windows 2000 operating system. SAP2000 is currently listed on the Qualified and Controlled Software Report (SW Tracking Number 11198-9.1.4-00) (Ref.2.2.22) as well as the Repository Project Management Automation Plan Ref. 2.1.3.

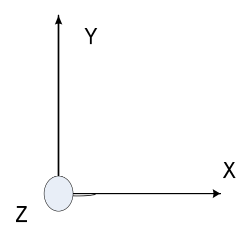
4.2.2 Microsoft Office 2000

Excel 2000 and Word 2000, which are part of the Microsoft Office 2000 Professional suite of programs, were used in this calculation. Microsoft Office 2000 Professional as used in this calculation is classified as Level 2 software defined in IT-PRO-0011, Software Management (Ref. 2.1.2). Microsoft Office 2000 Professional is listed on the current Software Report (SW Tracking Number 610236-2000-00). The software was executed on a personal computer (PC) system running Microsoft Windows XP operating system. Results were confirmed by visual inspection and by performing hand calculations. Excel 2000 was used to tabulate SAP2000 model output in this calculation. Word 2000 was used in the text preparation of this document; no calculation functions contained in Word 2000 were used in this document.

4.3 ANALYSIS METHOD

The IHF building is a bearing-bolted braced frame steel structure delineated by General Arrangement drawings identified in References 2.2.7 thru 2.2.14 and the building primary function is to handle waste containers and/or canisters by means of large industrial capacity overhead cranes.

- The structural analysis and design of the IHF steel framing will be performed using the Finite Element Model SAP2000. The structural steel model orientation is based on the Global Axis as defined in Figure 4.3.1 below. Further description of the FEM model is explained in Section 6.3



Coordinate System-Plan View

Figure 4.3.1 Coordinate System - Plan

- X and Y are horizontal positive directions, and Z is a positive vertical direction originating from the foundation base and extending upwards, using the right hand rule. The Origin (0, 0, 0) occurs at gridline 10-L. See figure 6.4.1 in Attachment A.
- The SAP2000 Analysis manual defines the member axis where the local axis of any steel member, (columns, beams and/or braces), follows the right hand rule. Local axis is defined such that the length of the member is depicted as the local 1-1, with positive direction from the beginning of that member to its opposite end. The strong axis of the member cross section is then assigned as the local 3-3 direction, with positive direction being towards the right, and the weak-axis cross section or minor axis is the local 2-2 axis where positive is up, as defined in Figure 4.3.2 below.

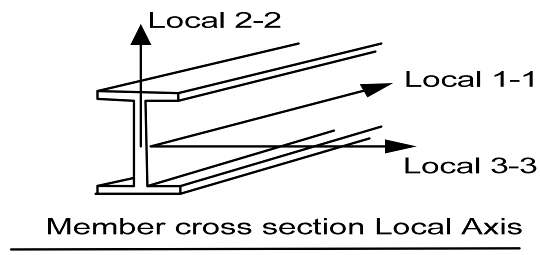


Figure 4.3.2 Member Cross Section Local Axis

- The steel structure is a braced frame structure, where column supports are considered restrained in translational, vertical and rotational directions at column bases. There will be no moment transfer about the translational axes to the foundation mat. The base plate and anchor bolt configuration at the column bases warrant this boundary condition.

- The seismic design input load for the IHF steel structure analysis is based on Design Basis Ground Motion 2 (DBGM-2), 2000-year return period, provided in terms of Acceleration Response Spectra (Ref. 2.2.15). The structural damping value for bearing-bolted steel structures for ITS response level 2, which corresponds to DBGM-2, is 7 % (Ref. 2.2.2, Table 7-1).

- Mass source for dynamic seismic loading is based on Dead Load + 0.25 of the Floor Live Load + 0.25 of the Roof Live Load or 0.75 of the Snow Load + Crane Payload (Ref.2.2.2 and Attachment H). Modal analysis is performed with necessary number of modes to achieve a minimum of 90% of structural mass participation in all three orthogonal directions. For modal combination 10% method is used.

- The response spectrum analysis is performed for two horizontal and one vertical seismic component (X, Y, and Z respectively), using ground response spectral acceleration input motion for 7% damping and dynamic mass source.

- The individual directional results of the seismic response spectrum analysis are combined for each component (X, Y, and Z) of the earthquake input motion using the square-root–of-the-sum-of-the-squares (SRSS) method (Ref. 2.2.2, Section 7.2.7).

- SAP2000 computer program is used in performing the analysis and design of the IHF structure steel frame members. The program only has the option to design the steel member sizes using AISC-ASD (Ref. 2.2.6) in lieu of ANSI/AISC N690 (Ref. 2.2.4) as specified. A comparison of pertinent design allowable stresses for dead and live loads between the two code requirements was performed. The limiting parameters and allowable stress requirements for tension, shear, column and other compression members, bending about the major and minor axes, and for laterally unsupported members are exactly the same for both codes. Therefore, the AISC-ASD steel design requirements adopted in SAP2000 comply with the ANSI/AISC N690 requirements for dead and live loads. AISC-ASD (Ref. 2.2.6 Section A.5.2, page 5-30) allows 1/3 increase in the allowable stresses under seismic and wind loads. This corresponds to a load factor of 1/(1+1/3) = 0.75. ANSI/AISC N690 (Ref. 2.2.4 Table Q1.5.7.1) allows a load factor of 1/1.4 = 0.714. This discrepancy is accounted for in the SAP2000 steel design process by overwriting the default stress increase factor of 1.333 with

1.0. And the load combinations containing seismic loads are multiplied with a load factor of 0.714.

- The base joint reactions will be used as input loads to the IHF foundation mat design. However, the seismic reaction forces obtained from the Response Spectrum Analysis of the IHF Steel Structure have no sign associated with the forces. In order to maintain the directional sign of the reactions the following steps have to be taken in the seismic analysis. The joint accelerations are gathered from separate Response Spectrum Analysis done for each earthquake component, Ex, Ey, and Ez respectively. Then static equivalent joint forces are obtained by multiplying each individual joint's assembled mass by its corresponding acceleration for each of the three earthquake components. To derive the set of static base joint reactions an Equivalent Static Method is performed with the calculated seismic joint forces, Fx, Fy and Fz, using the SAP2000 model of the IHF steel structure (See Attachment E). These equivalent static seismic joint forces are input loads into the SAP2000 model as StaticEX, StaticEY, and StaticEZ. The resulting static base joint reactions are used as input into the SAP2000 foundation mat model. These joint reactions are listed in Attachment E

5. LIST OF ATTACHMENTS

6. BODY OF CALCULATION

6.1 MATERIAL PROPERTIES

Structural Steel: W & WT shapes – ASTM A992/A 992M-06, Fy = 50 ksi, Fu = 65 ksi
Channels, Angles, & Plates – ASTM A36/A 36M-05, Fy = 36 ksi, Fu = 58 ksi
(Ref. 2.2.1, Section 4.2.11.6.1)

6.2 BUILT-UP STEEL SECTION PROPERTIES

There are six built-up steel sections in the IHF steel structure. The properties are calculated and tabulated in Attachment B. In the SAP2000 structural steel model of the IHF building, these built-up sections are input as tube sections with thickness and width/height dimensions such that the sectional properties are equal to the actual built-up section properties. Attachment B shows the built-up sections SAP2000 input properties, as well as their location in the structure. Their section names are BUILDUPCOL, COL1, COL2, COL3, CRANERAIL1 and CRANERAIL2. A comparison of the SAP2000 input section properties and the as-built section properties show that there is no significant difference between them (See Attachment B).

6.3 SAP2000 ANALYSIS CASES

For each of the seven pre-determined Crane Load Cases shown in Attachment C, the following analysis cases have been run in SAP2000 model of IHF steel structure.

Table 6.3.1 Analysis Case Definitions IHF Steel Structure

Case	Type	InitialCond	ModalCase	RunCase
Text	Text	Text	Text	Yes/No
SELF	LinStatic	Zero		Yes
ROOFDEAD	LinStatic	Zero		Yes
ROOFLIVE	LinStatic	Zero		Yes
SNOW	LinStatic	Zero		Yes
PLATFORMDEAD	LinStatic	Zero		Yes
PLATFORMLIVE	LinStatic	Zero		Yes
CLADDING	LinStatic	Zero		Yes
CRANEDEAD	LinStatic	Zero		Yes
CRANELIVE	LinStatic	Zero		Yes
CRANERAIL	LinStatic	Zero		Yes
MODAL	LinModal	Zero		Yes
SRSS	LinRespSpec		MODAL	Yes
EX	LinRespSpec		MODAL	Yes
EY	LinRespSpec		MODAL	Yes
EZ	LinRespSpec		MODAL	Yes

The descriptions of every load case used in the SAP2000 models are listed below:

Table 6.3.2 Load Cases Description

Load Case Name	Load Description
Platformdead	Superimposed dead load on platforms in the steel model
Platformlive	Superimposed live load on platforms in the steel model
Roofdead	Dead load due to superimposed dead load on the steel roof
Cladding	Dead load due to self-weight of cladding
Rooflive	Superimposed live load on the steel roof
Cranedead	Dead load due to the cranes
Cranelive	Live load or payload from the crane
Self	Self-weight of the steel structure
Cranerail	Self-weight of the crane rail (not include in self-weight of steel structure)
Snow	Load due to snow and snow drift
EX	X-direction Response Spectrum Analysis
EY	Y-direction Response Spectrum Analysis
EZ	Z-direction Response Spectrum Analysis
SRSS	SRSS combination of X, Y and Z Response Spectrum Analysis

6.3.1 Crane Load Cases (CLC)

Among many cases studied, seven distinctly different relative crane locations have been selected for the design and analysis of the IHF Building steel structure. There are seven predetermined load cases representing the location and loading of the six cranes located in the IHF Steel Structure. These seven cases as shown with their loading and various locations in the structure captures or envelopes the governing stress distribution of the structural steel frame elements. The analysis cases are called Crane Load Cases (CLC) 1 thru 7 and are shown in Attachment C. Assumption 3.2.2 addresses this selection of the analysis cases. IHF foundation mat calculation will include the results of the studies performed on this subject.

6.4 SAP2000 FEM DEVELOPMENT

The SAP2000 Finite Element Model of the Initial Handling Facility (IHF) closely represents the IHF steel structure layout presented on the general Arrangement Drawings (Ref.2.2.7 thru 2.2.14). The IHF Tier-1 model is developed using the graphical interface within SAP2000. All steel members used are standard AISC frame sections. Area sections represent the platform slab and these sections are further defined as shell elements located along the centerline of the slab. Location, dimensions, and other structural configurations, are obtained from the General Arrangement Drawings (Ref.2.2.7 thru 2.2.14). The origin (0,0,0) of the global coordinate system is located at the intersection of Column Line 10 and Column Line L. Figure 6.4.1 shows the origin for the IHF Tier-1 FEM together with layout of column lines. In Attachment A, the SAP2000 model geometry, plans and elevations, are presented in Figures 6.4.2 thru 6.4.24. In order to facilitate uniformity in selecting structural steel members for design, steel sections with the same properties, are grouped. The groups are named according to their intended structural use such as bracing, columns, etc. The following Table lists all groups used for the analysis and design of the steel members in the SAP2000 Model of the IHF Building Steel Structure. All the input data to the SAP2000 Model is included in Attachment D. For each Crane Load Case (CLC) there is one file that includes all the corresponding data for that specific CLC. There are seven in total and named IHF SAP2000 Analysis Crane Load Case 1, 2, 3, 4, 5, 6 and 7. These files are under directory called "Attachment D - CLC SAP2000 Analysis Input and Output files".

Table 6.4.1 Groups Definition

GroupName	Selection	SectionCut	Steel
Text	Yes/No	Yes/No	Yes/No
All	Yes	Yes	Yes
CRANECOL	Yes	Yes	Yes
SMALLVX	Yes	Yes	Yes
PURLIN	Yes	Yes	Yes
ROOFTRUSS	Yes	Yes	Yes
BUILDINGCOL2	Yes	Yes	Yes
SMALLHX	Yes	Yes	Yes
ROOFHX	Yes	Yes	Yes
LOWERPURLIN	Yes	Yes	Yes
LOWERROOFBEAM1	Yes	Yes	Yes
LOWERROOFBEAM2	Yes	Yes	Yes
LOWERROOFHX	Yes	Yes	Yes
HORZBEAM	Yes	Yes	Yes
TRUSTSMALL	Yes	Yes	Yes
BRACE@37	Yes	Yes	Yes
BRACE@65	Yes	Yes	Yes
BRACE@65UP	Yes	Yes	Yes
SINGLECOL	Yes	Yes	Yes
BUILDINGCOL65UP	Yes	Yes	Yes
BUILDINGCOL65DOWN	Yes	Yes	Yes
ATTACHCOL	Yes	No	No
ATTACHCOL2	Yes	Yes	Yes
ATTACHCOL3	Yes	Yes	Yes
SMALL1	Yes	Yes	Yes
SMALL@65	Yes	Yes	Yes
SMALL2	Yes	Yes	Yes
TRUSS@65	Yes	Yes	Yes
SMALLT@65	Yes	Yes	Yes
BRACE@98	Yes	Yes	Yes
ALLX	Yes	Yes	No
CraneStress	Yes	Yes	Yes
CLADCOL	Yes	No	No
SMALLHX@87	Yes	Yes	Yes
SMALLHX@65	Yes	Yes	Yes

Table 6.4.2 Frame Steel Section Properties

SectionName	Material	Shape	Area	TorsConst	I33	I22	TotalWt
Text	Text	Text	ft2	ft4	ft4	ft4	Kip
BUILDUPCOL	STEEL	Box/Tube	1.4412	1.091708	1.729849	0.438851	137.726
COL1	STEEL	Box/Tube	1.77	3.850856	2.573875	2.573875	112.763
COL2	STEEL	Box/Tube	0.9624	1.487114	0.80107	1.440372	61.312
COL3	STEEL	Box/Tube	1.0545	1.143443	1.003648	0.683398	33.591
CRANERAIL1	STEEL	Box/Tube	1.1584	0.899074	1.446272	0.358229	279.304
CRANERAIL2	STEEL	Box/Tube	0.6412	0.398785	0.557591	0.16631	332.431
W10X49	STEEL	I/Wide Flange	0.1	0.000067	0.013117	0.004504	38.971
W10X68	STEEL	I/Wide Flange	0.1389	0.000172	0.019001	0.006462	140.454
W12X19	STEEL	I/Wide Flange	0.0387	0.000008681	0.006269	0.000181	0.234
W12X65	STEEL	I/Wide Flange	0.1326	0.000105	0.025704	0.008391	546.982
W14X109	STEEL	I/Wide Flange	0.2222	0.000343	0.059799	0.021557	11.816
W14X132	STEEL	I/Wide Flange	0.2694	0.000593	0.073785	0.026427	496.771
W14X159	STEEL	I/Wide Flange	0.3243	0.00095	0.091628	0.036073	1106.381
W14X211	STEEL	I/Wide Flange	0.4306	0.002151	0.128279	0.049672	884.421
W14X426	STEEL	I/Wide Flange	0.8681	0.015963	0.318287	0.113812	33.607
W14X68	STEEL	I/Wide Flange	0.1389	0.000145	0.034819	0.005835	186.938
W14X90	STEEL	I/Wide Flange	0.184	0.000196	0.048177	0.017458	1101.444
W18X119	STEEL	I/Wide Flange	0.2437	0.000511	0.105613	0.012201	32.013
W18X35	STEEL	I/Wide Flange	0.0715	0.000024	0.024595	0.000738	2.892
W18X40	STEEL	I/Wide Flange	0.0819	0.000039	0.029514	0.000921	1.486
W24X131	STEEL	I/Wide Flange	0.2674	0.000458	0.193866	0.016397	26.205
W24X146	STEEL	I/Wide Flange	0.2986	0.000646	0.220872	0.018856	149.118
W24X176	STEEL	I/Wide Flange	0.359	0.001153	0.27392	0.0231	8.357
W24X250	STEEL	I/Wide Flange	0.5104	0.003212	0.409433	0.034915	30.016
W24X76	STEEL	I/Wide Flange	0.1556	0.000129	0.101273	0.003979	2.821
W30X148	STEEL	I/Wide Flange	0.3021	0.000699	0.322145	0.010947	5.477
W36X230	STEEL	I/Wide Flange	0.4694	0.001379	0.72338	0.045332	25.536
W36X260	STEEL	I/Wide Flange	0.5313	0.002001	0.834298	0.052566	77.062
W36X300	STEEL	I/Wide Flange	0.6132	0.003096	0.978974	0.062693	745.472
W36X328	STEEL	I/Wide Flange	0.6694	0.004056	1.085069	0.06848	1037.106
W36X393	STEEL	I/Wide Flange	0.8056	0.0068	1.326196	0.084394	646.339
W8X24	STEEL	I/Wide Flange	0.0492	0.000017	0.003988	0.000883	29.234
W8X31	STEEL	I/Wide Flange	0.0633	0.000026	0.005305	0.001789	9.98
W8X40	STEEL	I/Wide Flange	0.0812	0.000054	0.007041	0.002368	54.221
W8X58	STEEL	I/Wide Flange	0.1188	0.000161	0.010995	0.003622	333.138

6.5 SAP2000 INPUT LOADING AND LOAD COMBINATIONS

6.5.1 Applied Dead and Live Loads

Loads used in this calculation are documented in the *IHF Design Loads for the Steel and Concrete Structures* calculation (Ref.2.2.5). Table 6.5.1 below lists the SAP2000 load names, corresponding load descriptions and the percentage of loads used for calculating mass for seismic analysis.

Table 6.5.1 SAP2000 Loading Input

Load Description	SAP2000 Load Name	Applied Load	Seismic Mass Participation
Roof Dead Load	ROOFDEAD	25psf	100%
Roof Live Load	ROOFLIVE	20psf	25%
Steel Platform Dead Load	PLATFORMDEAD	100psf	100%
Steel Platform Live Load	PLATFORMLIVE	100psf	25%
Concrete Slab Platform	SELF	none	100%
Structure self weight	SELF	none	100%
Cladding	CLADDING	25psf	100%
Crane Dead Loads	CRANEDEAD	Ref.2.2.5	100%
Crane Live Loads	CRANELIVE	Ref.2.2.5	25%
Crane Rail Load	CRANERAIL	100plf	100%
Snow Load	SNOW	Ref.2.2.5	75%

6.5.2 Load Combinations

Section 4.2.11.4 of PDC (Ref. 2.2.1) specifies the structural design criteria for ITS structures. For structural steel, the following loading combinations are extracted from (Ref.2.2.1 Section 4.2.11.4.6).

1. $S = D+L+(L_r \text{ or } A)$
2. $S = D+L+S_N$
3. $S = D+L+L_r+W$
4. $S = D+L+S_N+W$
5. $1.4S = D+L+L_r+E$
6. $1.4S = D+L+S_N+E$
7. $1.4S = D+L+L_r+W_t$
8. $1.4S = D+L+S_N+W_t$

where:

A = Ash load
D = Dead load (includes cladding, platform, roof and crane dead loads and structure self weight)
L = Live load (includes crane and platform live load)

L_r = Roof live load
S_N = Snow load
E = Earthquake (seismic) load resulting from DBGM-2 seismic level input
S = Allowable stress per allowable stress design (ASD) method
W = Wind load
W_t = Tornado load

Note: According to SADA (Ref. 2.2.2), Section 8.3.3, the stress increase factor, k, for compression in members and shear in members shall be 1.4 for earthquake load combinations. A similar requirement exists in ANSI/ASCE N690 (Ref. 2.2.4), Supplement No. 2, Table Q1.5.7.1, Footnote k, restricts the stress limit coefficient to 1.5 for both earthquake and tornado loading combinations. Conservatively, the SADA limit of 1.4S shall be used for both the earthquake and tornado loading combinations. Section 4.2.11.4.6 of Ref. 2.2.1 has several additional load combinations that have loads such as H (Lateral earth pressure load), T_a (Thermal load during accident condition), T_o (Thermal load during normal operating conditions), F (Fluid load), F' (Buoyant force of design basis flood), and R_o (Operating pipe reaction load). These loads are not applicable for the IHF Steel Structure and, therefore, load combinations containing these loads are not included in this calculation. In addition load combinations including wind and tornado loads are not taken in consideration when designing the steel members as those load combination cases do not govern when compared to load combinations including seismic loads. Hence, the critical load combinations used in this calculation for the design of steel members, and for obtaining maximum deflections and support reactions are summarized as following:

1. S = D + L
2. 1.4S = D + 0.25L + SRSS
3. 1.4S = D + S_N + SRSS
4. 1.4S = 0.9D + SRSS

6.6 MODAL ANALYSIS

An Eigenvalue Modal Analysis is performed on the IHF Tier-1 FEM to determine the modeshapes and frequencies of the steel structure. A fixed base boundary condition is applied to the base mat joints. The mass source used in the modal analysis is shown on Table 6.6.2 and the model includes 100% of all dead loads, 25% of live loads and/or 75% of snow loads and 100% of the crane payload (Reference Attachment H). The mass is generated from these loads by SAP2000 program internally and applied in three orthogonal directions.

Table 6.6.1 Modal Analysis General Information

Case	ModeType	MaxNumModes	MinNumModes	EigenShift	EigenCutoff	EigenTol
Text	Text	Unitless	Unitless	Cyc/sec	Cyc/sec	Unitless
MODAL	Eigen	800	1	0	50	0.0000001

Within the 800 modes, cumulative mass participation is 99.3% for X-direction, 98.1% for Y-direction, and 89.1% for Z-direction. Table 6.6.3 shows the dominant fundamental frequencies of the IHF Steel Structure in three orthogonal directions. At 800^{th} mode the frequency is 39.4Hz. Hence the cutoff frequency is not reached, however the required mass participation ratios are achieved.

Table 6.6.2 Mass Source

MassFrom	LoadCase	Multiplier
Text	Text	Unitless
All	PLATFORMDEAD	1
All	PLATFORMLIVE	0.25
All	CRANELIVE	0.25
All	CLADDING	1
All	CRANERAIL	1
All	ROOFDEAD	1
All	ROOFLIVE	0.25
All	CRANEDEAD	1
All	SNOW	0.75

Table 6.6.3 Modal Analysis Results

Crane Load Cases	X - Direction				Y - Direction				Z - Direction			
	Mode #	Mass Part. %	Period (sec)	Freq. Hz	Mode #	Mass Part. %	Period (sec)	Freq. Hz	Mode #	Mass Part. %	Period (sec)	Freq. Hz
CLC1	1	78.7	0.407	2.454	2	63.0	0.277	3.604	77	23.01	0.116	8.642
CLC2	1	72.4	0.428	2.335	3	63.9	0.276	3.623	75	23.41	0.115	8.700
CLC3	1	72.9	0.427	2.343	2	64.4	0.266	3.763	77	23.48	0.115	8.681
CLC4	1	79.1	0.410	2.441	3	63.0	0.267	3.748	75	23.60	0.116	8.642
CLC5	1	76.7	0.416	2.404	2	63.4	0.277	3.610	76	22.47	0.113	8.816
CLC6	1	75.6	0.420	2.383	3	65.0	0.265	3.774	77	23.64	0.117	8.583
CLC7	1	76.2	0.418	2.393	3	64.8	0.266	3.766	78	23.93	0.116	8.642

For all periods, frequencies and modal participation factors of all seven Crane Load Cases (CLC) see Attachment D. The corresponding file names on the CD that includes Attachment D are listed in section 6.4 of this calculation.

6.7 RESPONSE SPECTRUM ANALYSIS

The seismic design load input for the IHF steel structure analysis is based on Design Basis Ground Motion 2 (DBGM-2), 2000-year return period, provided in terms of Acceleration Response Spectra (Ref. 2.2.15). The structural damping value for bearing-bolted steel structures for ITS response level 2 (corresponding to DBGM-2) is 7 % (Ref. 2.2.2, Table 7-1). The response spectrum analysis is performed for two horizontal and a vertical seismic component (X, Y, and Z respectively), using ground response spectral accelerations for 7% damping and dynamic mass source. The individual directional results of the seismic response spectrum analysis are combined for each component (X, Y, and Z) of the earthquake input motion using the square-root–of-the-sum-of-the-squares (SRSS) method (Ref. 2.2.2, Section 7.2.7).

Table 6.7.1 Response Spectrum Analysis General Information

Case	ModalCombo	DampingType	ConstDamp
Text	Text	Text	Unitless
SRSS	10 Percent	Constant	0.07
EX	10 Percent	Constant	0.07
EY	10 Percent	Constant	0.07
EZ	10 Percent	Constant	0.07

Table 6.7.2 (Not Used)

Table 6.7.3 Response Spectrum Input Function - Horizontal

Name	Period	Accel	FuncDamp
Text	Sec	Unitless	Unitless
RESPHORZ	0.01	0.4537	0.07
RESPHORZ	0.011	0.47	
RESPHORZ	0.0123	0.4911	
RESPHORZ	0.0142	0.5161	
RESPHORZ	0.0167	0.5373	
RESPHORZ	0.0201	0.5638	
RESPHORZ	0.0248	0.596	
RESPHORZ	0.0335	0.65	
RESPHORZ	0.0498	0.739	
RESPHORZ	0.1	1.0267	
RESPHORZ	0.1098	1.0218	
RESPHORZ	0.1233	1.0125	
RESPHORZ	0.1417	1.0019	
RESPHORZ	0.1668	0.9904	
RESPHORZ	0.2009	0.9562	
RESPHORZ	0.2477	0.8916	
RESPHORZ	0.3352	0.8025	
RESPHORZ	0.4977	0.6778	
RESPHORZ	1	0.3746	
RESPHORZ	1.1233	0.332	
RESPHORZ	1.2618	0.2942	

Table 6.7.3 Response Spectrum Input Function – Horizontal (continued)

Name	Period	Accel	FuncDamp
Text	Sec	Unitless	Unitless
RESPHORZ	1.4174	0.2607	0.07
RESPHORZ	1.6681	0.2153	
RESPHORZ	2.0092	0.1701	
RESPHORZ	2.4771	0.124	
RESPHORZ	3.3512	0.0747	
RESPHORZ	4.9776	0.037	
RESPHORZ	10	0.009784	

Table 6.7.4 Response Spectrum Input Function - Vertical

Name	Period	Accel	FuncDamp
Text	Sec	Unitless	Unitless
RESPVERT	0.01	0.3194	0.07
RESPVERT	0.011	0.3369	
RESPVERT	0.0123	0.36	
RESPVERT	0.0142	0.3742	
RESPVERT	0.0167	0.4004	
RESPVERT	0.0201	0.4334	
RESPVERT	0.0248	0.4758	
RESPVERT	0.0335	0.5473	
RESPVERT	0.0498	0.6652	
RESPVERT	0.1	0.7169	
RESPVERT	0.1098	0.6937	
RESPVERT	0.1233	0.6629	
RESPVERT	0.1417	0.6261	
RESPVERT	0.1668	0.5833	
RESPVERT	0.2009	0.5371	
RESPVERT	0.2477	0.4904	
RESPVERT	0.3352	0.4323	
RESPVERT	0.4977	0.3641	
RESPVERT	1	0.1939	
RESPVERT	1.1233	0.1726	
RESPVERT	1.2618	0.1543	
RESPVERT	1.4174	0.1371	
RESPVERT	1.6681	0.1166	
RESPVERT	2.0092	0.0961	
RESPVERT	2.4771	0.0668	
RESPVERT	3.3512	0.038	
RESPVERT	4.9776	0.0172	
RESPVERT	10	0.004382	

Table 6.7.5 Modal Participating Mass Ratios For Crane Load Case 5 (CLC5)

StepType	Mode#	Period	UX	UY	UZ	SumUX	SumUY	SumUZ
Text		Sec	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
Mode	1	4.17E-01	7.67E-01	5.20E-04	4.03E-10	7.67E-01	5.20E-04	4.03E-10
Mode	2	2.78E-01	1.03E-03	6.34E-01	1.17E-05	7.68E-01	6.34E-01	1.17E-05
Mode	3	2.54E-01	2.63E-03	2.39E-03	9.54E-05	7.71E-01	6.37E-01	1.10E-04
Mode	4	2.41E-01	1.65E-06	4.28E-05	2.09E-03	7.71E-01	6.37E-01	2.19E-03
Mode	5	2.32E-01	5.80E-02	4.66E-05	8.16E-06	8.29E-01	6.37E-01	2.20E-03
Mode	6	2.31E-01	1.10E-04	2.73E-08	5.80E-04	8.29E-01	6.37E-01	2.78E-03
Mode	7	2.28E-01	4.21E-05	2.48E-05	8.51E-03	8.29E-01	6.37E-01	1.13E-02
Mode	8	2.12E-01	5.63E-05	4.84E-05	1.00E-02	8.29E-01	6.37E-01	2.13E-02
Mode	9	2.11E-01	6.90E-04	2.89E-07	9.80E-04	8.30E-01	6.37E-01	2.23E-02
Mode	10	2.02E-01	1.05E-05	5.61E-03	2.37E-05	8.30E-01	6.43E-01	2.23E-02
Mode	465	4.07E-02	4.95E-06	1.50E-04	2.86E-03	9.84E-01	9.69E-01	8.01E-01
Mode	466	4.06E-02	1.21E-05	1.20E-04	5.41E-05	9.84E-01	9.69E-01	8.01E-01
Mode	467	4.04E-02	1.12E-05	3.00E-04	2.09E-05	9.84E-01	9.69E-01	8.01E-01
Mode	468	4.04E-02	5.50E-05	4.69E-06	2.11E-05	9.84E-01	9.69E-01	8.01E-01
Mode	469	4.03E-02	4.10E-04	1.48E-05	9.20E-04	9.84E-01	9.69E-01	8.02E-01
Mode	470	4.02E-02	6.12E-06	9.05E-05	2.35E-07	9.84E-01	9.69E-01	8.02E-01
Mode	471	4.02E-02	1.10E-04	1.40E-04	2.36E-05	9.84E-01	9.70E-01	8.02E-01
Mode	472	4.00E-02	5.86E-05	1.60E-04	1.90E-04	9.85E-01	9.70E-01	8.02E-01
Mode	473	3.99E-02	2.44E-05	1.80E-04	1.21E-07	9.85E-01	9.70E-01	8.02E-01
Mode	474	3.99E-02	1.27E-05	2.00E-04	4.92E-06	9.85E-01	9.70E-01	8.02E-01
Mode	475	3.98E-02	7.69E-05	2.12E-05	2.60E-04	9.85E-01	9.70E-01	8.02E-01
Mode	790	2.57E-02	3.28E-07	1.72E-05	1.13E-07	9.93E-01	9.81E-01	8.90E-01
Mode	791	2.57E-02	1.67E-05	4.91E-05	6.99E-05	9.93E-01	9.81E-01	8.91E-01
Mode	792	2.57E-02	4.20E-06	1.67E-05	1.51E-09	9.93E-01	9.81E-01	8.91E-01
Mode	793	2.56E-02	5.86E-06	4.58E-05	4.67E-05	9.93E-01	9.81E-01	8.91E-01
Mode	794	2.56E-02	1.19E-05	3.20E-07	9.15E-06	9.93E-01	9.81E-01	8.91E-01
Mode	795	2.56E-02	2.18E-07	1.22E-06	9.07E-05	9.93E-01	9.81E-01	8.91E-01
Mode	796	2.56E-02	4.18E-05	8.15E-06	3.07E-05	9.94E-01	9.81E-01	8.91E-01
Mode	797	2.55E-02	4.43E-09	2.18E-05	1.30E-04	9.94E-01	9.81E-01	8.91E-01
Mode	798	2.55E-02	1.86E-06	5.27E-06	1.35E-05	9.94E-01	9.81E-01	8.91E-01
Mode	799	2.54E-02	1.20E-06	9.24E-07	1.60E-04	9.94E-01	9.81E-01	8.91E-01
Mode	800	2.54E-02	1.14E-05	1.45E-05	3.66E-05	9.94E-01	9.81E-01	8.91E-01

Note:
For Modal Participating Mass Ratios of other Crane Load Analysis Cases see Attachment D.

6.8 STRUCTURAL STEEL DESIGN

The selection of structural steel members is determined by the SAP2000 (Ref 2.2.21). All load combinations used by SAP2000 are defined in Table 6.8.1 below and are in agreement with the Project Design Criteria load combinations (Section 6.5.2 of this calculation).

Table 6.8.1 Load Combination Definitions for Steel Design

ComboName	ComboType	CaseType	CaseName	ScaleFactor	SteelDesign
Text	Text	Text	Text	Unitless	Yes/No
DL	Linear Add	Linear Static	CLADDING	1	No
DL		Linear Static	CRANEDEAD	1	
DL		Linear Static	PLATFORMDEAD	1	
DL		Linear Static	ROOFDEAD	1	
DL		Linear Static	SELF	1	
DL		Linear Static	CRANERAIL	1	
LL	Linear Add	Linear Static	CRANELIVE	1	No
LL		Linear Static	PLATFORMLIVE	1	
LL		Linear Static	ROOFLIVE	1	
D+L+SRSS	Linear Add	Response Combo	DL	0.714	No
D+L+SRSS		Response Combo	LL	0.1785	
D+L+SRSS		Response Spectrum	SRSS	0.714	
0.9DL+SRSS	Linear Add	Response Combo	DL	0.643	No
0.9DL+SRSS		Response Spectrum	SRSS	0.714	
D+S+SRSS	Linear Add	Response Combo	DL	0.714	No
D+S+SRSS		Linear Static	SNOW	0.714	
D+S+SRSS		Response Spectrum	SRSS	0.714	
D+S+SRSS		Linear Static	CRANELIVE	0.1785	
D+L	Linear Add	Response Combo	DL	1	No
D+L		Response Combo	LL	1	
ENVELOPE	Envelope	Response Combo	0.9DL+SRSS	1	Yes
ENVELOPE		Response Combo	D+L	1	
ENVELOPE		Response Combo	D+L+SRSS	1	
ENVELOPE		Response Combo	D+S+SRSS	1	

The IHF is composed of a large amount of steel members with different steel section properties. Based on their structural function, these members were classified into 33 groups (Table 6.4.1). However some members may have been included in more than one group. The member selection was made based on the most highly stressed member per group. The same selection was then conservatively used for all the members of that group. The most highly stressed member in each group, the Demand/Capacity (D/C) ratios in those members, and the section selected steel check data sheets generated by SAP2000 are listed in Attachment D. All the inputs used to generate the model and the base joint reactions due to governing load combinations are also listed as outputs in Attachment D.

7. RESULTS AND CONCLUSIONS

7.1 RESULTS

7.1.1 Maximum Joint Accelerations

Attachment F lists the maximum accelerations in the IHF Steel Structure. The global X axis pertains to the North – South direction, the global Y axis pertains to the East – West direction, and global Z axis is in the vertical direction. The maximum accelerations in the horizontal and vertical direction due the load combination, "SRSS", are shown in Table 7.1.1 through 7.1.5 below. Five elevations are selected for the accelerations, 26.75 ft, 37 ft, 65 ft, 87.25 ft and 104.5 ft. Elevation 26.75 ft and 37 ft are two platforms, elevation 65 ft is where the major cranes are located, elevation 87 ft is where the maintenance cranes are located and the highest point in the building is EL 104.5 ft. The enveloped maximum accelerations are extracted from SAP2000 analysis computer output (Attachment F).

For a typical IHF steel building acceleration refer to Table 7.1.6, which is due to crane load case 5 (CLC5).

Table 7.1.1 Maximum Accelerations at EL. 26.75 FT – SAP2000 Output

Load Case	North - South Accelerations		East - West Accelerations		Vertical Accelerations	
	Joint ID	U1 (G's)	Joint ID	U2 (G's)	Joint ID	U3 (G's)
CLC1	223	1.48	228	1.87	220	0.35
CLC2	223	1.70	228	2.07	220	0.33
CLC3	222	1.68	228	1.82	220	0.34
CLC4	223	1.37	228	1.96	220	0.34
CLC5	223	1.53	228	1.76	220	0.32
CLC6	223	1.39	228	1.96	220	0.34
CLC7	222	1.72	228	2.26	220	0.33
Max.	222	1.72	228	2.26	220	0.35

Note 1: All accelerations listed in the table above, are selected from joints that connect all major structural column members.
Note 2: All accelerations listed in the table come from the SRSS combination, which is described in Section 4.3.

Table 7.1.2 Maximum Accelerations at EL. 37 FT – SAP2000 Output

Load Case	North - South Accelerations		East - West Accelerations		Vertical Accelerations	
	Joint ID	U1 (G's)	Joint ID	U2 (G's)	Joint ID	U3 (G's)
CLC1	496	1.17	380	1.81	372	0.48
CLC2	486	1.51	380	2.14	372	0.46
CLC3	486	1.42	375	1.77	372	0.47
CLC4	486	1.23	375	1.86	372	0.47
CLC5	486	1.11	380	1.74	372	0.45
CLC6	439	1.26	380	1.83	372	0.47
CLC7	486	1.39	380	2.26	372	0.46
Max.	486	1.51	380	2.26	372	0.48

Note 1: All accelerations listed in the table above, are selected from joints that connect all major structural column members.
Note 2: All accelerations listed in the table come from the SRSS combination, which is described in Section 4.3.

Table 7.1.3 Maximum Accelerations at EL. 65 FT – SAP2000 Output

Load Case	North - South Accelerations		East - West Accelerations		Vertical Accelerations	
	Joint ID	U1 (G's)	Joint ID	U2 (G's)	Joint ID	U3 (G's)
CLC1	859	1.23	798	1.93	875	0.84
CLC2	833	1.25	793	2.07	834	0.77
CLC3	838	1.25	793	2.05	790	0.76
CLC4	859	1.29	798	2.04	854	0.76
CLC5	859	1.26	793	1.90	834	0.88
CLC6	875	1.64	798	2.10	876	0.80
CLC7	812	1.66	798	2.13	812	0.75
Max.	812	1.66	798	2.13	834	0.88

Note 1: All accelerations listed in the table above, are selected from joints that connect all major structural column members, as well as the joints along the crane rails at the above elevation (65'-0").
Note 2: All accelerations listed in the table come from the SRSS combination, which is described in Section 4.3.

Table 7.1.4 Maximum Accelerations at EL. 87 FT – SAP2000 Output

Load Case	North - South Accelerations		East - West Accelerations		Vertical Accelerations	
	Joint ID	U1 (G's)	Joint ID	U2 (G's)	Joint ID	U3 (G's)
CLC1	1133	1.57	1058	1.89	1056	1.36
CLC2	1133	1.54	1058	1.89	1086	1.48
CLC3	1133	1.62	1063	2.20	1083	1.70
CLC4	1110	1.50	1175	2.13	1152	1.74
CLC5	1133	1.49	1175	2.25	1128	1.91
CLC6	1133	1.54	1176	2.03	1152	1.61
CLC7	1082	1.54	1175	2.06	1083	1.66
Max.	1133	1.62	1175	2.25	1128	1.91

Note 1: All accelerations listed in the table above, are selected from joints that connect all major structural column members, as well as the joints along the crane rails at the above elevation (87'-3").
Note 2: All accelerations listed in the table come from the SRSS combination, which is described in Section 4.3.

Table 7.1.5 Maximum Accelerations at EL. 104.5 FT – SAP2000 Output

Load Case	North - South Accelerations		East - West Accelerations		Vertical Accelerations	
	Joint ID	U1 (G's)	Joint ID	U2 (G's)	Joint ID	U3 (G's)
CLC1	1383	1.24	1453	1.45	1359	0.95
CLC2	1383	1.33	1453	1.48	1360	0.92
CLC3	1383	1.33	1454	1.50	1363	0.99
CLC4	1383	1.31	1454	1.50	1503	1.01
CLC5	1383	1.32	1453	1.45	1360	0.90
CLC6	1383	1.39	1454	1.50	1503	1.00
CLC7	1359	1.43	1454	1.51	1363	0.95
Max.	1359	1.43	1454	1.51	1503	1.01

Note 1: All accelerations listed in the table above, are selected from joints that connect all major structural column members.
Note 2: All accelerations listed in the table come from the SRSS combination, which is described in Section 4.3.

The maximum accelerations tabulated in Table 7.1.6, results from crane load case 5 (CLC5) analyses and is representative of a frame along column line 7, which is represented by column H-7. See Attachment F\Joint Displacements and Acceleration\Joint Selection Figures for Displacement and Acceleration.xls.

Table 7.1.6 Maximum Accelerations

Elevation (ft)	Joint Label	North - South (g)	East - West (g)	Vertical (g)
104.5	1453	1.16	1.45	0.57
87.25	1130	1.17	1.25	0.50
65	856	1.00	1.04	0.41
0	-	0.45	0.45	0.32

7.1.2 Maximum Joint Displacements

Attachment F lists the maximum deflections in the IHF Steel Structure. The global X axis pertains to the North – South direction, the global Y axis pertains to the East – West direction, and global Z axis is in the vertical direction. The maximum deflections in the horizontal and vertical direction due to the load combination, "Envelope", are shown in Table 7.1.7 through 7.1.11 below. Five elevations are selected for the displacements, 26.75 ft, 37 ft, 65 ft, 87.25 ft and 104.5 ft. Elevation 26.75 ft and 37 ft are two platforms, elevation 65 ft is where the major cranes are located, elevation 87 ft is where the maintenance cranes are located and the highest point in the building is EL 104.5 ft. The enveloped maximum and minimum displacements are extracted from SAP2000 analysis computer output (Refer to Attachment F) and only the absolute maximum values are tabulated below. It should be noted that these displacements have to be multiplied by a factor of 1.4 since in the SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

For a typical IHF steel building frame displacement, refer to Table 7.1.12, which is due to crane load case 5 (CLC5).

Table 7.1.7 Maximum Displacements at EL. 26.75 FT – SAP2000 Output

Load Case	North - South Displacements			East - West Displacements			Vertical Displacements		
	Joint ID	U1 (in)	U1x1.4 (in)	Joint ID	U2 (in)	U1x1.4 (in)	Joint ID	U3 (in)	U1x1.4 (in)
CLC1	273	0.38	0.53	223	0.50	0.70	252	0.10	0.14
CLC2	240	0.38	0.53	223	0.57	0.80	253	0.11	0.15
CLC3	235	0.40	0.56	223	0.56	0.78	236	0.11	0.15
CLC4	273	0.41	0.57	223	0.54	0.76	252	0.10	0.14
CLC5	266	0.38	0.53	223	0.50	0.70	252	0.11	0.15
CLC6	260	0.44	0.62	223	0.55	0.77	253	0.10	0.14
CLC7	235	0.46	0.64	223	0.54	0.76	236	0.10	0.14
Max.	235	0.46	0.64	223	0.57	0.80	252	0.11	0.15

Note 1: All displacements listed in the table above, are selected from joints that connect all major structural column members.
Note 2: Displacements are based on load combination, "ENVELOPE" (See Section 6.8), and are multiplied by a factor of 1.4 since in SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

The maximum absolute factored displacement at EL 26.75 ft. in the North – South (X) direction is 0.64". The North – South displacement is the direction in which the IHF interior concrete structure's lower floor slab is adjacent to this steel building's platform. Therefore, there will be a seismic separation between the IHF interior concrete structure floor slab at this elevation and the platform in this steel building at the same elevation.

Table 7.1.8 Maximum Displacements at EL. 37 FT – SAP2000 Output

Load Case	North - South Displacements			East - West Displacements			Vertical Displacements		
	Joint ID	U1 (in)	U1x1.4 (in)	Joint ID	U2 (in)	U1x1.4 (in)	Joint ID	U3 (in)	U1x1.4 (in)
CLC1	425	0.54	0.76	375	0.62	0.87	420	0.13	0.18
CLC2	398	0.58	0.81	375	0.69	0.97	421	0.14	0.20
CLC3	402	0.62	0.87	375	0.68	0.95	394	0.13	0.18
CLC4	448	0.57	0.80	375	0.66	0.92	420	0.12	0.17
CLC5	444	0.58	0.81	375	0.62	0.87	420	0.13	0.18
CLC6	402	0.67	0.94	375	0.67	0.94	421	0.12	0.17
CLC7	393	0.70	0.98	375	0.67	0.94	394	0.13	0.18
Max.	393	0.70	0.98	375	0.69	0.97	421	0.14	0.20

Note 1: All displacements listed in the table above, are selected from joints that connect all major structural column members.
Note 2: Displacements are based on load combination, "ENVELOPE" (See Section 6.8), and are multiplied by a factor of 1.4 since in SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

The maximum absolute factored displacement at EL 37 ft. in the North – South (X) direction is 0.98”. The North – South displacement is the direction in which the IHF interior concrete structure’s upper floor slab is adjacent to this steel building’s platform. Therefore, there will be a seismic separation between the IHF interior concrete structure floor slab at this elevation and the platform in this steel building at the same elevation greater than 0.98”, as noted in Table 7.1.8.

Table 7.1.9 Maximum Displacements at EL. 65 FT – SAP2000 Output

Load Case	North - South Displacements			East - West Displacements			Vertical Displacements		
	Joint ID	U1 (in)	U1x1.4 (in)	Joint ID	U2 (in)	U1x1.4 (in)	Joint ID	U3 (in)	U1x1.4 (in)
CLC1	879	1.04	1.46	793	0.75	1.05	876	0.20	0.28
CLC2	816	1.25	1.75	793	0.80	1.12	813	0.20	0.28
CLC3	817	1.25	1.75	793	0.81	1.13	812	0.20	0.28
CLC4	875	1.06	1.48	793	0.78	1.09	875	0.20	0.28
CLC5	858	1.19	1.67	793	0.75	1.05	855	0.19	0.27
CLC6	817	1.37	1.92	793	0.80	1.12	875	0.20	0.28
CLC7	812	1.37	1.92	793	0.80	1.12	812	0.20	0.28
Max.	812	1.37	1.92	793	0.81	1.13	812	0.20	0.28

Note 1: All displacements listed in the table above, are selected from joints that connect all major structural column members, as well as the joints along the crane rails at the above elevation (65'-0").
Note 2: Displacements are based on load combination, "ENVELOPE" (See Section 6.8), and are multiplied by a factor of 1.4 since in SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

Table 7.1.10 Maximum Displacements at EL. 87 FT – SAP2000 Output

Load Case	North - South Displacements			East - West Displacements			Vertical Displacements		
	Joint ID	U1 (in)	U1x1.4 (in)	Joint ID	U2 (in)	U1x1.4 (in)	Joint ID	U3 (in)	U1x1.4 (in)
CLC1	1110	1.15	1.61	1058	0.68	0.95	1082	0.18	0.25
CLC2	1086	1.34	1.88	1058	0.70	0.98	1082	0.25	0.35
CLC3	1087	1.35	1.89	1058	0.70	0.98	1082	0.24	0.34
CLC4	1110	1.17	1.64	1058	0.69	0.97	1082	0.19	0.27
CLC5	1109	1.20	1.68	1058	0.69	0.97	1082	0.18	0.25
CLC6	1087	1.38	1.93	1058	0.70	0.98	1151	0.20	0.28
CLC7	1082	1.39	1.95	1058	0.71	0.99	1082	0.24	0.34
Max.	1082	1.39	1.95	1058	0.71	0.99	1082	0.25	0.35

Note 1: All displacements listed in the table above, are selected from joints that connect all major structural column members, as well as the joints along the crane rails at the above elevation (87'-3").
Note 2: Displacements are based on load combination, "ENVELOPE" (See Section 6.8), and are multiplied by a factor of 1.4 since in SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

Table 7.1.11 Maximum Displacements at EL. 104.5 FT – SAP2000 Output

Load Case	North - South Displacements			East - West Displacements			Vertical Displacements		
	Joint ID	U1 (in)	U1x1.4 (in)	Joint ID	U2 (in)	U1x1.4 (in)	Joint ID	U3 (in)	U1x1.4 (in)
CLC1	1415	1.24	1.74	1481	0.72	1.01	1388	0.17	0.24
CLC2	1383	1.41	1.97	1453	0.72	1.01	1388	0.19	0.27
CLC3	1383	1.40	1.96	1453	0.69	0.97	1388	0.19	0.27
CLC4	1415	1.25	1.75	1509	0.69	0.97	1388	0.18	0.25
CLC5	1383	1.28	1.79	1481	0.72	1.01	1388	0.17	0.24
CLC6	1383	1.38	1.93	1509	0.70	0.98	1388	0.18	0.25
CLC7	1383	1.37	1.92	1509	0.70	0.98	1388	0.19	0.27
Max.	1383	1.41	1.97	1481	0.72	1.01	1388	0.19	0.27

Note 1: All displacements listed in the table above, are selected from joints that connect all major structural column members.
Note 2: Displacements are based on load combination, "ENVELOPE" (See Section 6.8), and are multiplied by a factor of 1.4 since in SAP2000 analysis a factor of [1/1.4] was applied to all load combinations including earthquake loads.

Drift Requirements: The enveloped loading combinations maximum horizontal displacement (1.41 inches) occurs in U1 (X) direction at joint 1383 for load case CLC2 (see Table 7.1.11). From Ref. 2.2.1, Section 4.2.11.4.10 maximum allowable story drift = 0.01 x H, where H= height of the structure (H=104.5ft for IHF Steel Structure). Hence allowable drift = 0.01 x 105ft = 1.05ft or 1.05ftx12 in/ft = 12.6 inches. The adjusted maximum displacement from Table 7.1.11 is1.97 inches which is much less than allowable drift of 12.6 inches. Hence drift requirement as set by PDC (Ref.2.2.1) is satisfied.

The maximum displacements tabulated in Table 7.1.12, results from crane load case 5 (CLC5) analyses and is representative of a frame along column line 7, which is represented by column H-7. See Attachment F\Joint Displacements and Acceleration\Joint Selection Figures for Displacement and Acceleration.xls

Table 7.1.12 Maximum Displacements

Elevation (ft)	Joint Label	North - South (in)	East - West (in)	Vertical (in)
104.5	1453	1.17	0.72	0.09
87.25	1130	1.20	0.64	0.08
65	856	1.16	0.53	0.09
37	443	0.57	0.28	0.09
26.75	265	0.38	0.19	0.08

7.1.3 Story Shear

The story shear of the IHF steel building, for crane load case 5, was attained by the product of the assembled nodal masses and their corresponding one directional seismic acceleration (DBGM-2) for the North – South direction (X) and the East – West direction (Y). The story shear which provide the largest forces to their floors are for elevations 104.5ft, 97.5ft, 87.25ft, 65ft, 37ft, 26.75ft, and 0ft (base floor). These elevations correspond to significant mass sources in the IHF building model because story floor elevations are not clearly defined in the IHF. Elevation 104.5ft is the roof level, 97.5ft is the bottom chord elevation of the roof truss, 87.25ft corresponds to the CTM Maintenance and the Cask Preparation crane, 65ft corresponds to the CTM and Cask Handling crane elevation, 37ft is the elevation of the first platform, 26.75ft is the elevation of the second platform, and lastly 0ft is the base floor. The story shear diagram due to one directional response spectra accelerations in the X-direction (XX), North – South, and the Y-direction (YY), East – West, is shown in Figure 7.1.1. The story shear values (cumulative) and the force at each elevation for the North – South (X) and East – West (Y) directions are tabulated in Table 7.1.13 and Table 7.1.14, respectively.

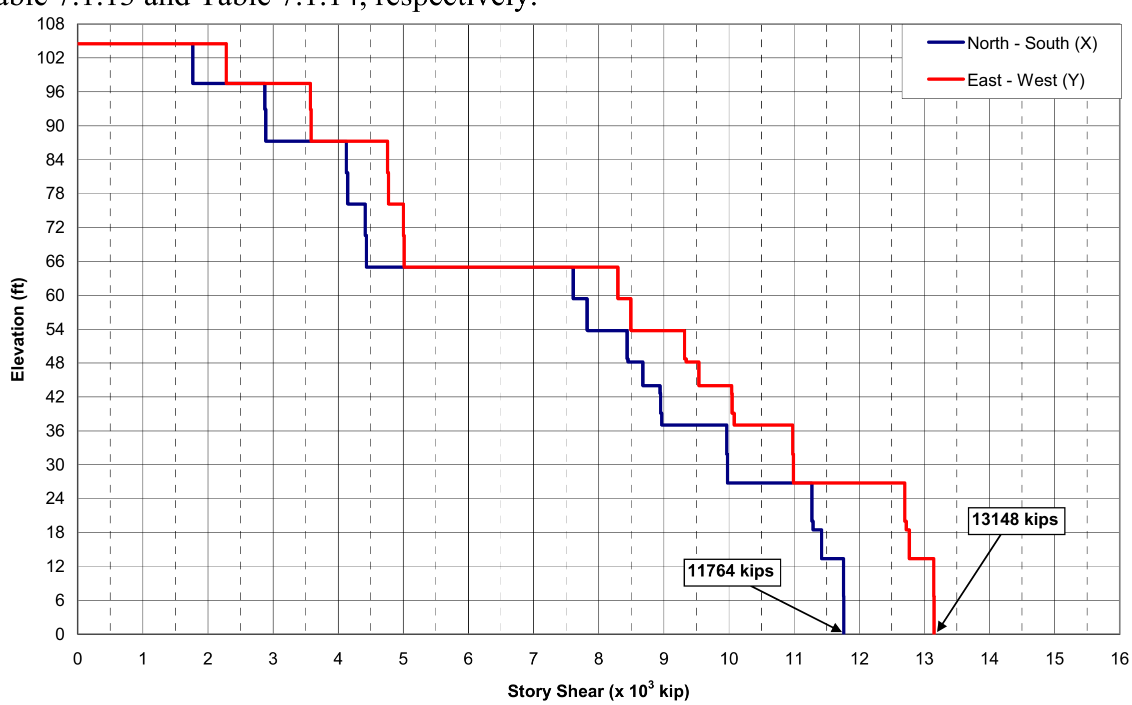


Figure 7.1.1 DBGM-2 Story Shear Diagram (LC 5) Fixed Base RSA – XX & YY

Table 7.1.13 Story Shear (North – South)

Steel North - South (X)		
Elevation	Story Shear	Story Force
ft	kip	kip
104.5	1769	1769
97.5	2875	1106
92.875	2890	15
87.25	4126	1236
81.6875	4149	23
76.1667	4165	16
76.125	4417	252
70.5625	4435	18
65	7607	3172
59.4	7823	216
53.8	7834	11
53.75	8437	603
48.75	8449	12
48.2	8680	231
44	8943	263
42.6	8952	9
39.125	8968	17
37	9966	998
31.875	9974	8
26.75	11277	1303
20	11292	15
18.5	11422	130
13.38	11760	338
6.69	11764	4
0	11764	0

Table 7.1.14 Story Shear (East – West)

Steel East - West (Y)		
Elevation	Story Shear	Story Force
ft	kip	kip
104.5	2281	2281
97.5	3574	1292
92.875	3584	11
87.25	4758	1174
81.6875	4773	15
76.1667	4782	9
76.125	5003	221
70.5625	5013	11
65	8297	3283
59.4	8495	199
53.8	8503	8
53.75	9320	816
48.75	9343	23
48.2	9538	195
44	10043	505
42.6	10049	6
39.125	10080	31
37	10980	900
31.875	10987	7
26.75	12701	1713
20	12722	21
18.5	12771	49
13.38	13144	373
6.69	13148	4
0	13148	0

7.1.4 Structural Steel Design

The Initial Handling Facility is composed of a large amount of steel members with different steel section properties. Seven different crane load cases were selected for analysis. Each crane load case has all six cranes placed in pre-determined locations as to cause maximum moments, and/or maximum shears, and/or maximum axial loads, and/or maximum displacements in structural members in different areas of the IHF steel structure. Attachment C shows the position, on the structure, of all 6-cranes for each of the seven crane load cases analyzed. The IHF steel structure was analyzed and designed for governing loads and load combinations using SAP2000.

In order to facilitate uniformity in selecting structural steel members for design, steel sections with the same properties are grouped. The groups are named according to their intended structural use such as bracing, columns, etc. (Refer to Group Definition Table 6.4.1)

The SAP2000 program processes the results utilizing the AISC interaction formulas for axial and bending forces and compares them to the allowable stress in a ratio. This ratio is known as the Demand/Capacity ratio (Ref 2.2.2).

For the purpose of displaying the Demand/Capacity (D/C) ratios for the most critical elements, only 11 groups out of 33 have been selected. These 11 selected groups contain structural members with significant stress levels. Tables 7.1.15 thru 7.1.25 summarize the maximum D/C ratios for each of the seven SAP2000 crane load case (CLC) design runs of each group. Tables 7.1.26 through 7.1.36 provide the SAP2000 steel section code check for each critical element within the 11 groups selected.

Table 7.1.15 Steel Design Summary – Group CRANECOL

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
CRANECOL	CLC1	W36X393	1256	0.548
CRANECOL	CLC2	W36X393	1205	0.541
CRANECOL	CLC3	W36X393	20	0.541
CRANECOL	CLC4	W36X393	1255	0.536
CRANECOL	CLC5	W36X393	1239	0.521
CRANECOL	CLC6	W36X393	1255	0.548
CRANECOL	CLC7	W36X393	1204	0.546
MAX.	CLC1	W36X393	1256	0.548

Refer to Table 7.1.26 for detail design of frame elements under group, CRANECOL.

Table 7.1.16 Steel Design Summary – Group BUILDINGCOL65DOWN

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
BUILDINGCOL65DOWN	CLC1	W36X328	805	0.557
BUILDINGCOL65DOWN	CLC2	W36X328	756	0.547
BUILDINGCOL65DOWN	CLC3	W36X328	738	0.57
BUILDINGCOL65DOWN	CLC4	W36X328	805	0.567
BUILDINGCOL65DOWN	CLC5	W36X328	756	0.533
BUILDINGCOL65DOWN	CLC6	W36X328	738	0.578
BUILDINGCOL65DOWN	CLC7	W36X328	805	0.578
MAX.	CLC7	W36X328	805	0.578 (See Note 1)

NOTE 1: Increase the D/C ratio 15% = 0.578 +0.15 = 0.728 (15% increase on corner columns is to account for accidental torsion, Refer to Attachment H. Refer to Table 7.1.27 for detail design of frame elements under group, BUILDINGCOL65DOWN.

Table 7.1.17 Steel Design Summary – Group BUILDINGCOL65UP

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
BUILDINGCOL65UP	CLC1	W36X300	2772	0.363
BUILDINGCOL65UP	CLC2	W36X300	584	0.473
BUILDINGCOL65UP	CLC3	W36X300	584	0.461
BUILDINGCOL65UP	CLC4	W36X300	3140	0.505
BUILDINGCOL65UP	CLC5	W36X300	2576	0.395
BUILDINGCOL65UP	CLC6	W36X300	597	0.52
BUILDINGCOL65UP	CLC7	W36X300	584	0.485
MAX.	CLC6	W36X300	597	0.52

Refer to Table 7.1.28 for detail design of frame elements under group, BUILDINGCOL65UP.

Table 7.1.18 Steel Design Summary – Group ROOFTRUSS

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
ROOFTRUSS	CLC1	W14X159	3204	0.611
ROOFTRUSS	CLC2	W14X159	3204	0.636
ROOFTRUSS	CLC3	W14X159	3204	0.598
ROOFTRUSS	CLC4	W14X159	3204	0.652
ROOFTRUSS	CLC5	W14X159	3204	0.612
ROOFTRUSS	CLC6	W14X159	4148	0.582
ROOFTRUSS	CLC7	W14X159	3204	0.614
MAX.	CLC4	W14X159	3204	0.652

Refer to Table 7.1.29 for detail design of frame elements under group, ROOFTRUSS.

Table 7.1.19 Steel Design Summary – Group SMALLVX

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
SMALLVX	CLC1	W8X58	132	0.453
SMALLVX	CLC2	W8X58	1692	0.49
SMALLVX	CLC3	W8X58	43	0.432
SMALLVX	CLC4	W8X58	132	0.475
SMALLVX	CLC5	W8X58	132	0.442
SMALLVX	CLC6	W8X58	119	0.507
SMALLVX	CLC7	W8X58	107	0.489
MAX.	CLC6	W8X58	119	0.507

Refer to Table 7.1.30 for detail design of frame elements under group, SMALLVX.

Table 7.1.20 Steel Design Summary – Group SMALLHX@65

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
SMALLHX@65	CLC1	W12X65	2295	0.539
SMALLHX@65	CLC2	W12X65	2110	0.481
SMALLHX@65	CLC3	W12X65	2117	0.35
SMALLHX@65	CLC4	W12X65	2310	0.452
SMALLHX@65	CLC5	W12X65	2248	0.382
SMALLHX@65	CLC6	W12X65	2280	0.687
SMALLHX@65	CLC7	W12X65	2310	0.576
MAX.	CLC6	W12X65	2280	0.687

Refer to Table 7.1.31 for detail design of frame elements under group, SMALLHX@65.

Table 7.1.21 Steel Design Summary – Group SMALLHX@87

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
SMALLHX@87	CLC1	W12X65	2997	0.199
SMALLHX@87	CLC2	W12X65	2840	0.229
SMALLHX@87	CLC3	W12X65	2844	0.187
SMALLHX@87	CLC4	W12X65	2983	0.186
SMALLHX@87	CLC5	W12X65	2957	0.219
SMALLHX@87	CLC6	W12X65	2983	0.246
SMALLHX@87	CLC7	W12X65	2844	0.243
MAX.	CLC6	W12X65	2983	0.246

Refer to Table 7.1.32 for detail design of frame elements under group, SMALLHX@87.

Table 7.1.22 Steel Design Summary – Group ROOFBRACING

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
ROOFBRACING	CLC1	W12X65	3438	0.411
ROOFBRACING	CLC2	W12X65	3438	0.448
ROOFBRACING	CLC3	W12X65	3438	0.418
ROOFBRACING	CLC4	W12X65	3438	0.383
ROOFBRACING	CLC5	W12X65	3438	0.435
ROOFBRACING	CLC6	W12X65	1630	0.735
ROOFBRACING	CLC7	W12X65	1630	0.773
MAX.	CLC7	W12X65	1630	0.773

Note: ROOFBRACING includes groups ROOFHX and LOWERROOFHX.
Refer to Table 7.1.33 for detail design of frame elements under group, ROOFBRACING.

Table 7.1.23 Steel Design Summary – Group BRACE@37

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
BRACE@37	CLC1	W14X211	830	0.444
BRACE@37	CLC2	W14X211	467	0.421
BRACE@37	CLC3	W14X211	467	0.41
BRACE@37	CLC4	W14X211	830	0.439
BRACE@37	CLC5	W14X211	830	0.406
BRACE@37	CLC6	W14X211	830	0.412
BRACE@37	CLC7	W14X211	830	0.414
MAX.	CLC1	W14X211	830	0.444

Refer to Table 7.1.34 for detail design of frame elements under group, BRACE@37.

Table 7.1.24 Steel Design Summary – Group BRACE@65

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
BRACE@65	CLC1	W14X159	1527	0.412
BRACE@65	CLC2	W14X159	1526	0.499
BRACE@65	CLC3	W14X159	1527	0.491
BRACE@65	CLC4	W14X159	1527	0.418
BRACE@65	CLC5	W14X159	1526	0.43
BRACE@65	CLC6	W14X159	1527	0.493
BRACE@65	CLC7	W14X159	1526	0.472
MAX.	CLC2	W14X159	1526	0.499

Refer to Table 7.1.35 for detail design of frame elements under group, BRACE@65.

Table 7.1.25 Steel Design Summary – Group BRACE@65UP

GROUP NAME	LOAD CASE	MEMBER SIZE	MEMBER ID	MAX. D/C RATIO
BRACE@65UP	CLC1	W14X132	2707	0.49
BRACE@65UP	CLC2	W14X132	2707	0.434
BRACE@65UP	CLC3	W14X132	2707	0.433
BRACE@65UP	CLC4	W14X132	2707	0.486
BRACE@65UP	CLC5	W14X132	2707	0.475
BRACE@65UP	CLC6	W14X132	2707	0.464
BRACE@65UP	CLC7	W14X132	2707	0.467
MAX.	CLC1	W14X132	2707	0.49

Refer to Table 7.1.36 for detail design of frame elements under group, BRACE@65UP.

Table 7.1.26 Steel Section Code Check for Group CRANECOL Frame Elements

AISC-ASD89 STEEL SECTION CHECK
Combo : ENVELOPE
Units : Kip, ft, F

Frame : 1256	Design Sect: W36X393					
X Mid : 59.500	Design Type: Column					
Y Mid : 98.000	Frame Type : Braced Frame					
Z Mid : 42.600	Sect Class : Compact					
Length : 11.200	Major Axis : 0.000 degrees counterclockwise from local 3					
Loc : 0.000	RLLF : 1.000					

Area : 0.806	SMajor : 0.842	rMajor : 1.283	AVMajor: 0.320
IMajor : 1.326	SMinor : 0.121	rMinor : 0.324	AVMinor: 0.428
IMinor : 0.084	ZMajor : 0.966	E : 4176000.000	
Ixy : 0.000	ZMinor : 0.188	Fy : 7200.000	

STRESS CHECK FORCES & MOMENTS

Location	P	M33	M22	V2	V3	T
0.000	-869.006	-75.197	19.908	4.594	-2.382	-0.085

PMM DEMAND/CAPACITY RATIO

Governing Equation	Total Ratio		P Ratio		MMajor Ratio		MMinor Ratio	Ratio Limit	Status Check
(H1-1)	0.548	=	0.488	+	0.036	+	0.025	0.600	OK

AXIAL FORCE DESIGN

	P Force	fa Stress	Fa Allowable	Ft Allowable
Axial	-869.006	1078.766	2211.177	4320.000

MOMENT DESIGN

	M Moment	fb Stress	Fb Allowable	Fe Allowable	Cm Factor	K Factor	L Factor	Cb Factor
Major Moment	-75.197	89.304	4752.000	2277.677	1.000	4.453	2.500	1.399
Minor Moment	19.908	165.128	5400.000	17959.538	0.764	1.000	1.000	

SHEAR DESIGN

	V Force	fv Stress	Fv Allowable	Stress Ratio	Status Check	T Torsion
Major Shear	4.632	14.463	2880.000	0.005	OK	0.000
Minor Shear	2.557	5.978	2880.000	0.002	OK	0.000

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Table 7.1.27 Steel Section Code Check for Group BUILDINGCOL65DOWN Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 805              Design Sect: W36X328
X Mid  : 167.000          Design Type: Column
Y Mid  : 123.000          Frame Type : Braced Frame
Z Mid  : 31.875           Sect Class : Compact
Length : 10.250           Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 0.000            RLLF       : 1.000

Area   : 0.669            SMajor : 0.702          rMajor : 1.273          AVMajor: 0.263
IMajor : 1.085            SMinor : 0.099          rMinor : 0.320          AVMinor: 0.355
IMinor : 0.068            ZMajor : 0.799          E      : 4176000.000
Ixy    : 0.000            ZMinor : 0.153          Fy     : 7200.000


STRESS CHECK FORCES & MOMENTS
    Location               P         M33         M22          V2          V3           T
    0.000           -347.898    -487.976    -159.323     -73.767     -20.512       0.000

PMM DEMAND/CAPACITY RATIO
    Governing          Total           P      MMajor      MMinor       Ratio      Status
    Equation           Ratio       Ratio       Ratio       Ratio       Limit       Check
    (H1-3)             0.578   =   0.134   +   0.146   +   0.298       0.600          OK

AXIAL FORCE DESIGN
                           P          fa          Fa          Ft
                       Force      Stress   Allowable   Allowable
    Axial           -347.898     519.681    3873.024    4320.000

MOMENT DESIGN
                           M          fb          Fb          Fe       Cm        K        L       Cb
                      Moment      Stress   Allowable   Allowable   Factor   Factor   Factor   Factor
    Major Moment    -487.976     695.190    4752.000  331748.448    0.830    1.000    1.000    1.245
    Minor Moment    -159.323    1609.211    5400.000   20937.013    0.681    1.000    1.000

SHEAR DESIGN
                           V          fv          Fv      Stress      Status           T
                       Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear       73.767     280.706    2880.000       0.097          OK       0.000
    Minor Shear       20.512      57.709    2880.000       0.020          OK       0.000
```

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Table 7.1.28 Steel Section Code Check for Group BUILDINGCOL65up Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 597               Design Sect: W36X300
X Mid  : -4.500            Design Type: Column
Y Mid  : 98.000            Frame Type : Braced Frame
Z Mid  : 81.688            Sect Class : Compact
Length : 11.125            Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 11.125            RLLF       : 1.000

Area   : 0.613             SMajor : 0.640          rMajor : 1.264          AVMajor: 0.241
IMajor : 0.979             SMinor : 0.090          rMinor : 0.320          AVMinor: 0.325
IMinor : 0.063             ZMajor : 0.729          E      : 4176000.000
Ixy    : 0.000             ZMinor : 0.139          Fy     : 7200.000

STRESS CHECK FORCES & MOMENTS
    Location             P         M33         M22          V2          V3           T
    11.125        -418.555     121.602    -156.614      -7.314      16.991      -0.080

PMM DEMAND/CAPACITY RATIO
    Governing        Total           P      MMajor      MMinor       Ratio      Status
    Equation         Ratio       Ratio       Ratio       Ratio       Limit       Check
    (H1-2)           0.520  =    0.158  +    0.040  +    0.322       0.600          OK

AXIAL FORCE DESIGN
                         P          fa          Fa          Ft
                     Force      Stress   Allowable   Allowable
    Axial         -418.555     682.581    3821.847    4320.000

MOMENT DESIGN
                         M          fb          Fb          Fe         Cm       K       L       Cb
                    Moment      Stress   Allowable   Allowable     Factor  Factor  Factor   Factor
    Major Moment   121.602     189.943    4752.000   69346.803     1.000   1.000   2.000    1.414
    Minor Moment  -156.614    1738.274    5400.000   17763.713     0.626   1.000   1.000

SHEAR DESIGN
                         V          fv          Fv      Stress      Status           T
                     Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear      7.314      30.370    2880.000       0.011          OK       0.000
    Minor Shear     16.991      52.324    2880.000       0.018          OK       0.000
```

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Table 7.1.29 Steel Section Code Check for Group ROOFTRUSS Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo   : ENVELOPE
Units   : Kip, ft, F



Frame   : 3204           Design Sect: W14X159
X Mid   : 80.208         Design Type: Beam
Y Mid   : 0.000          Frame Type : Braced Frame
Z Mid   : 97.500         Sect Class : Compact
Length  : 7.917          Major Axis : 0.000 degrees counterclockwise from local 3
Loc     : 7.917          RLLF       : 1.000

Area    : 0.324          SMajor : 0.147        rMajor : 0.532          AVMajor: 0.078
IMajor  : 0.092          SMinor : 0.055        rMinor : 0.334          AVMinor: 0.215
IMinor  : 0.036          ZMajor : 0.166        E      : 4176000.000
Ixy     : 0.000          ZMinor : 0.084        Fy     : 7200.000


DESIGN MESSAGES
    Section overstressed

STRESS CHECK FORCES & MOMENTS
    Location              P          M33          M22           V2          V3           T
    7.917          -314.546       24.351     -117.698       -2.388      14.867      -0.043

PMM DEMAND/CAPACITY RATIO
    Governing         Total            P       MMajor       MMinor       Ratio      Status
    Equation          Ratio        Ratio        Ratio        Ratio       Limit       Check
    (H1-2)            0.652   =    0.225   +    0.035   +    0.393       0.600  Overstress

AXIAL FORCE DESIGN
                          P           fa           Fa           Ft
                      Force       Stress    Allowable    Allowable
    Axial          -314.546      969.907     4016.498     4320.000

MOMENT DESIGN
                          M           fb           Fb           Fe        Cm        K        L       Cb
                     Moment       Stress    Allowable    Allowable    Factor   Factor   Factor   Factor
    Major Moment     24.351      166.103     4752.000    96940.030     0.850    1.000    1.000    1.750
    Minor Moment   -117.698     2120.830     5400.000    38163.759     0.600    1.000    1.000

SHEAR DESIGN
                          V           fv           Fv       Stress      Status           T
                      Force       Stress    Allowable        Ratio       Check     Torsion
    Major Shear       3.720       47.932     2880.000        0.017          OK       0.000
    Minor Shear      14.867       69.194     2880.000        0.024          OK       0.000
```

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Table 7.1.30 Steel Section Code Check for Group SMALLVX Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo   : ENVELOPE
Units   : Kip, ft, F



Frame   : 119             Design Sect: W8X58
X Mid   : -8.250          Design Type: Brace
Y Mid   : 98.000          Frame Type : Braced Frame
Z Mid   : 6.690           Sect Class : Compact
Length  : 15.339          Major Axis : 0.000 degrees counterclockwise from local 3
Loc     : 7.669           RLLF       : 1.000

Area    : 0.119           SMajor : 0.030        rMajor : 0.304        AVMajor: 0.031
IMajor  : 0.011           SMinor : 0.011        rMinor : 0.175        AVMinor: 0.077
IMinor  : 0.004           ZMajor : 0.035        E      : 4176000.000
Ixy     : 0.000           ZMinor : 0.016        Fy     : 7200.000

STRESS CHECK FORCES & MOMENTS
    Location             P        M33        M22         V2         V3          T
    7.669         -216.468      0.837      0.000      0.000      0.000      0.000

PMM DEMAND/CAPACITY RATIO
    Governing        Total          P     MMajor     MMinor      Ratio     Status
    Equation         Ratio      Ratio      Ratio      Ratio      Limit      Check
    (H1-1)           0.507  =   0.501  +   0.006  +   0.000      0.600         OK

AXIAL FORCE DESIGN
                         P         fa         Fa         Ft
                     Force     Stress  Allowable  Allowable
    Axial         -216.468   1822.893   3638.967   4320.000

MOMENT DESIGN
                         M         fb         Fb         Fe        Cm         K         L        Cb
                    Moment     Stress  Allowable  Allowable    Factor    Factor    Factor    Factor
    Major Moment     0.837     27.748   4320.000  33851.288     0.850     1.000     0.500     1.000
    Minor Moment     0.000      0.000   5400.000  11150.139     1.000     1.000     0.500

SHEAR DESIGN
                         V         fv         Fv     Stress     Status          T
                     Force     Stress  Allowable      Ratio      Check    Torsion
    Major Shear      0.000      0.000   2880.000      0.000         OK      0.000
    Minor Shear      0.000      0.000   2880.000      0.000         OK      0.000
```

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Table 7.1.31 Steel Section Code Check for Group SMALLHX@65 Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 2280              Design Sect: W12X65
X Mid  : -8.250            Design Type: Beam
Y Mid  : 104.250           Frame Type : Braced Frame
Z Mid  : 65.000            Sect Class : Non-Compact
Length : 14.577            Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 7.289             RLLF       : 1.000

Area   : 0.133             SMajor : 0.051          rMajor : 0.440          AVMajor: 0.033
IMajor : 0.026             SMinor : 0.017          rMinor : 0.252          AVMinor: 0.084
IMinor : 0.008             ZMajor : 0.056          E      : 4176000.000
Ixy    : 0.000             ZMinor : 0.026          Fy     : 7200.000


DESIGN MESSAGES
    Section overstressed

STRESS CHECK FORCES & MOMENTS
    Location              P         M33         M22          V2          V3           T
    7.289          -298.926       1.727       0.000       0.000       0.000       0.000

PMM DEMAND/CAPACITY RATIO
    Governing         Total           P      MMajor      MMinor       Ratio      Status
    Equation          Ratio       Ratio       Ratio       Ratio       Limit       Check
     (H1-1)           0.687  =    0.679  +    0.009  +    0.000       0.600  Overstress

AXIAL FORCE DESIGN
                          P          fa          Fa          Ft
                      Force      Stress   Allowable   Allowable
    Axial          -298.926    2253.680    3321.105    4320.000

MOMENT DESIGN
                          M          fb          Fb          Fe       Cm        K        L       Cb
                     Moment      Stress   Allowable   Allowable   Factor   Factor   Factor   Factor
    Major Moment      1.727      33.866    4320.000   19610.382    1.000    1.000    1.000    1.000
    Minor Moment      0.000       0.000    5215.454    6401.888    1.000    1.000    1.000

SHEAR DESIGN
                          V          fv          Fv      Stress      Status           T
                      Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear       0.000       0.000    2880.000       0.000          OK       0.000
    Minor Shear       0.000       0.000    2880.000       0.000          OK       0.000
```

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Table 7.1.32 Steel Section Code Check for Group SMALLHX@87 Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 2983           Design Sect: W12X65
X Mid  : -8.250         Design Type: Beam
Y Mid  : 104.250        Frame Type : Braced Frame
Z Mid  : 87.250         Sect Class : Non-Compact
Length : 14.577         Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 7.289          RLLF       : 1.000

Area   : 0.133          SMajor : 0.051        rMajor : 0.440         AVMajor: 0.033
IMajor : 0.026          SMinor : 0.017        rMinor : 0.252         AVMinor: 0.084
IMinor : 0.008          ZMajor : 0.056        E      : 4176000.000
Ixy    : 0.000          ZMinor : 0.026        Fy     : 7200.000

STRESS CHECK FORCES & MOMENTS
    Location             P        M33        M22         V2         V3          T
    7.289         -104.636      1.727      0.000      0.000      0.000      0.000

PMM DEMAND/CAPACITY RATIO
    Governing        Total          P     MMajor     MMinor      Ratio     Status
    Equation         Ratio      Ratio      Ratio      Ratio      Limit      Check
     (H1-1)          0.246  =   0.238  +   0.008  +   0.000      0.600         OK

AXIAL FORCE DESIGN
                         P         fa         Fa         Ft
                     Force     Stress  Allowable  Allowable
    Axial         -104.636    788.878   3321.105   4320.000

MOMENT DESIGN
                         M         fb         Fb         Fe       Cm        K        L       Cb
                    Moment     Stress  Allowable  Allowable   Factor   Factor   Factor   Factor
    Major Moment     1.727     33.866   4320.000  19610.382    1.000    1.000    1.000    1.000
    Minor Moment     0.000      0.000   5215.454   6401.888    1.000    1.000    1.000

SHEAR DESIGN
                         V         fv         Fv     Stress     Status          T
                     Force     Stress  Allowable      Ratio      Check    Torsion
    Major Shear      0.000      0.000   2880.000      0.000         OK      0.000
    Minor Shear      0.000      0.000   2880.000      0.000         OK      0.000
```

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Table 7.1.33 Steel Section Code Check for Group ROOFBRACING Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 1630            Design Sect: W12X65
X Mid  : 159.500         Design Type: Beam
Y Mid  : 35.500          Frame Type : Braced Frame
Z Mid  : 97.500          Sect Class : Non-Compact
Length : 29.155          Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 5.831           RLLF       : 1.000

Area   : 0.133           SMajor : 0.051          rMajor : 0.440          AVMajor: 0.033
IMajor : 0.026           SMinor : 0.017          rMinor : 0.252          AVMinor: 0.084
IMinor : 0.008           ZMajor : 0.056          E      : 4176000.000
Ixy    : 0.000           ZMinor : 0.026          Fy     : 7200.000


DESIGN MESSAGES
    Section overstressed

STRESS CHECK FORCES & MOMENTS
    Location              P         M33         M22          V2          V3           T
    5.831            95.507     133.639       0.000       0.150       0.000       0.000

PMM DEMAND/CAPACITY RATIO
    Governing         Total           P      MMajor      MMinor       Ratio      Status
    Equation          Ratio       Ratio       Ratio       Ratio       Limit       Check
    (H2-1)            0.773   =   0.167   +   0.607   +   0.000       0.600  Overstress

AXIAL FORCE DESIGN
                          P          fa          Fa          Ft
                      Force      Stress   Allowable   Allowable
    Axial            95.507     720.053    3321.105    4320.000

MOMENT DESIGN
                          M          fb          Fb          Fe       Cm        K        L       Cb
                     Moment      Stress   Allowable   Allowable   Factor   Factor   Factor   Factor
    Major Moment    133.639    2621.222    4320.000   19610.382    1.000    1.000    0.500    1.410
    Minor Moment      0.000       0.000    5215.454    6401.888    1.000    1.000    0.500

SHEAR DESIGN
                          V          fv          Fv      Stress      Status           T
                      Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear       1.265      38.603    2880.000       0.013          OK       0.000
    Minor Shear       0.000       0.000    2880.000       0.000          OK       0.000
```

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Table 7.1.34 Steel Section Code Check for Group BRACE@37 Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 830              Design Sect: W14X211
X Mid  : 29.750           Design Type: Brace
Y Mid  : 123.000          Frame Type : Braced Frame
Z Mid  : 35.375           Sect Class : Compact
Length : 29.556           Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 14.778           RLLF       : 1.000

Area   : 0.431            SMajor : 0.196          rMajor : 0.546          AVMajor: 0.107
IMajor : 0.128            SMinor : 0.075          rMinor : 0.340          AVMinor: 0.285
IMinor : 0.050            ZMajor : 0.226          E      : 4176000.000
Ixy    : 0.000            ZMinor : 0.115          Fy     : 7200.000


STRESS CHECK FORCES & MOMENTS
    Location              P         M33         M22          V2          V3           T
    14.778         -665.598      18.709       0.000       0.000       0.000       0.000

PMM DEMAND/CAPACITY RATIO
    Governing         Total           P      MMajor      MMinor       Ratio      Status
    Equation          Ratio       Ratio       Ratio       Ratio       Limit       Check
     (H1-1)           0.444   =   0.424   +   0.020   +   0.000       0.600          OK

AXIAL FORCE DESIGN
                          P          fa          Fa          Ft
                      Force      Stress   Allowable   Allowable
    Axial          -665.598    1545.905    3647.529    4320.000

MOMENT DESIGN
                          M          fb          Fb          Fe          Cm           K           L          Cb
                     Moment      Stress   Allowable   Allowable      Factor      Factor      Factor      Factor
    Major Moment     18.709      95.407    4320.000   29336.420       0.850       1.000       0.500       1.000
    Minor Moment      0.000       0.000    5400.000   11359.591       1.000       1.000       0.500

SHEAR DESIGN
                          V          fv          Fv      Stress      Status           T
                      Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear       0.000       0.000    2880.000       0.000          OK       0.000
    Minor Shear       0.000       0.000    2880.000       0.000          OK       0.000
```

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Table 7.1.35 Steel Section Code Check for Group BRACE@65 Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo  : ENVELOPE
Units  : Kip, ft, F



Frame  : 1526            Design Sect: W14X159
X Mid  : 114.625         Design Type: Brace
Y Mid  : 0.000           Frame Type : Braced Frame
Z Mid  : 51.000          Sect Class : Compact
Length : 40.492          Major Axis : 0.000 degrees counterclockwise from local 3
Loc    : 20.246          RLLF       : 1.000

Area   : 0.324           SMajor : 0.147          rMajor : 0.532          AVMajor: 0.078
IMajor : 0.092           SMinor : 0.055          rMinor : 0.334          AVMinor: 0.215
IMinor : 0.036           ZMajor : 0.166          E      : 4176000.000
Ixy    : 0.000           ZMinor : 0.084          Fy     : 7200.000


STRESS CHECK FORCES & MOMENTS
    Location             P         M33         M22          V2          V3           T
    20.246        -489.720      23.529       0.000       0.000       0.000       0.000

PMM DEMAND/CAPACITY RATIO
    Governing        Total           P      MMajor      MMinor       Ratio      Status
    Equation         Ratio       Ratio       Ratio       Ratio       Limit       Check
     (H1-1)          0.499   =   0.464   +   0.035   +   0.000       0.600          OK

AXIAL FORCE DESIGN
                         P          fa          Fa          Ft
                     Force      Stress   Allowable   Allowable
    Axial         -489.720    1510.058    3253.943    4320.000

MOMENT DESIGN
                         M          fb          Fb          Fe          Cm         K          L         Cb
                    Moment      Stress   Allowable   Allowable      Factor    Factor     Factor     Factor
    Major Moment    23.529     160.493    4320.000   14822.446       0.850     1.000      0.500      1.000
    Minor Moment     0.000       0.000    5400.000    5835.363       1.000     1.000      0.500

SHEAR DESIGN
                         V          fv          Fv      Stress      Status           T
                     Force      Stress   Allowable       Ratio       Check     Torsion
    Major Shear      0.000       0.000    2880.000       0.000          OK       0.000
    Minor Shear      0.000       0.000    2880.000       0.000          OK       0.000
```

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Table 7.1.36 Steel Section Code Check for Group BRACE@65UP Frame Elements

```
AISC-ASD89 STEEL SECTION CHECK
Combo   : ENVELOPE
Units   : Kip, ft, F



Frame   : 2707              Design Sect: W14X132
X Mid   : 53.875            Design Type: Brace
Y Mid   : 123.000           Frame Type : Braced Frame
Z Mid   : 76.125            Sect Class : Compact
Length  : 32.911            Major Axis : 0.000 degrees counterclockwise from local 3
Loc     : 16.455            RLLF       : 1.000

Area    : 0.269             SMajor : 0.120          rMajor : 0.523          AVMajor: 0.066
IMajor  : 0.074             SMinor : 0.043          rMinor : 0.313          AVMinor: 0.175
IMinor  : 0.026             ZMajor : 0.135          E      : 4176000.000
Ixy     : 0.000             ZMinor : 0.065          Fy     : 7200.000

STRESS CHECK FORCES & MOMENTS
    Location                P          M33          M22           V2           V3            T
    16.455           -433.809       13.173        0.000        0.000        0.000        0.000

PMM DEMAND/CAPACITY RATIO
    Governing           Total            P       MMajor       MMinor        Ratio       Status
    Equation            Ratio        Ratio        Ratio        Ratio        Limit        Check
    (H1-1)              0.490   =    0.467   +    0.023   +    0.000        0.600           OK

AXIAL FORCE DESIGN
                            P           fa           Fa           Ft
                        Force       Stress    Allowable    Allowable
    Axial            -433.809     1610.014     3448.714     4320.000

MOMENT DESIGN
                            M           fb           Fb           Fe        Cm        K        L       Cb
                       Moment       Stress    Allowable    Allowable    Factor   Factor   Factor   Factor
    Major Moment       13.173      109.350     4320.000    21746.646     0.850    1.000    0.500    1.000
    Minor Moment        0.000        0.000     5400.000     7788.995     1.000    1.000    0.500

SHEAR DESIGN
                            V           fv           Fv       Stress       Status            T
                        Force       Stress    Allowable        Ratio        Check      Torsion
    Major Shear         0.000        0.000     2880.000        0.000           OK        0.000
    Minor Shear         0.000        0.000     2880.000        0.000           OK        0.000
```

SAP2000 v9.1.4 - File: November 8, 2007 13:38

7.1.5 Foundation Loads

Support reactions generated by applying each directional earthquake force as static equivalent loads to the IHF Steel Structure will be used as input loads to the foundation mat design of the IHF Building. Attachment E lists these loads and in Section 4.3 the methodology is described in detail.

7.2 CONCLUSIONS

The IHF Steel Structure was modeled in SAP2000 to reflect the General Arrangement Drawings for design and analysis of its structural members under prevailing loads and load combinations.

The predetermined seven load cases of the six cranes as shown with their seismic loadings and their various locations in the structure were considered, as capturing as many possible maximum stress conditions of the structure's members collectively. The assortment of Crane Load Cases, were carefully selected to cover the cranes positions that would provide the worst loading case to design the steel structure (See Attachment D). The worst loading case can occur wherever the heaviest vertical load may occur, or where the most torsional moment in the structure exists or where the bracing members are significantly stressed for a given loading arrangement.

It has been shown that regardless where the cranes are placed for the analysis, the fundamental frequency of the structure does not significantly change (See Table 6.6.3). The frequency band near the maximum accelerations on the input response spectra does not shift any significant amount to affect the seismic response. Considering member stresses, the selected crane locations closely envelop all possible combinations of crane positions.

Based on the specific needs of this structure and criteria set-forth by PDC (Ref.2.2.1) and SADA (Ref. 2.2.2), and based on the summary of results obtained from the SAP2000 computer analysis, the IHF Steel Structure as designed and documented in this calculation, is acceptable and meets and/or exceeds the minimum requirements.

The results of the calculation are to be used as the basis for the IHF structural steel drawings as part of Tier-1 design and as load input for the foundation mat design for the IHF building.

ATTACHMENT A

IHF BUILDING PLAN AND X-SECTIONS

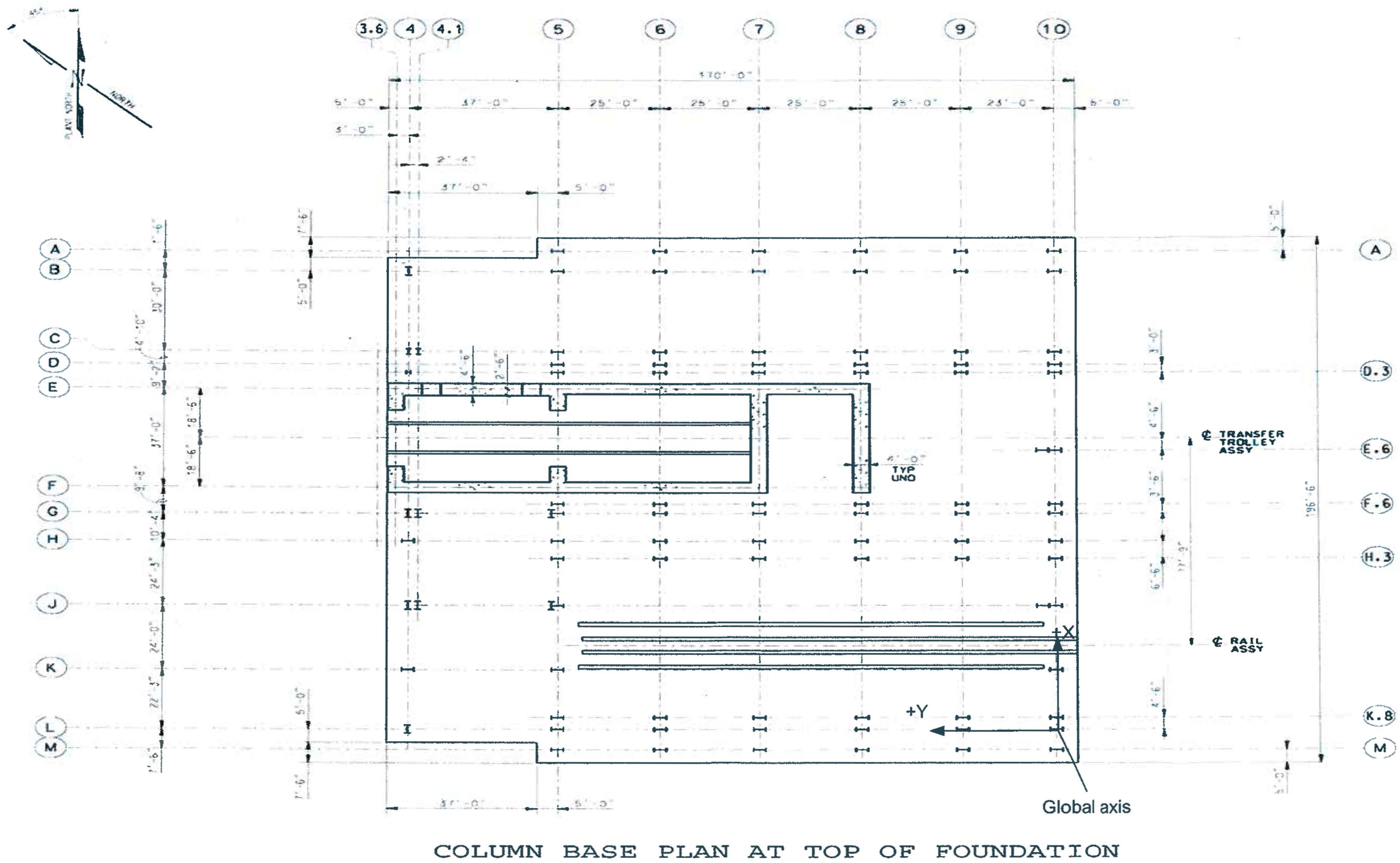


FIG. 6.4.1
IHF Steel Structure Column Lines

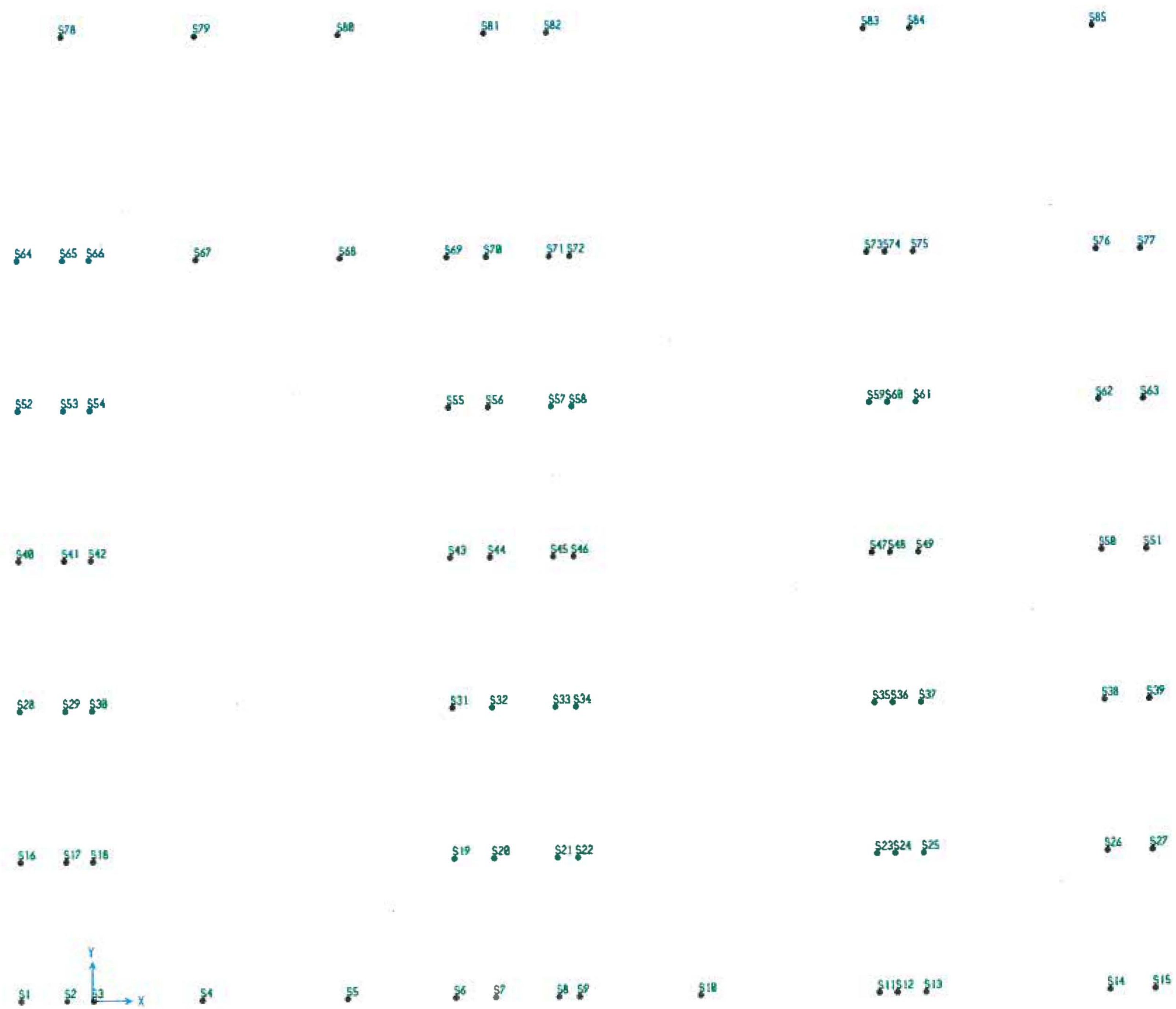


FIG 6.4.2

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=0 - Kip, ft, F Units

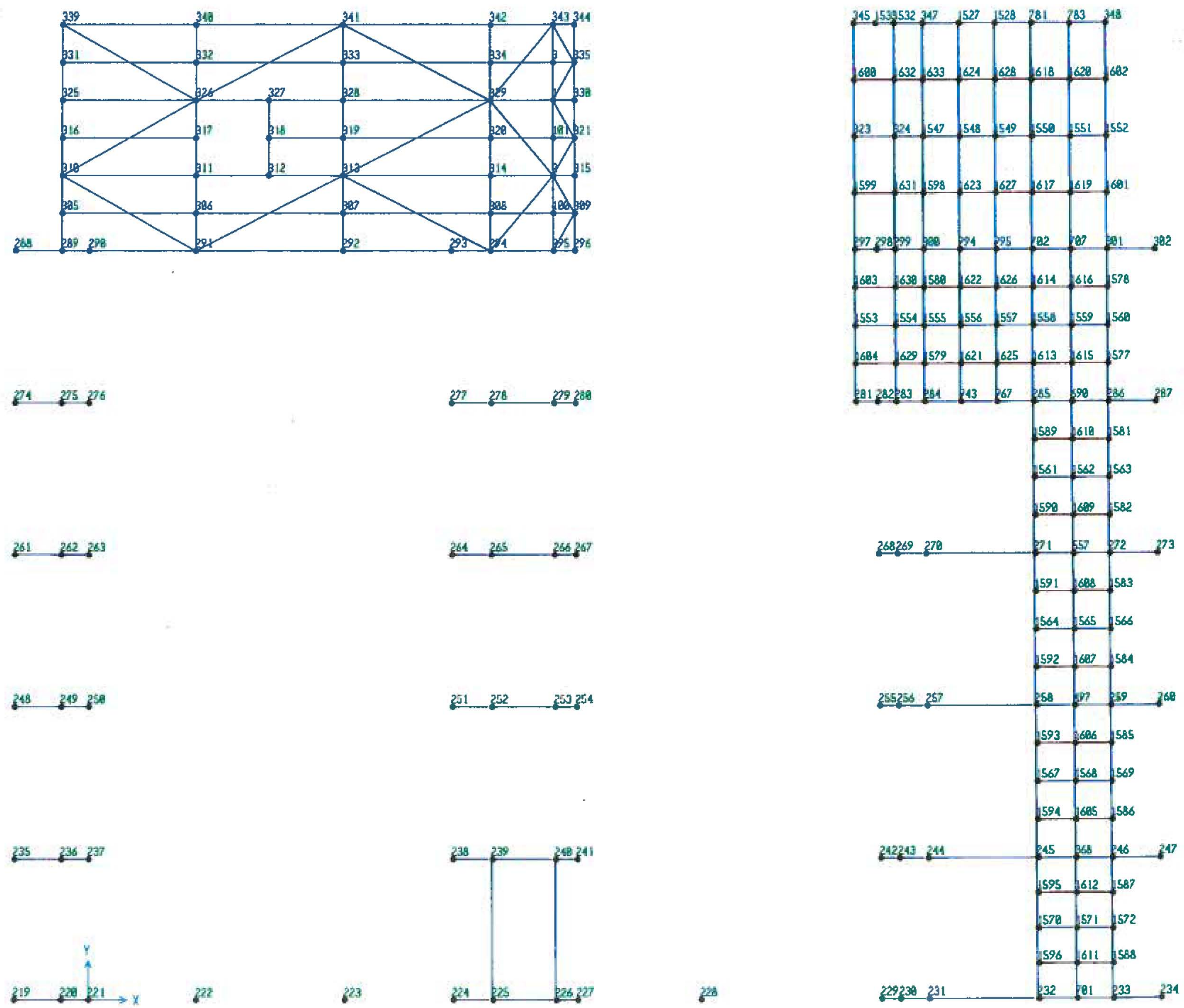


FIG: 6.4.3

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=26.75 - Kip, ft, F Units

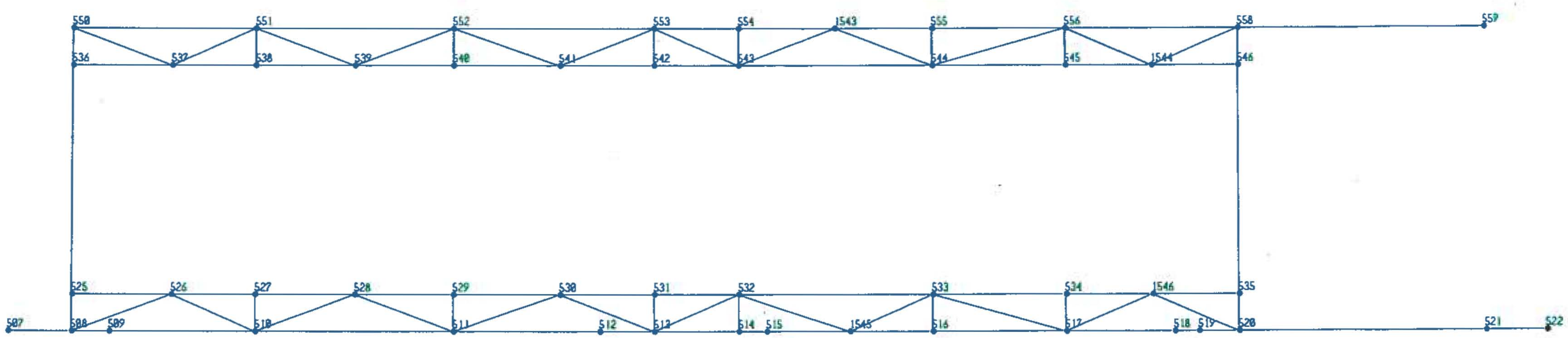


FIG 6.4.1

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=44 - Kip, ft, F Units

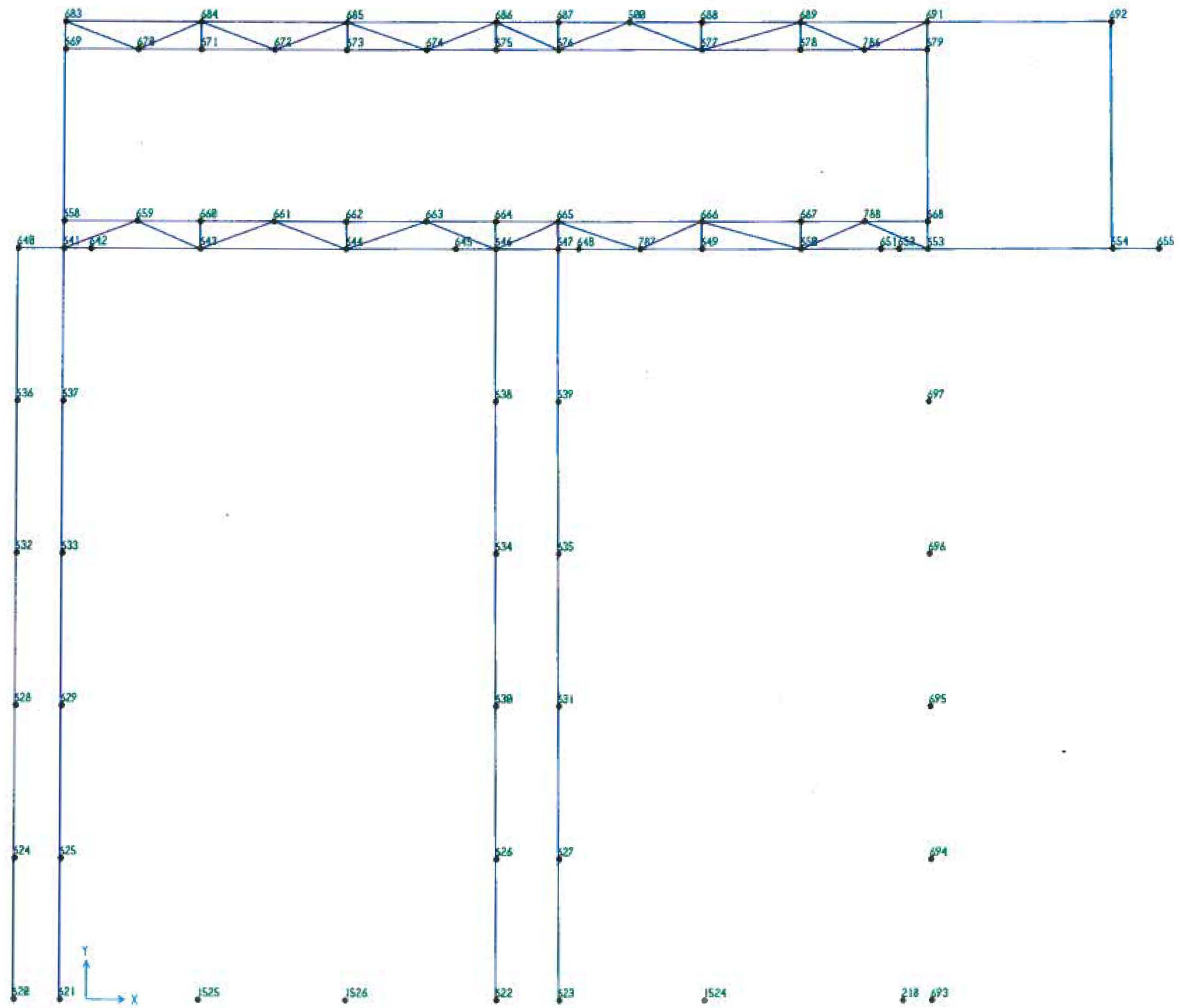


FIG. 6.4.5

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=53.75 - Kip, ft, F Units

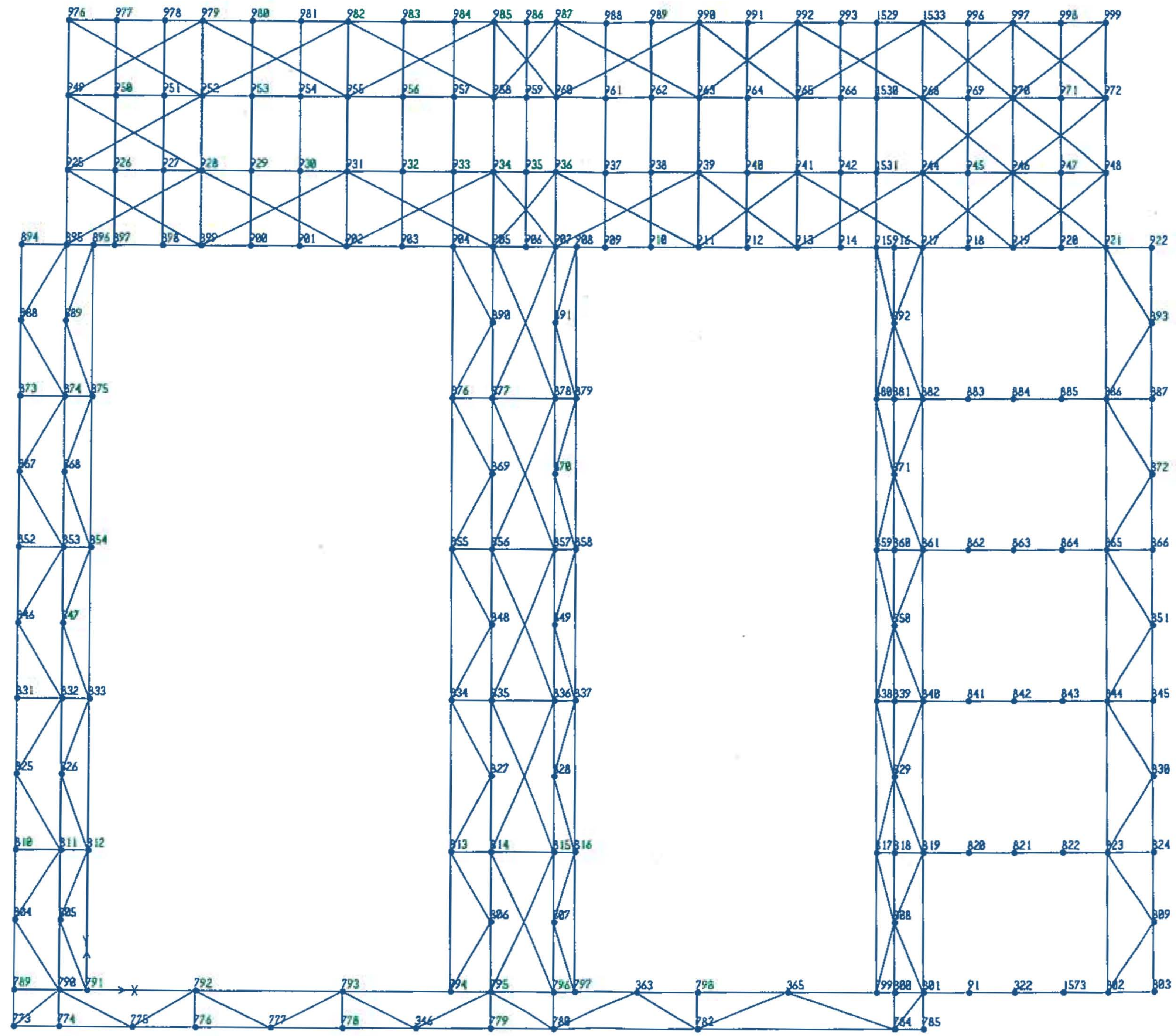


FIG. 6.4.6

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=65 - Kip, ft, F Units

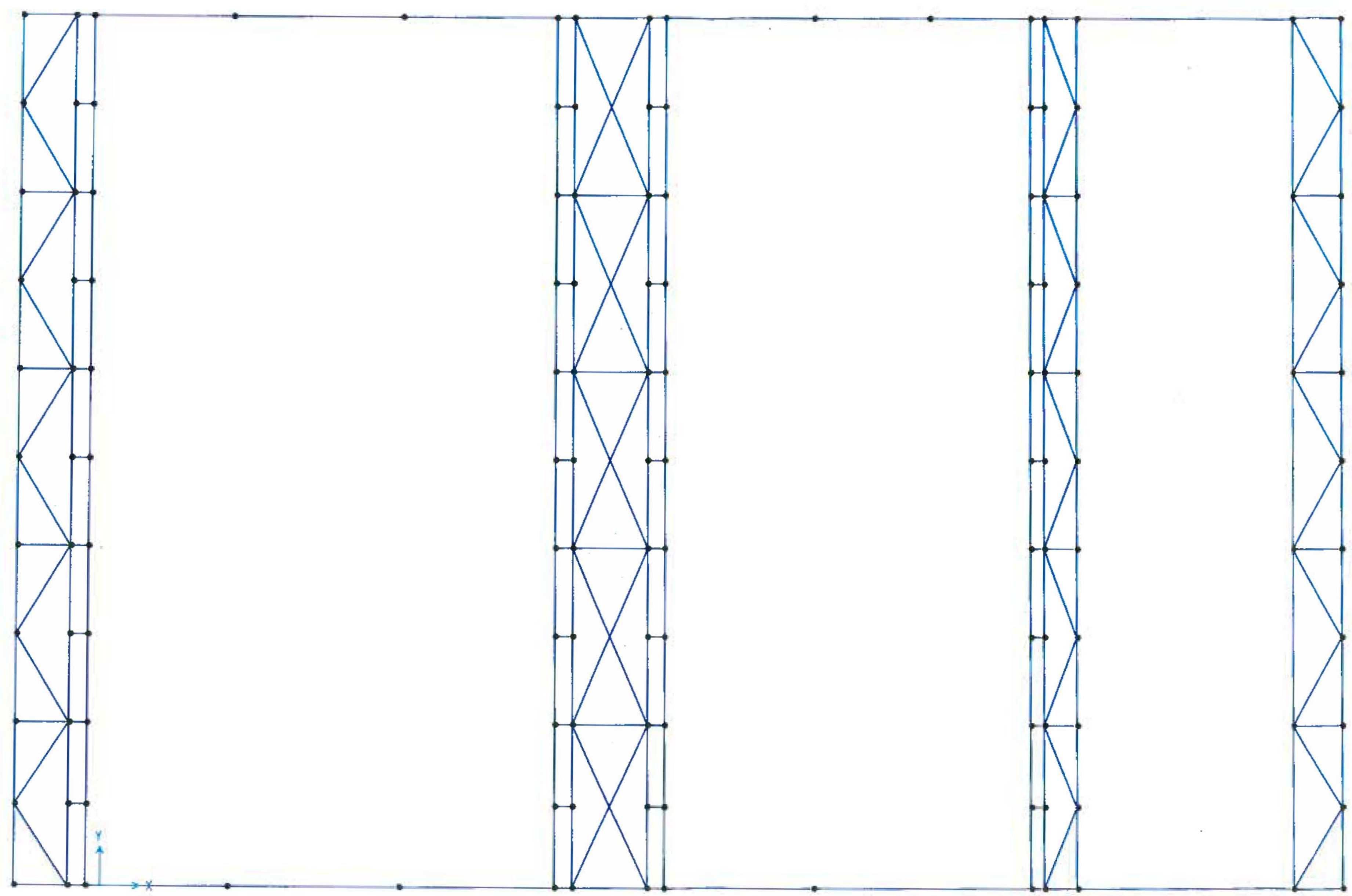


FIG 6.4.7

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=87.25 - Kip, ft, F Units

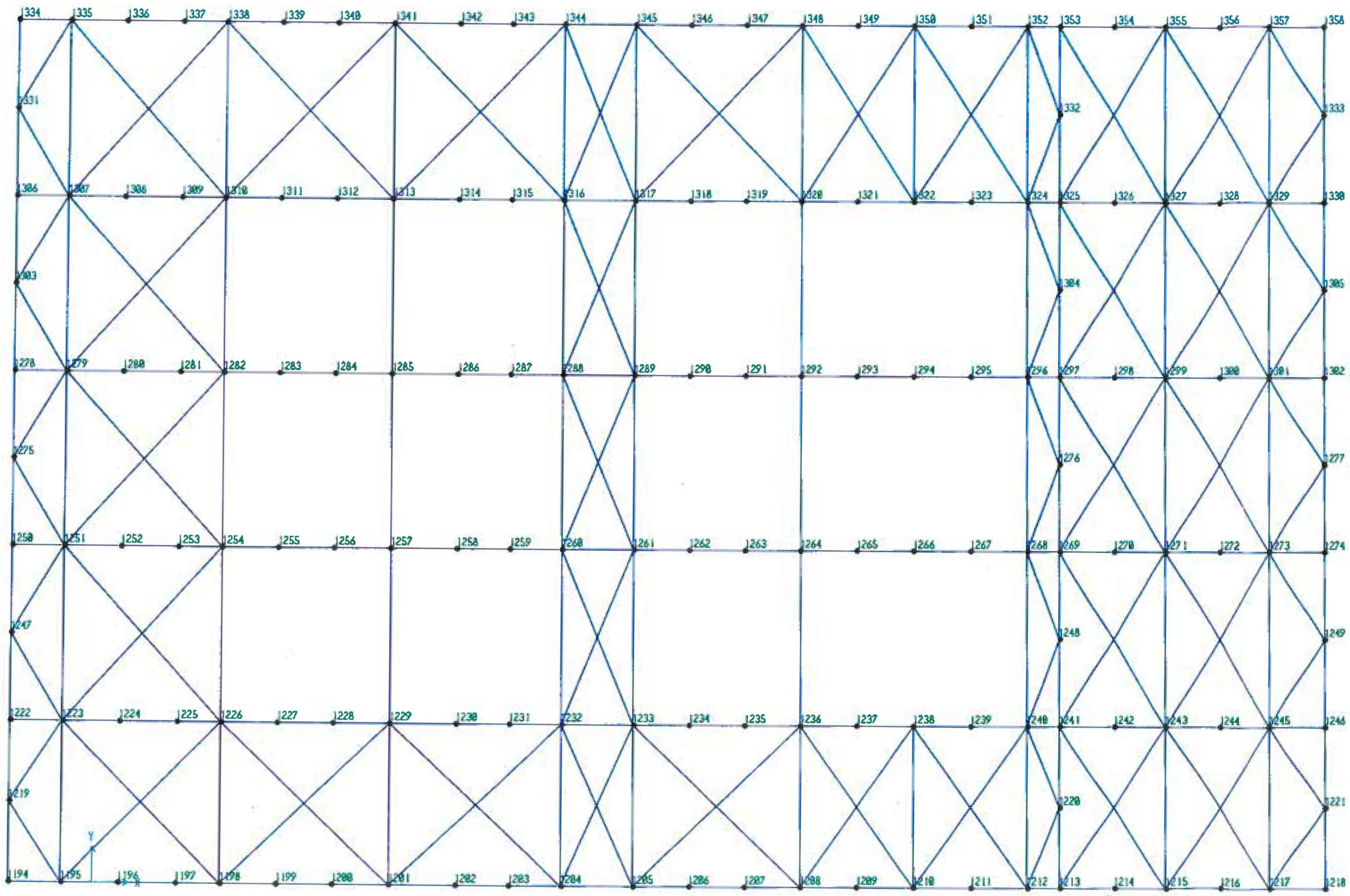


FIG. 6.4.8

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=97.5 - Kip, ft, F Units

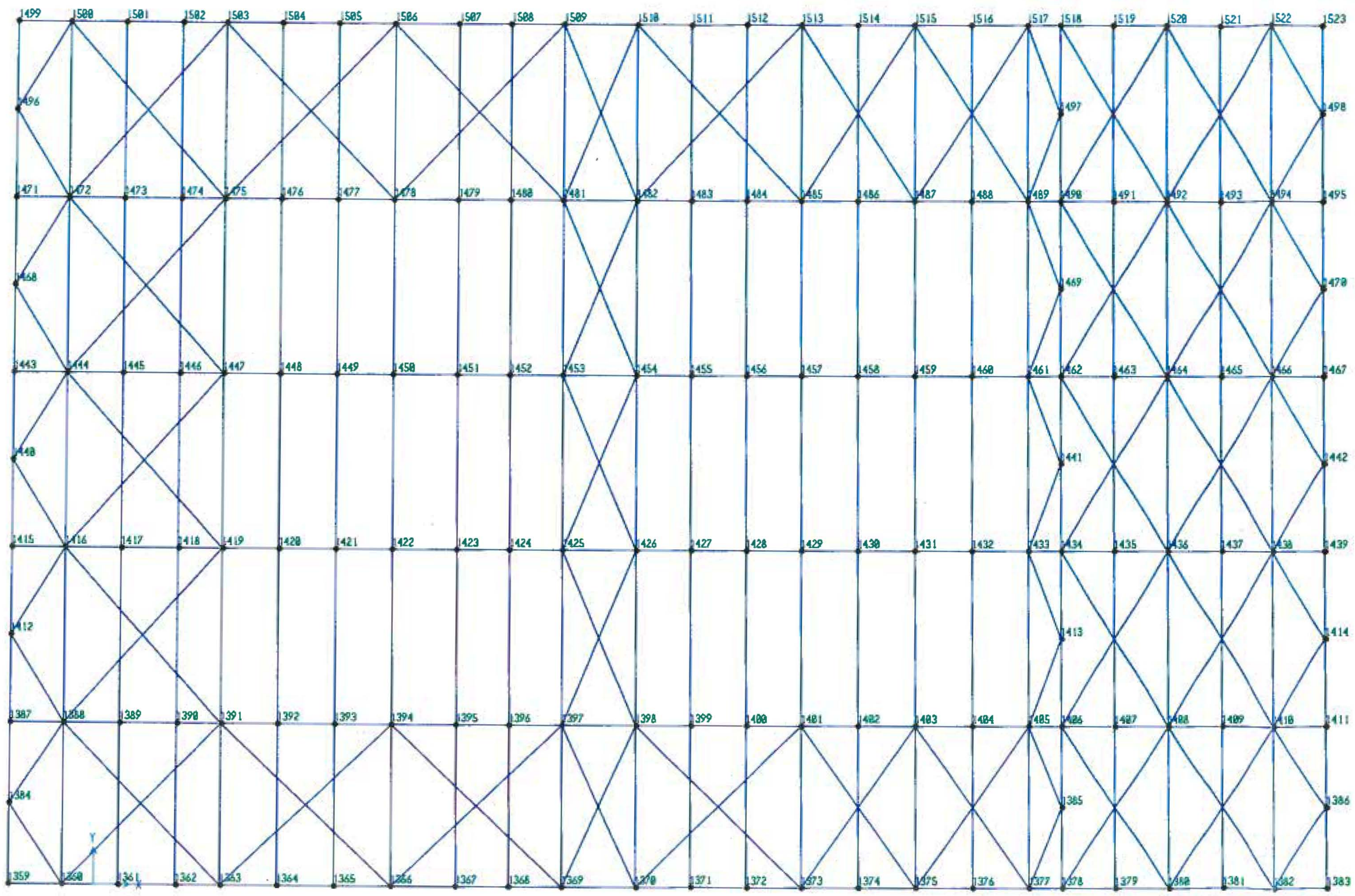


FIG. 6.4.9

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Y Plane @ Z=104.5 - Kip, ft, F Units

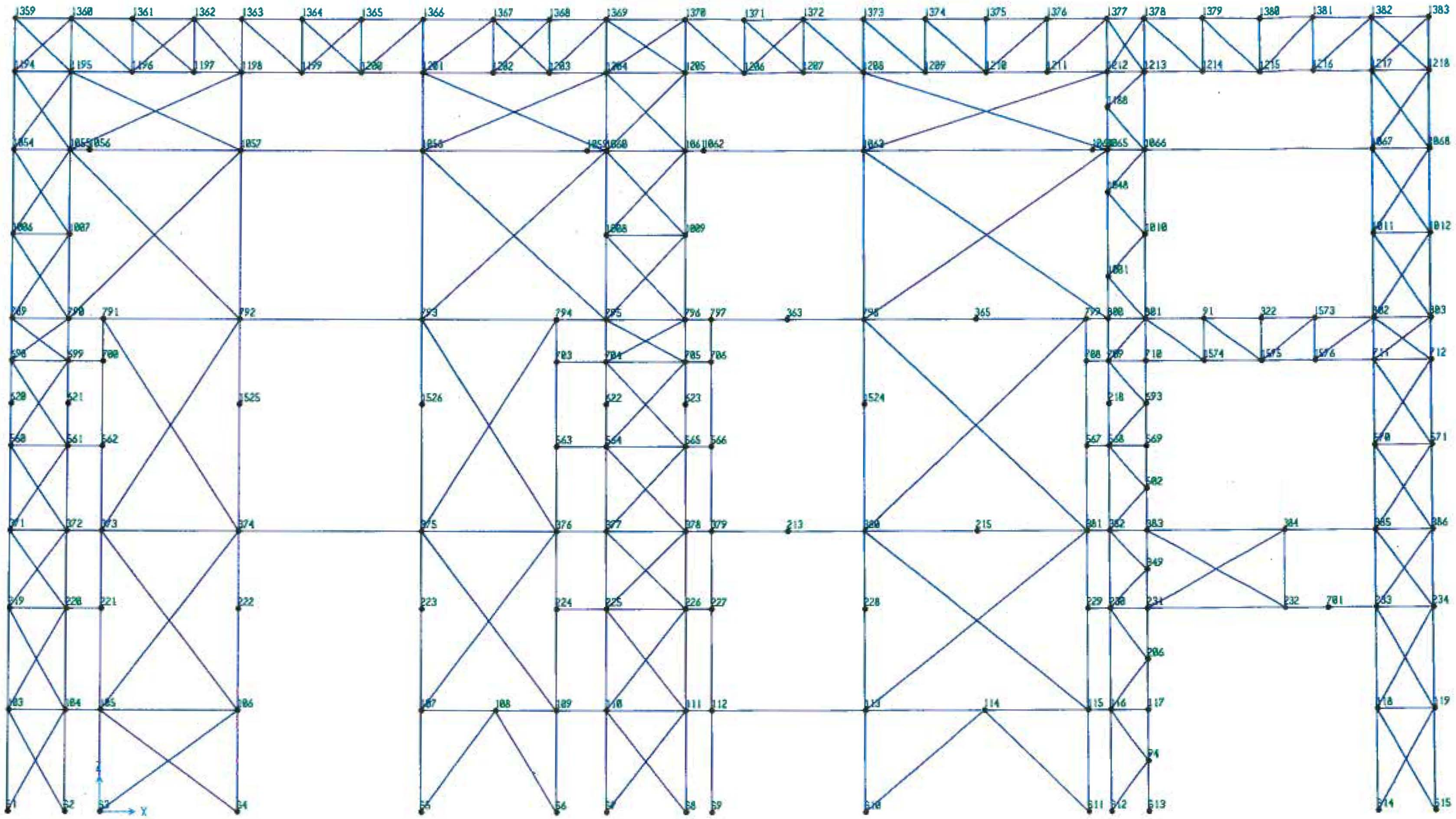


FIG. 6.4.10

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Z Plane @ Y=0 - Kip, ft, F Units

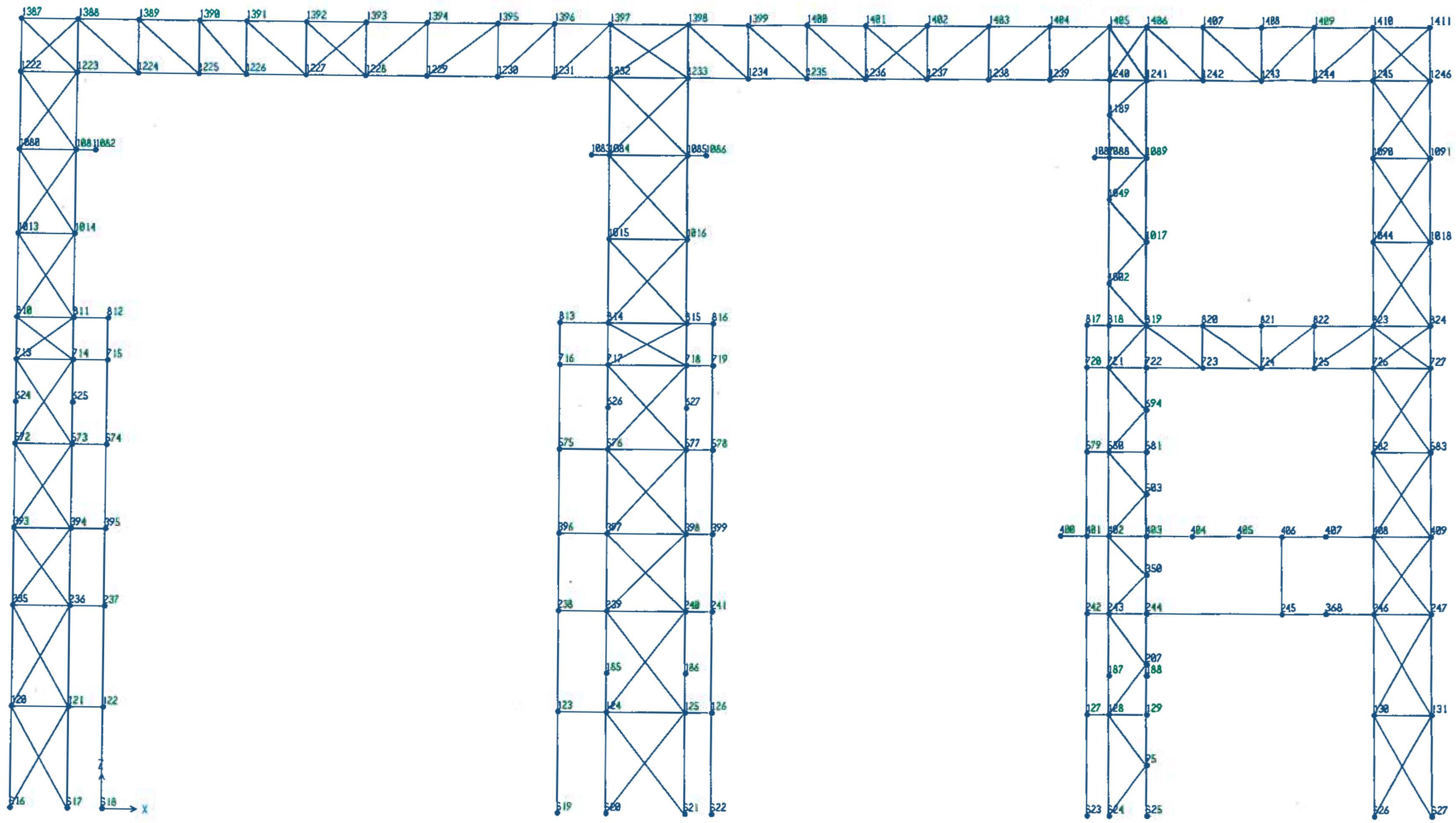


FIG. 6·4·11

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Z Plane @ Y=23 - Kip, ft, F Units

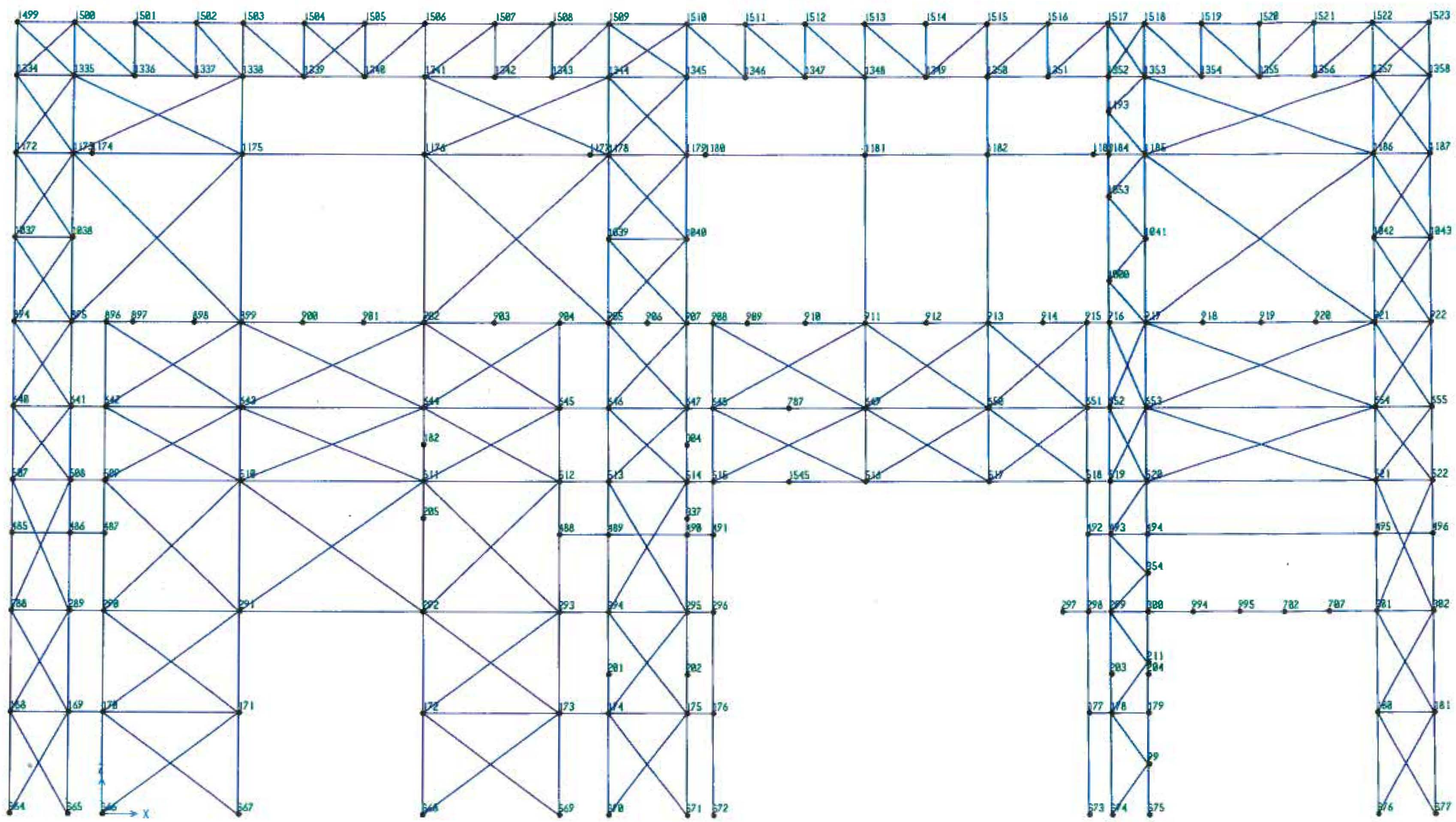


FIG. 6·4·12

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Z Plane @ Y=123 - Kip, ft, F Units

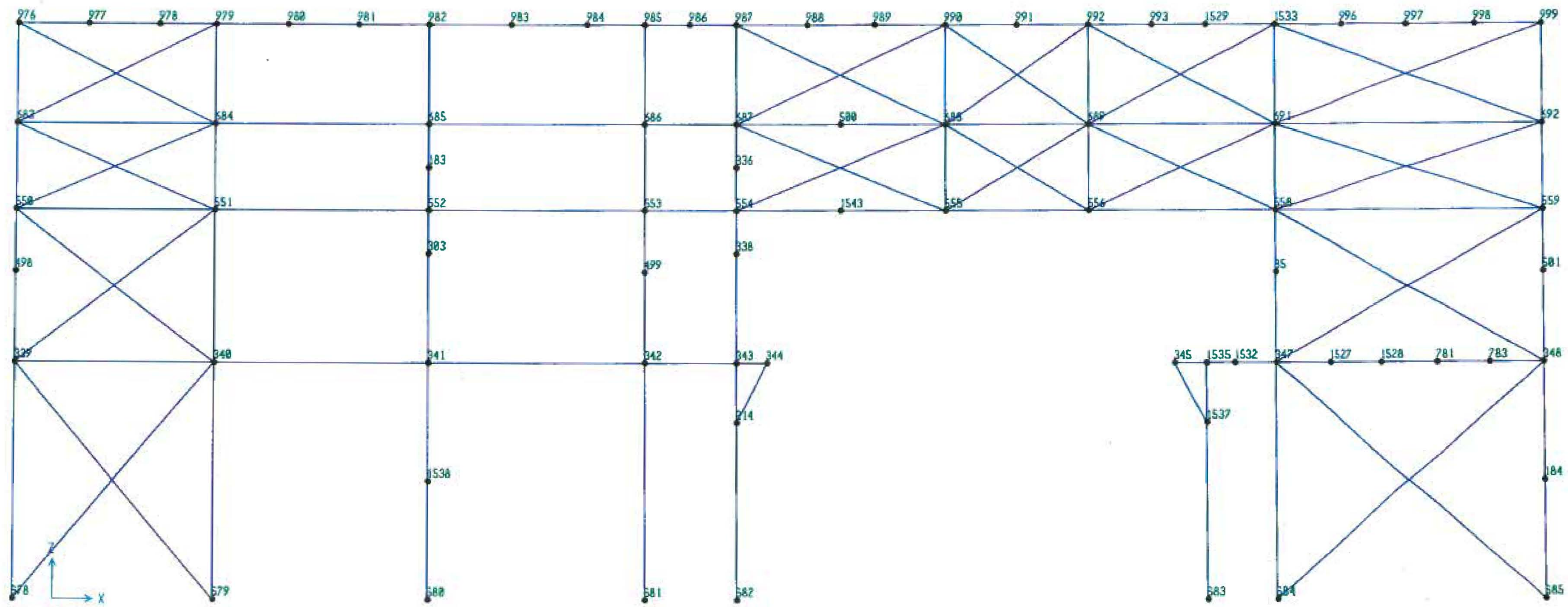


FIG. 6·4·13

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - X-Z Plane @ Y=160 - Kip, ft, F Units

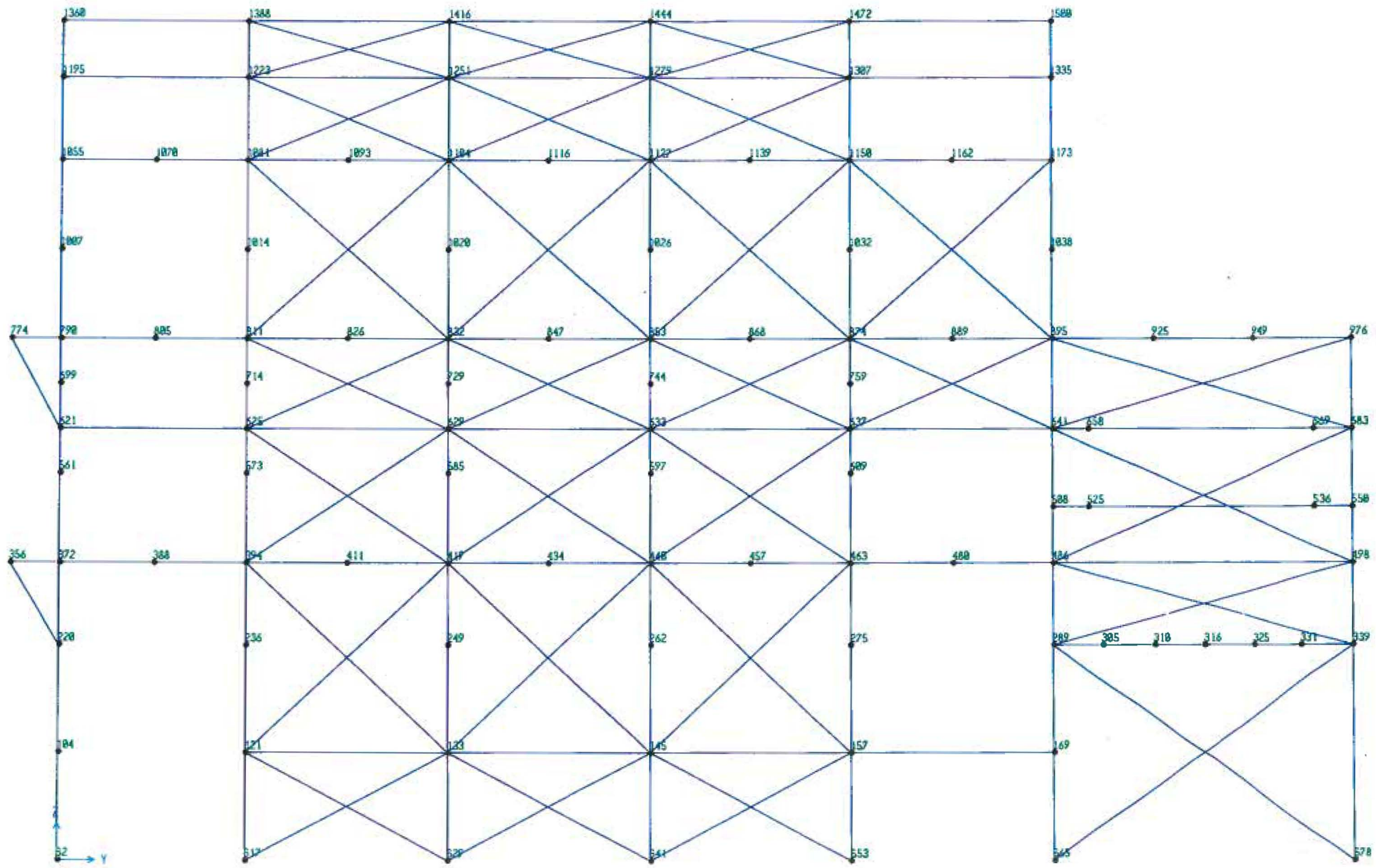


FIG. 6·4·14.

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - Y-Z Plane @ X=-4.5 - Kip, ft, F Units

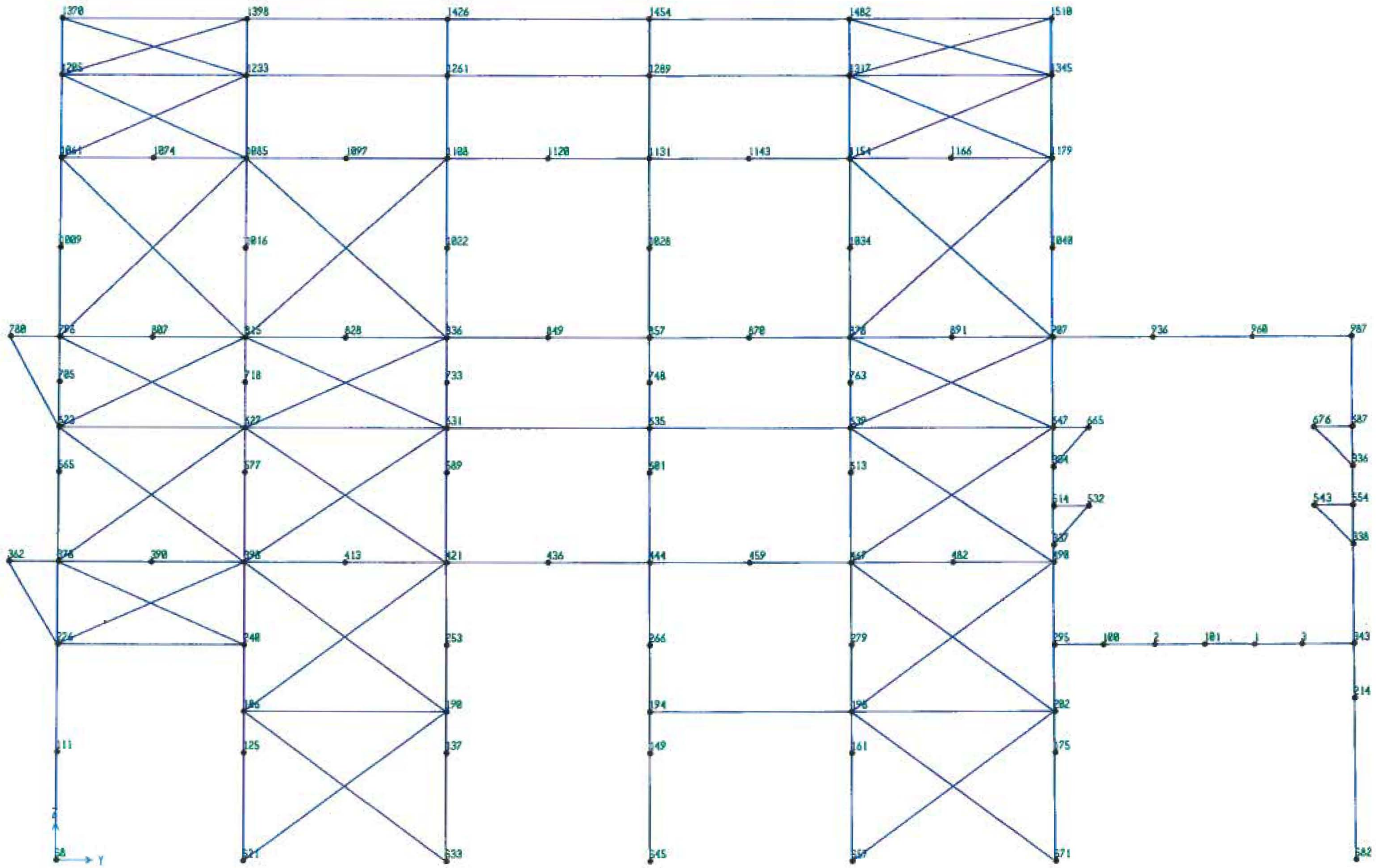


FIG. 6.4.15

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - Y-Z Plane @ X=76.25 - Kip, ft, F Units

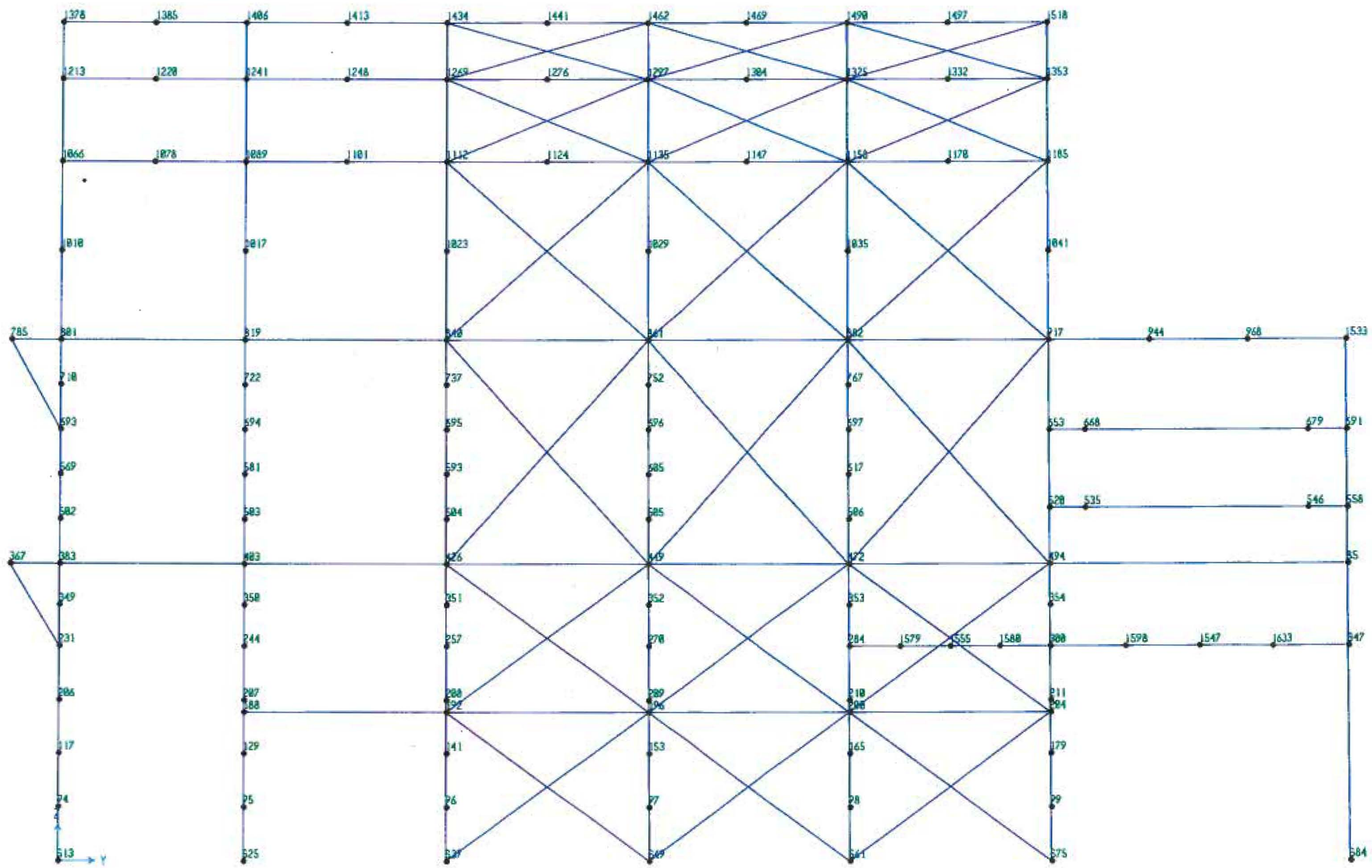


FIG. 6.4.16

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - Y-Z Plane @ X=137 - Kip, ft, F Units

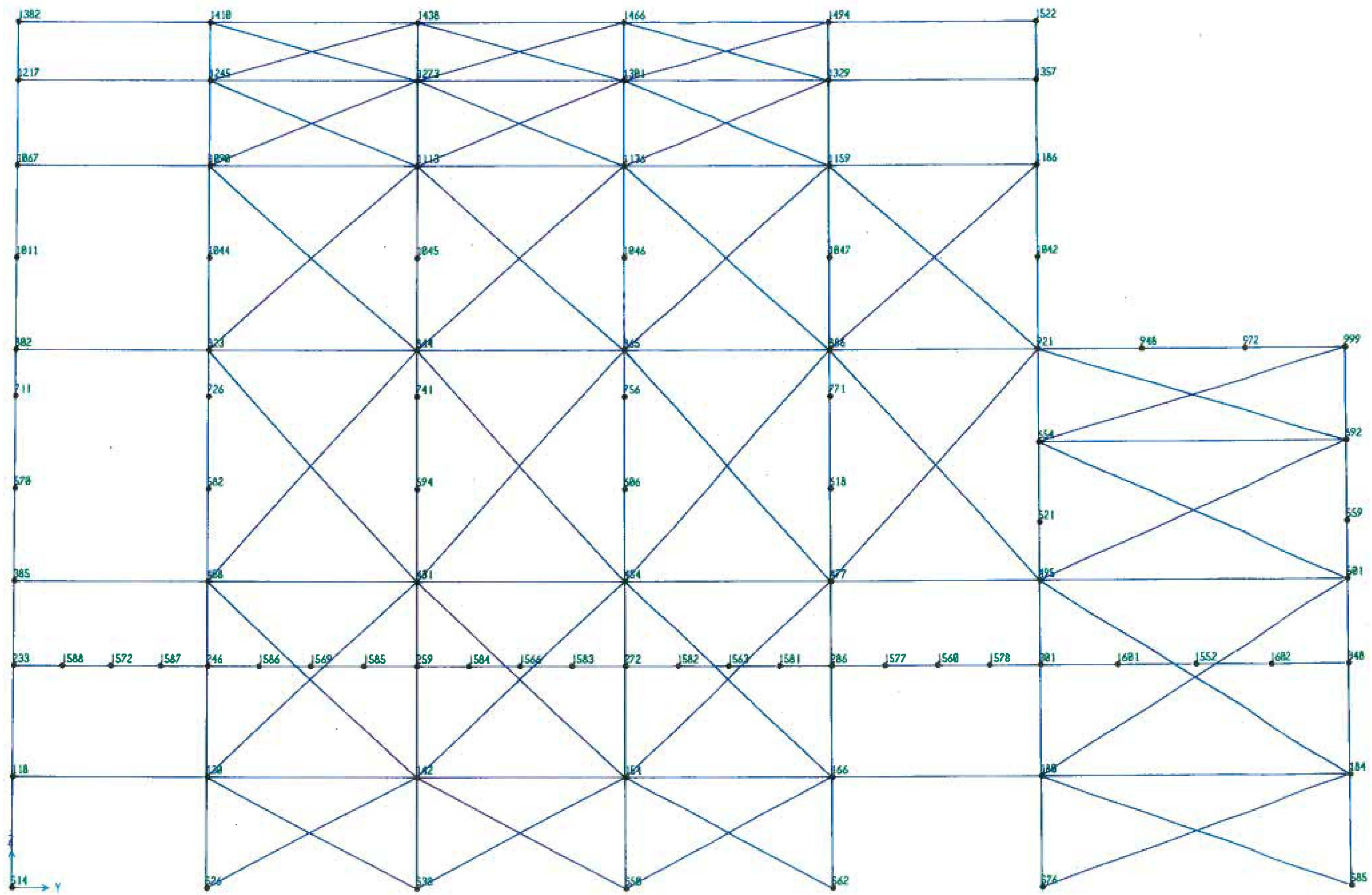


FIG 6.4.17.

SAP2000 v9.1.4 - File:steel-10.23.2007 LOAD 5 - Y-Z Plane @ X=167 - Kip, ft, F Units

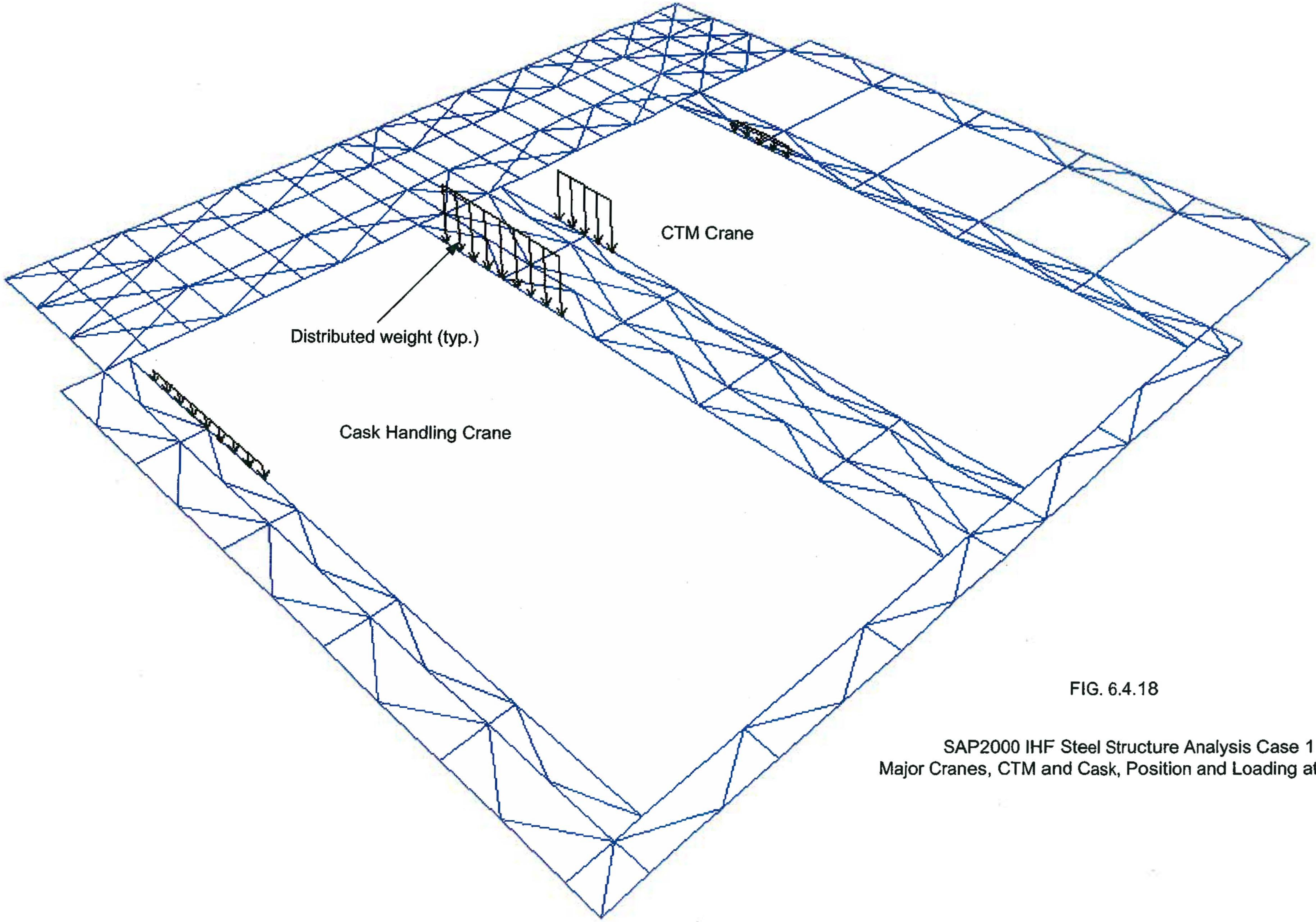


FIG. 6.4.18

SAP2000 IHF Steel Structure Analysis Case 1
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

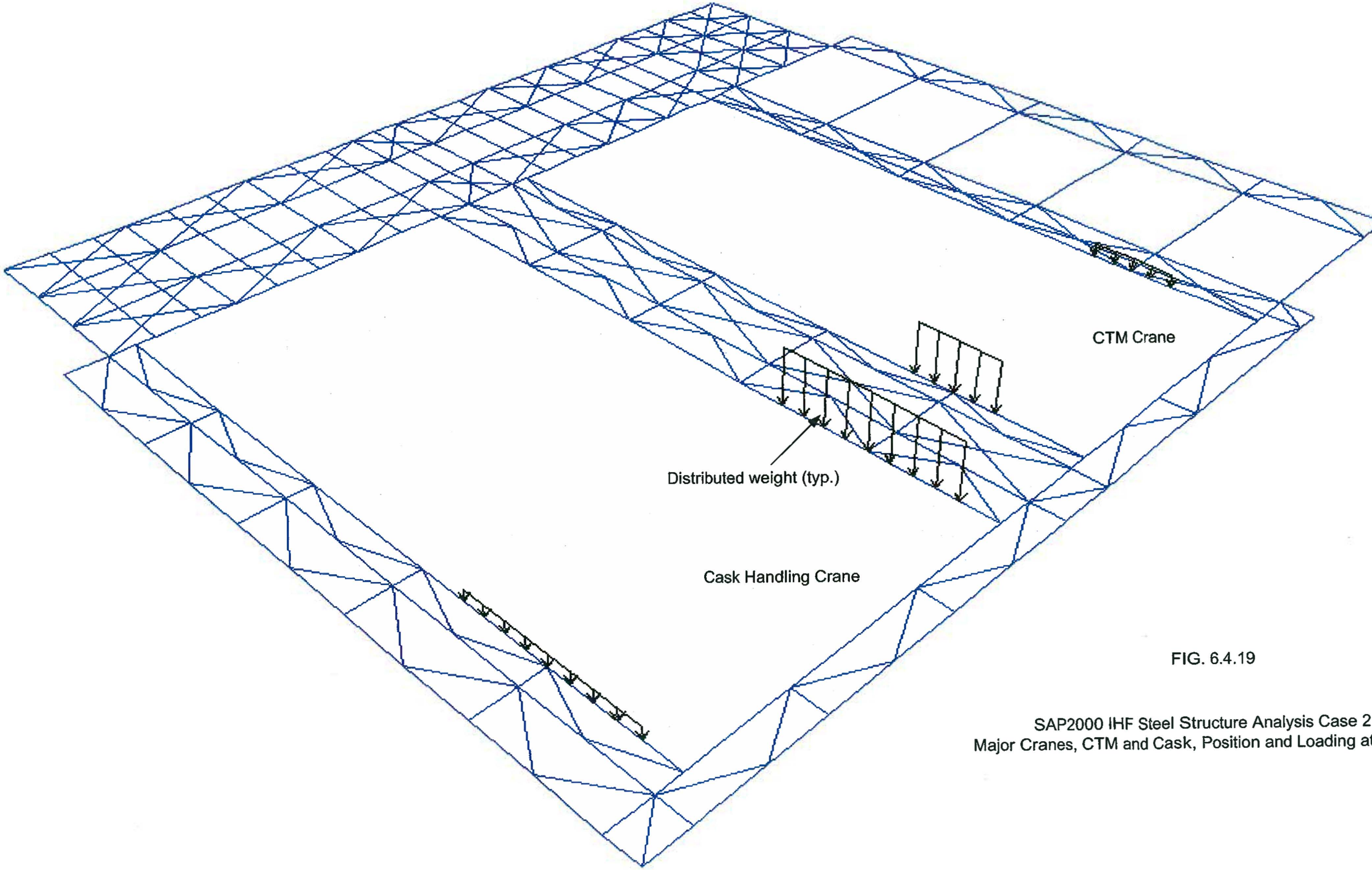


FIG. 6.4.19

SAP2000 IHF Steel Structure Analysis Case 2
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

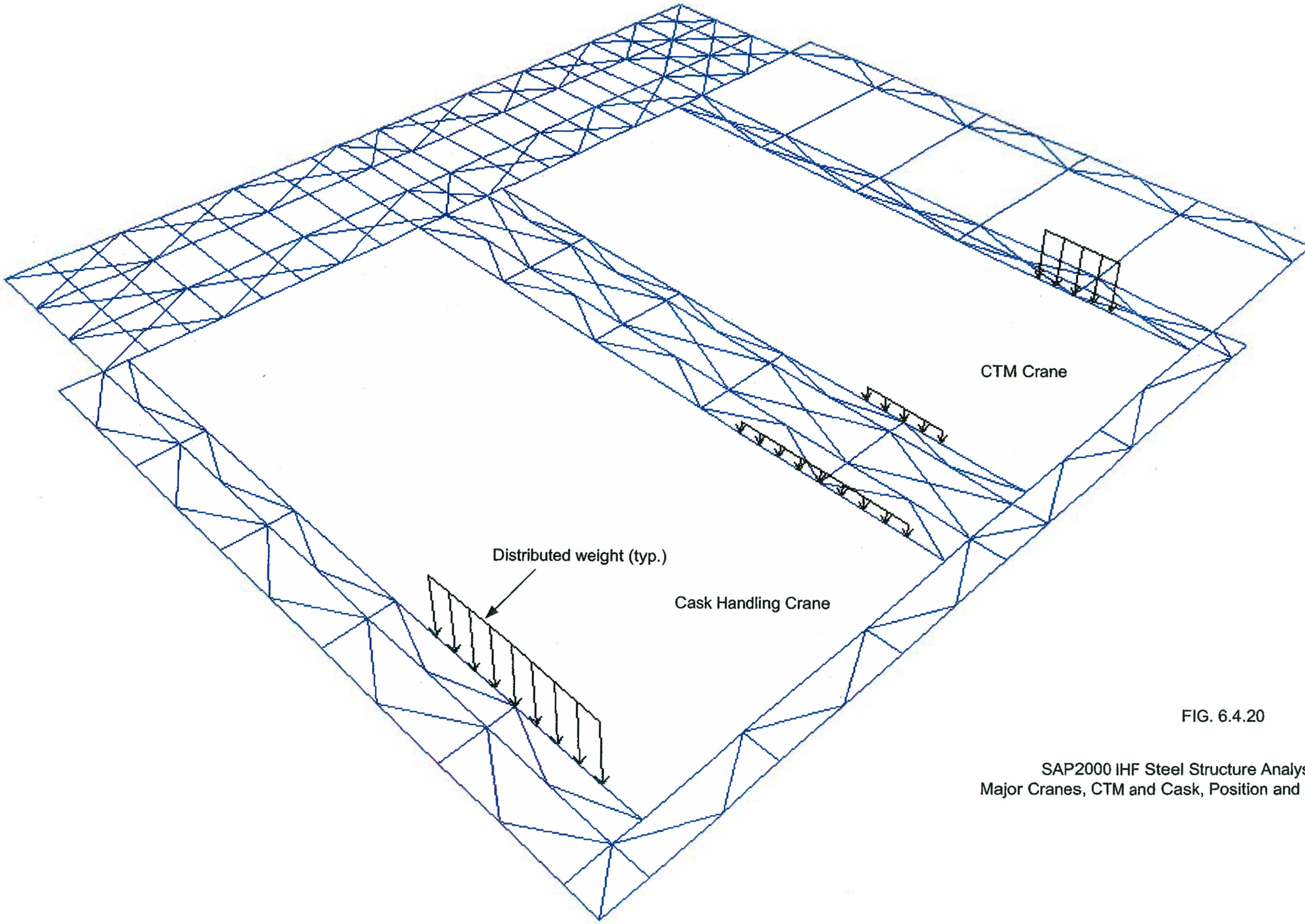


FIG. 6.4.20

SAP2000 IHF Steel Structure Analysis Case 3
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

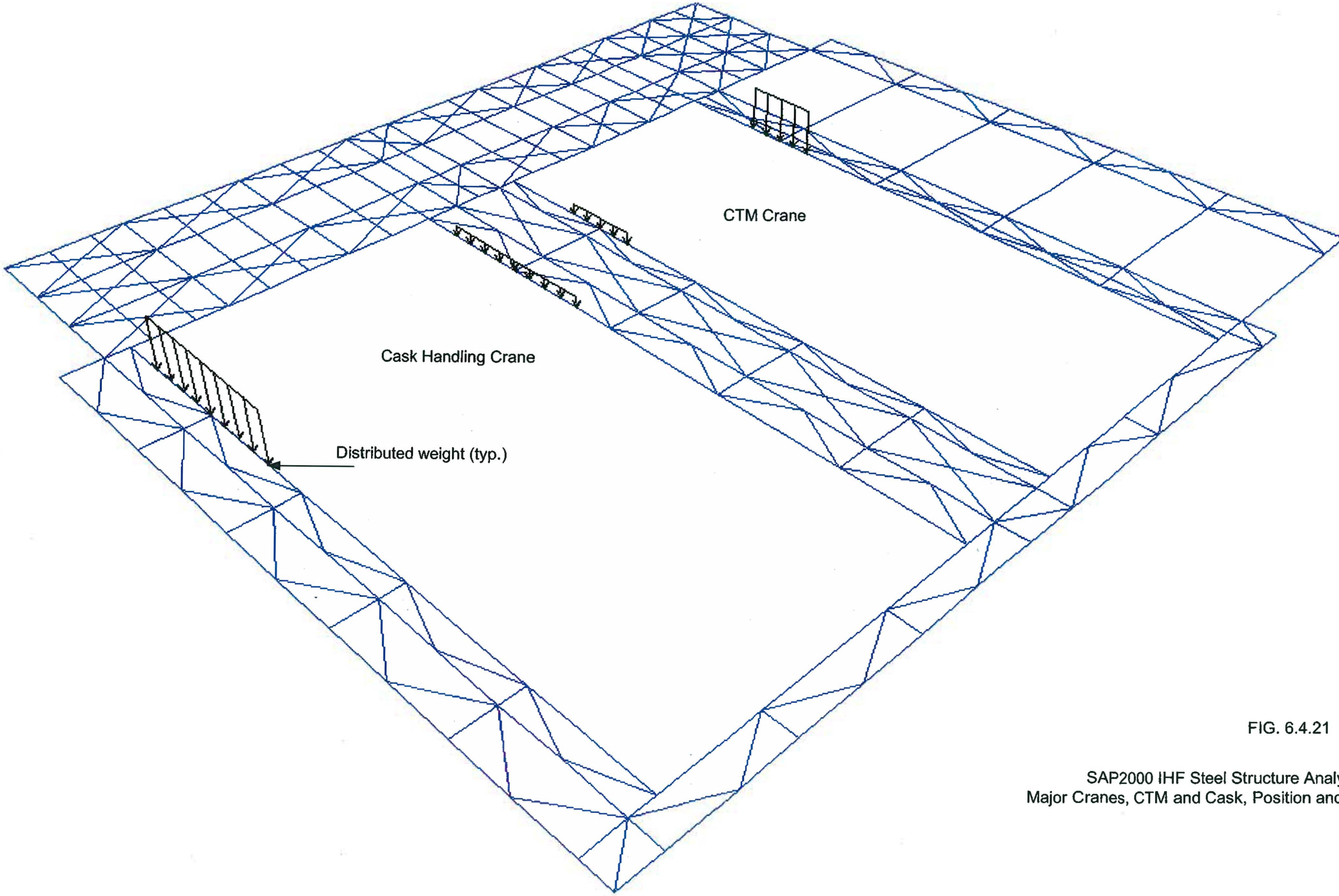


FIG. 6.4.21

SAP2000 IHF Steel Structure Analysis Case 4
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

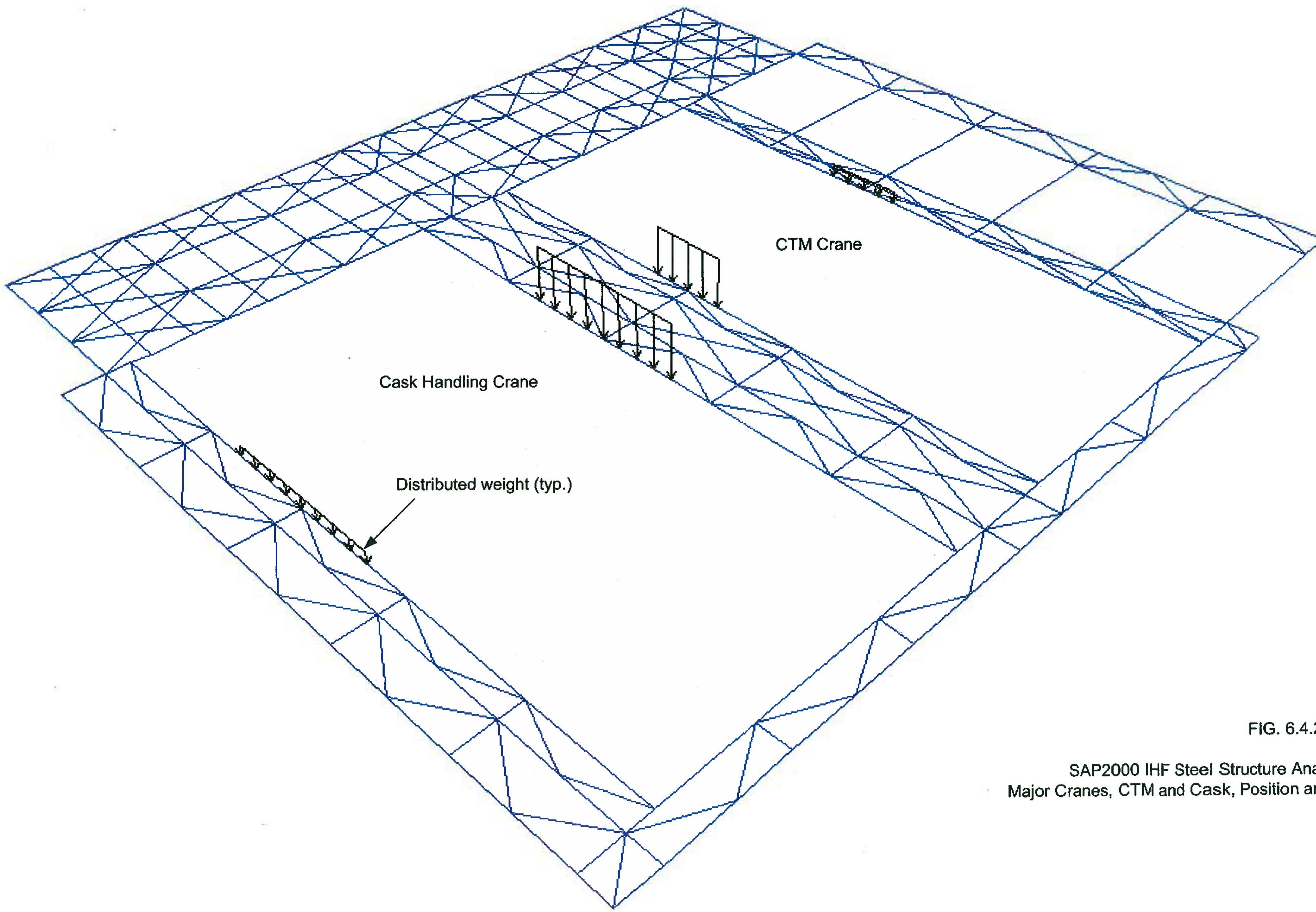


FIG. 6.4.22

SAP2000 IHF Steel Structure Analysis Case 5
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

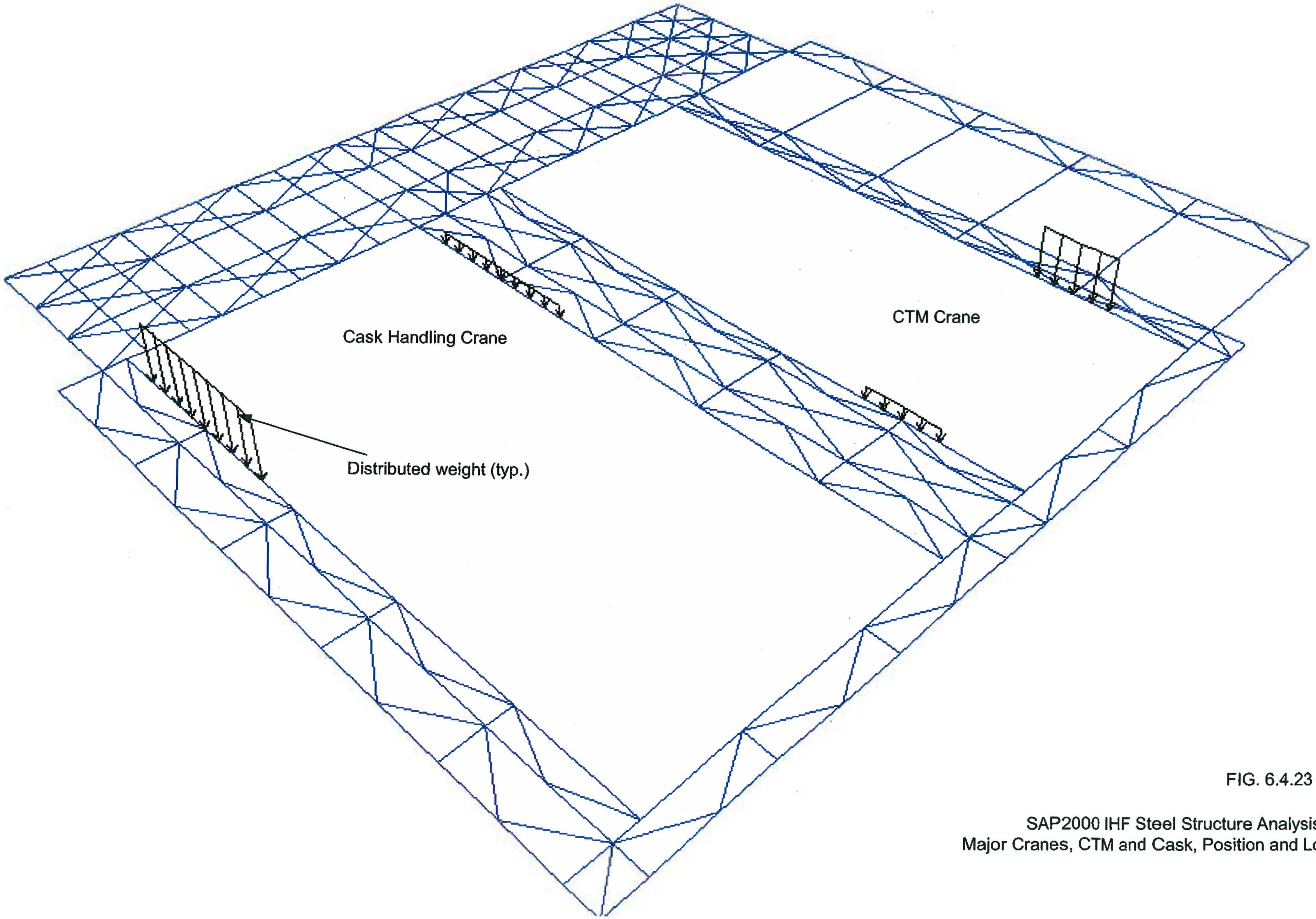


FIG. 6.4.23

SAP2000 IHF Steel Structure Analysis Case 6
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

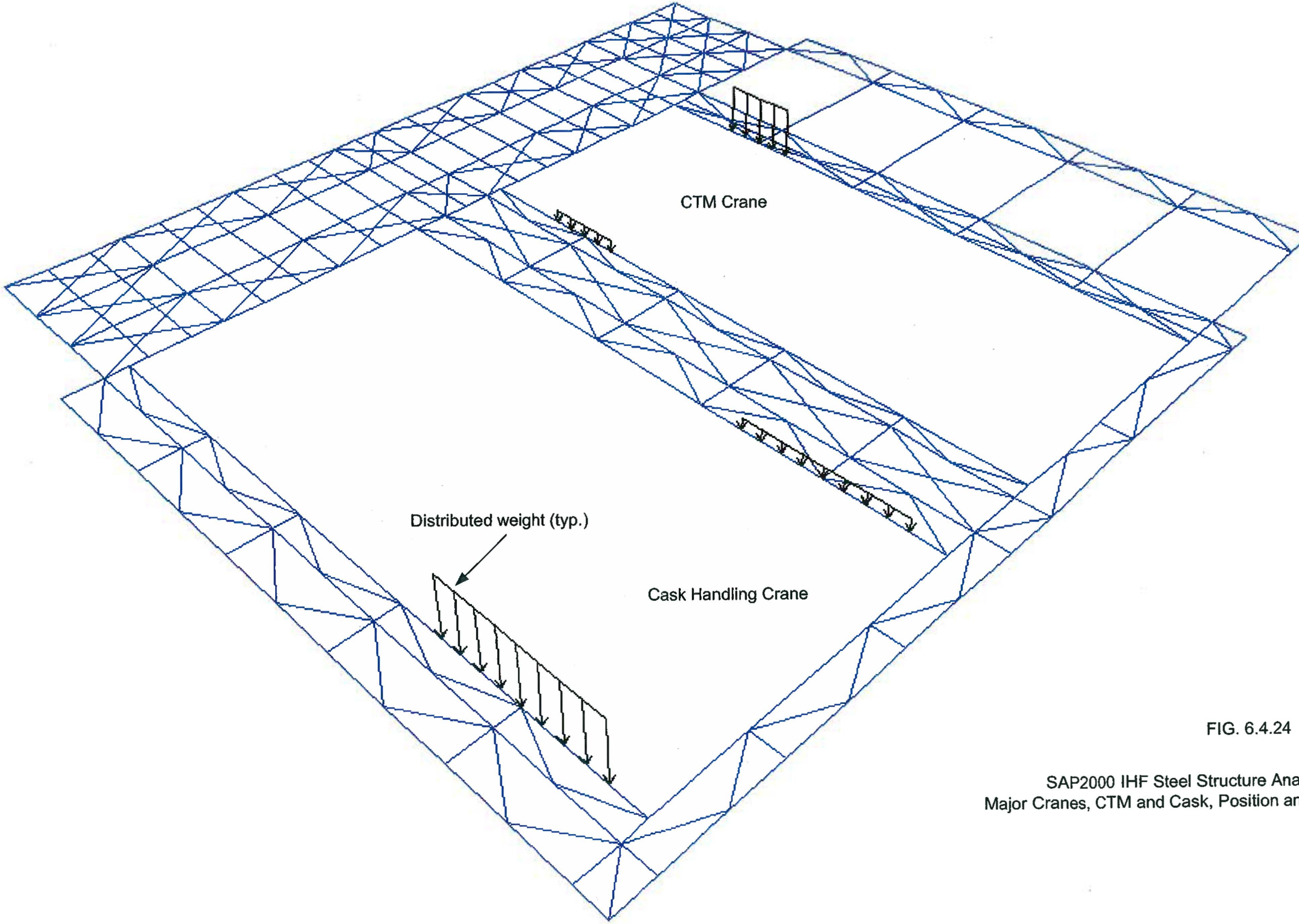


FIG. 6.4.24

SAP2000 IHF Steel Structure Analysis Case 7
Major Cranes, CTM and Cask, Position and Loading at EL.65ft

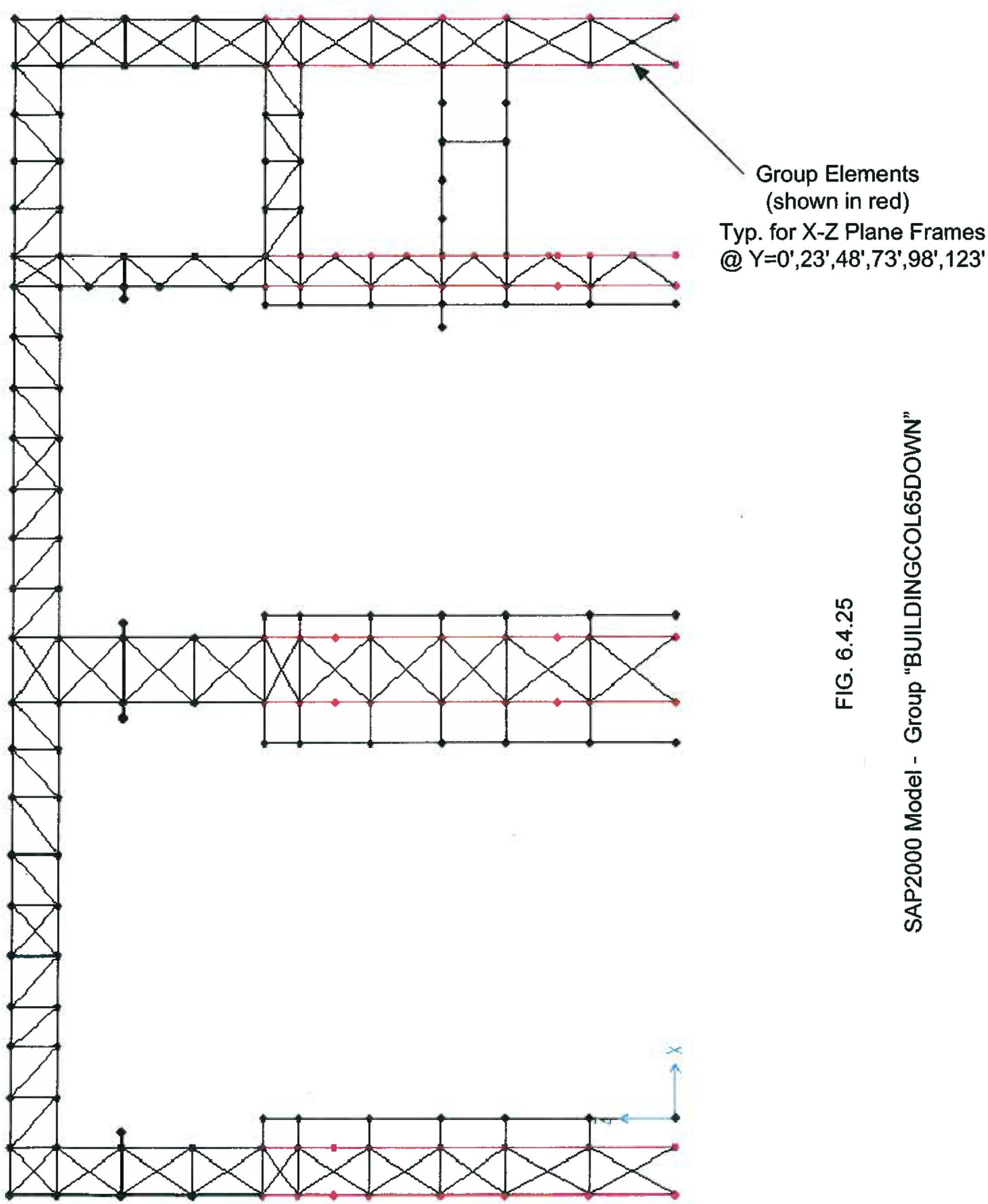


FIG. 6.4.25
SAP2000 Model - Group "BUILDINGCOL65DOWN"

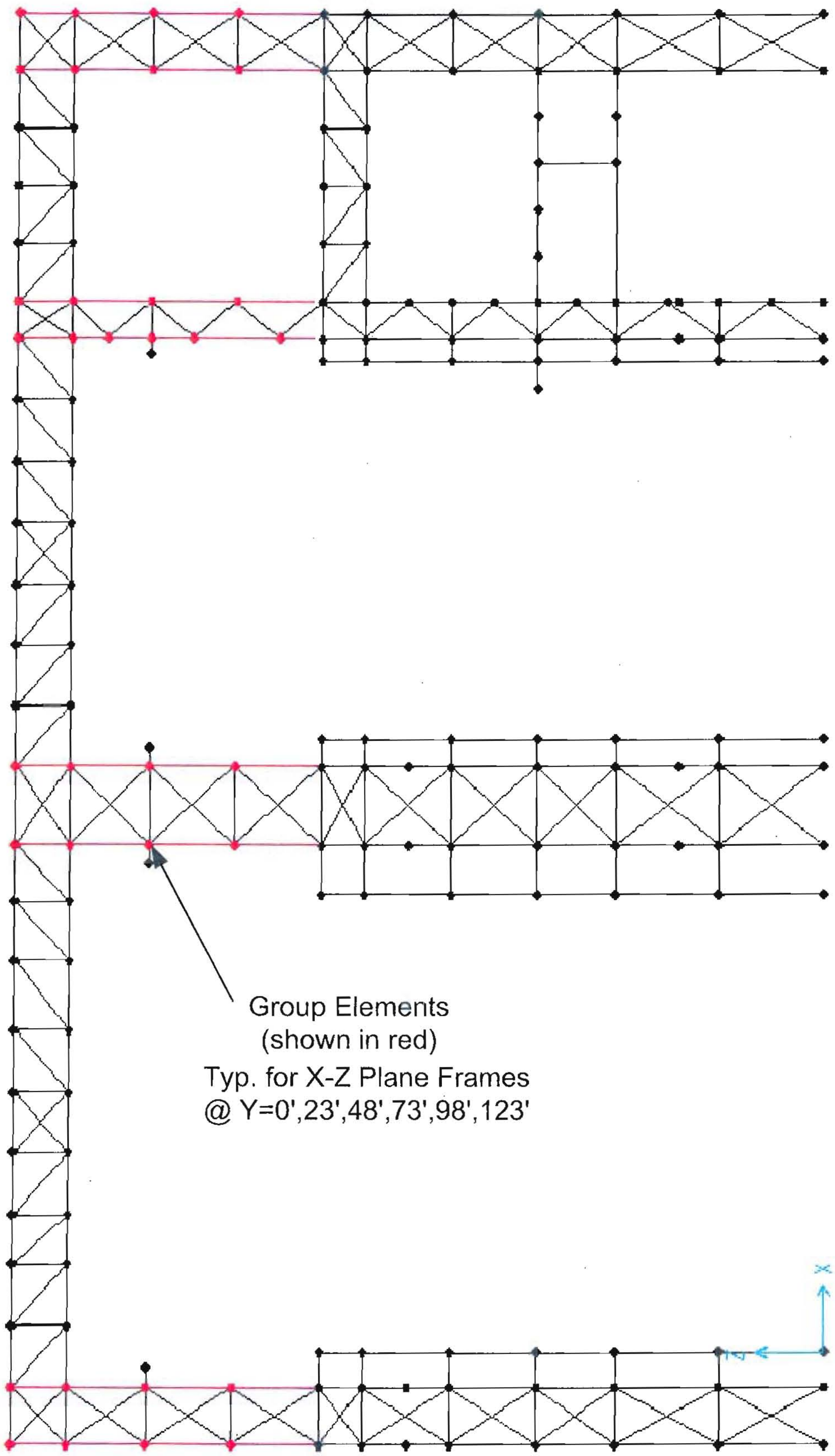


FIG. 6.4.26

SAP2000 Model - Group "BUILDINGCOL65UP"

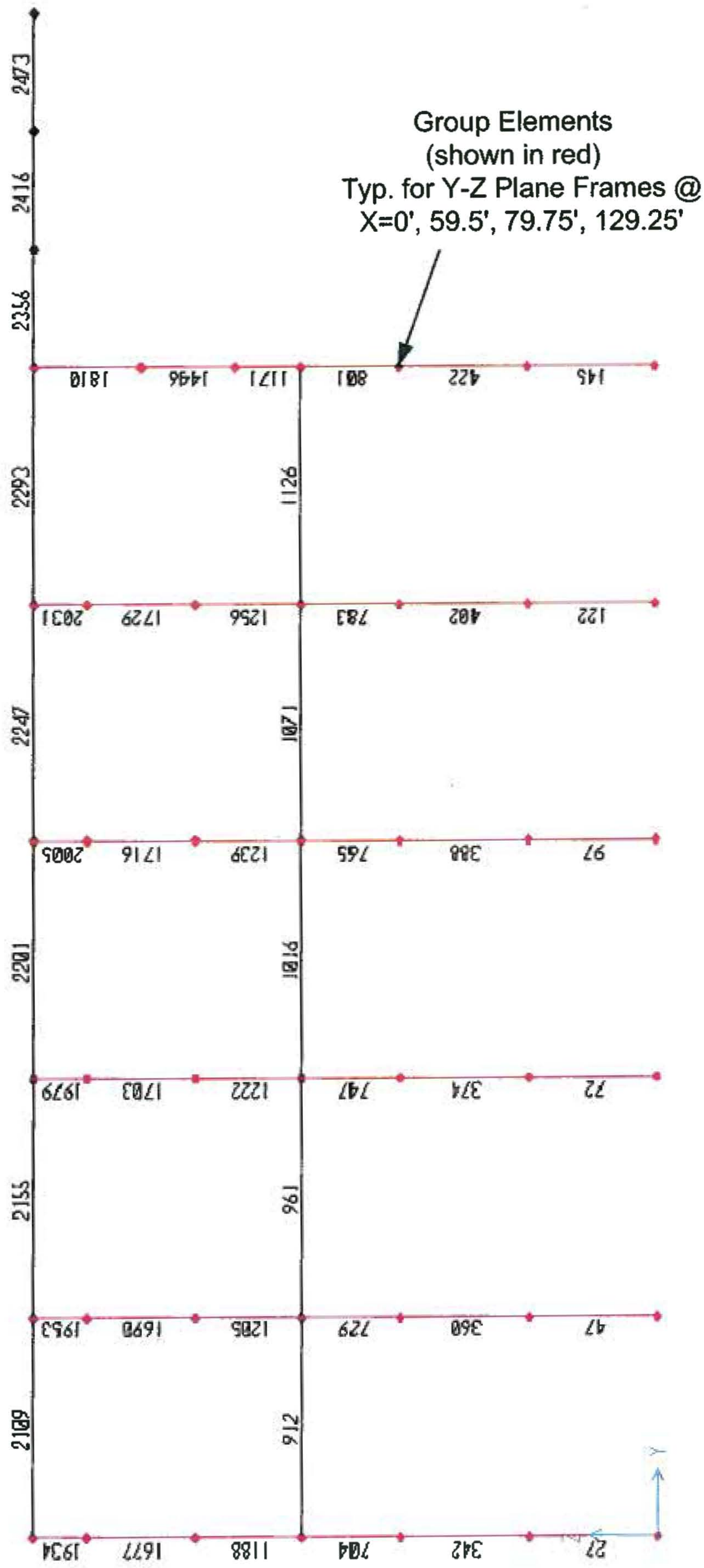


FIG. 6.4.27

SAP2000 Model - Group "CRANECOL"

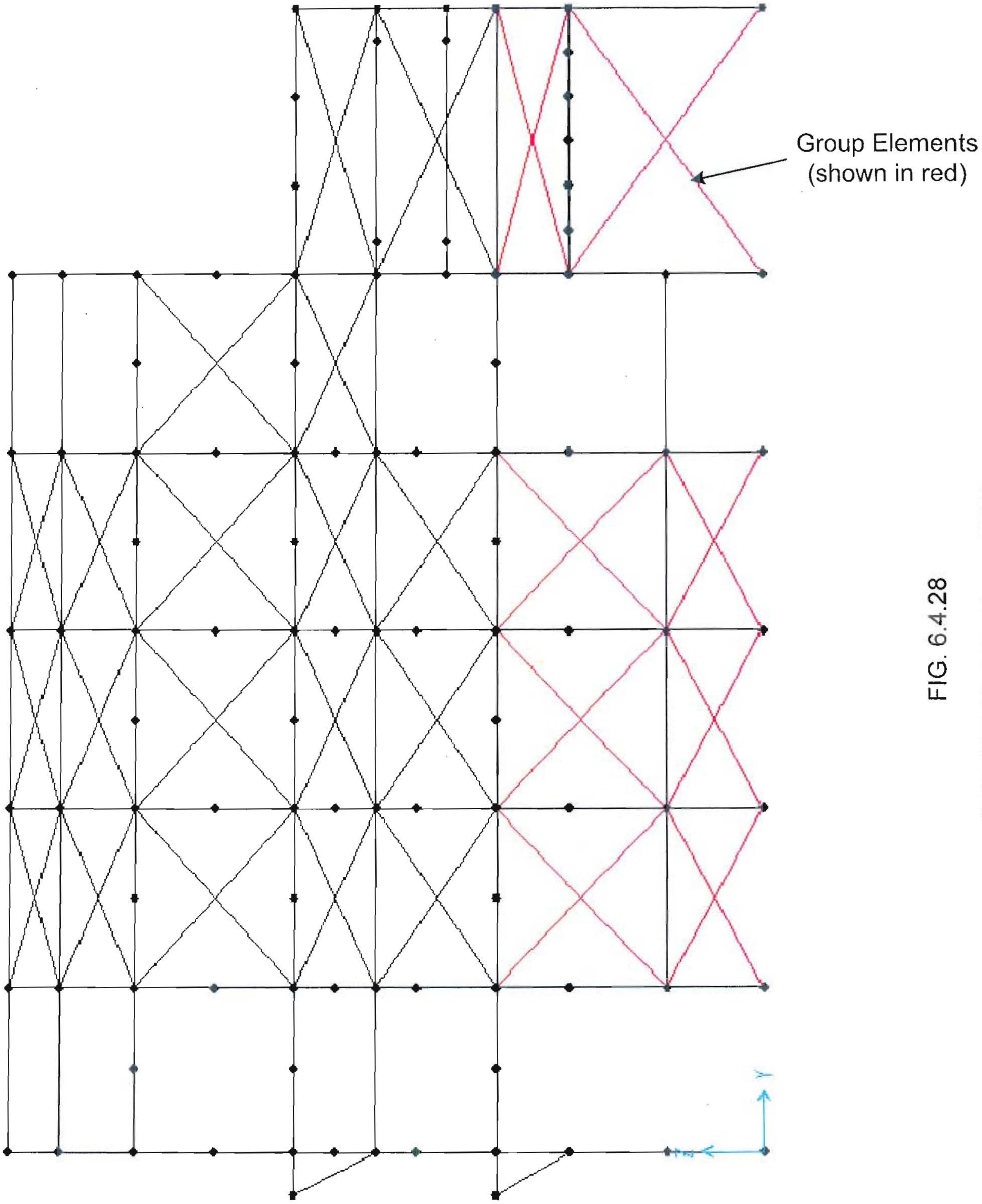


FIG. 6.4.28
SAP2000 Model - Group "BRACE@37"
Y-Z Plane @ X = 167ft

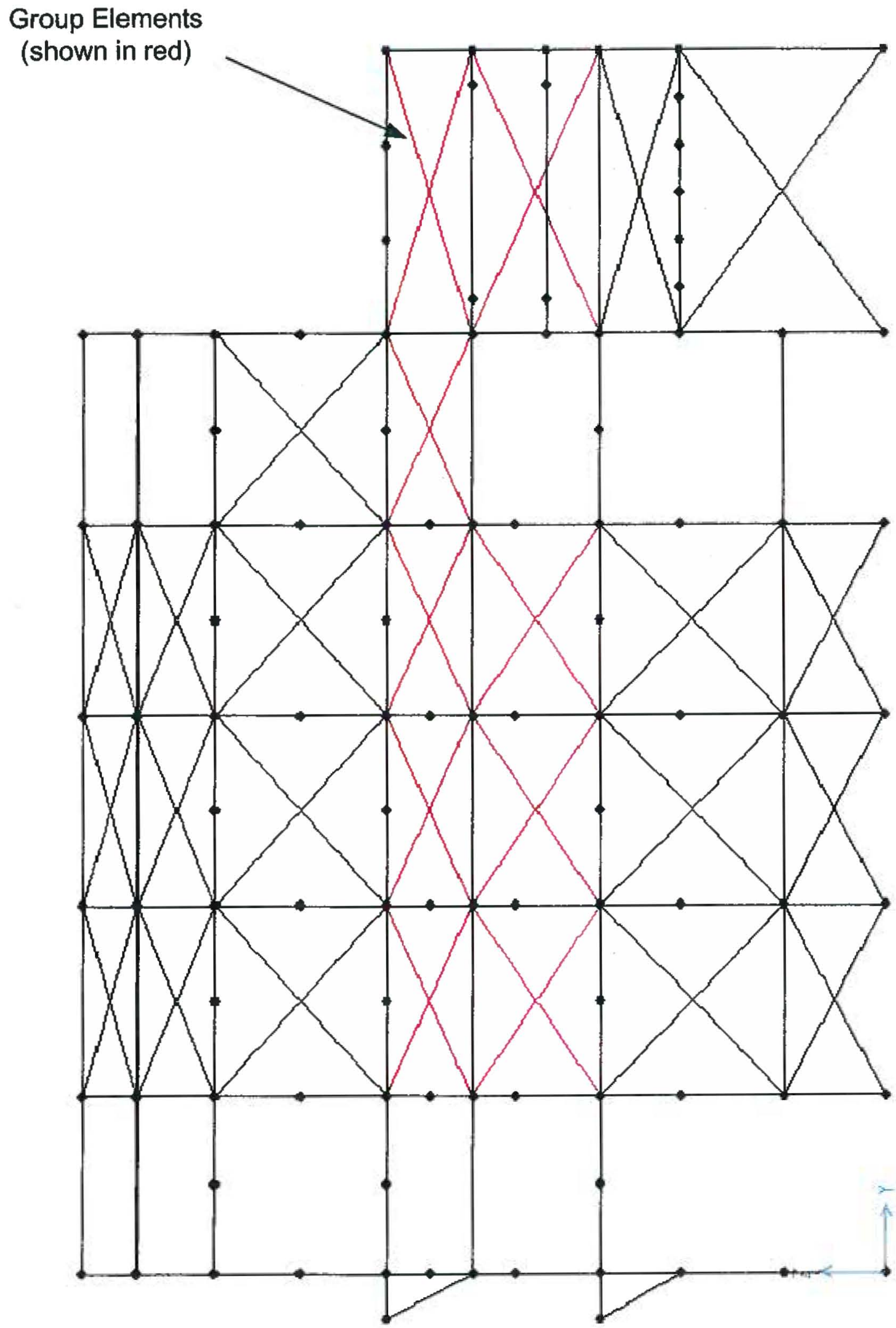


FIG. 6.4.29

SAP2000 Model - Group "BRACE@65"
Y-Z Plane @X = -4.5ft

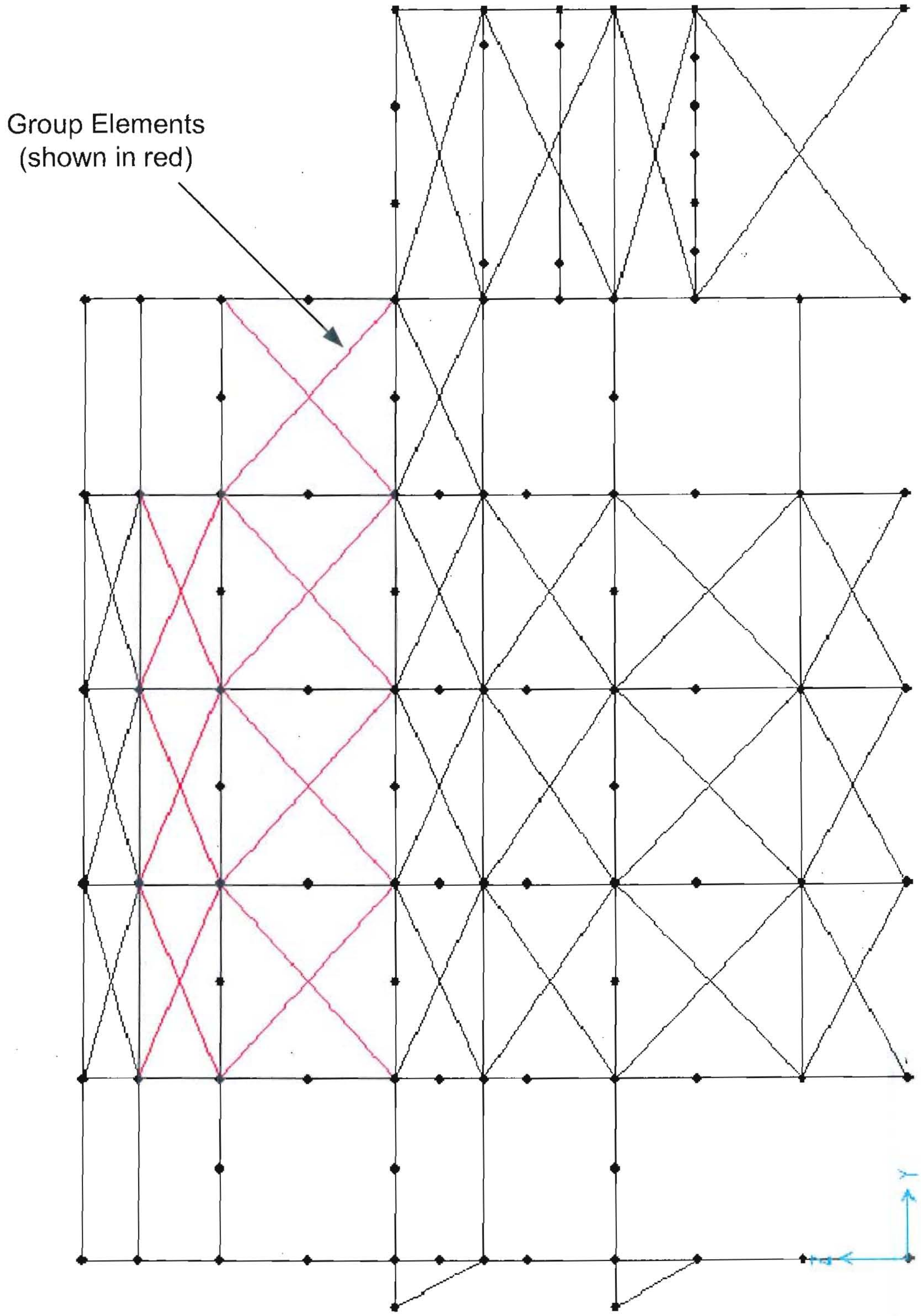


FIG. 6.4.30
SAP2000 Model - Group "BRACE@65UP"
Y-Z Plane @ X = -4.5ft

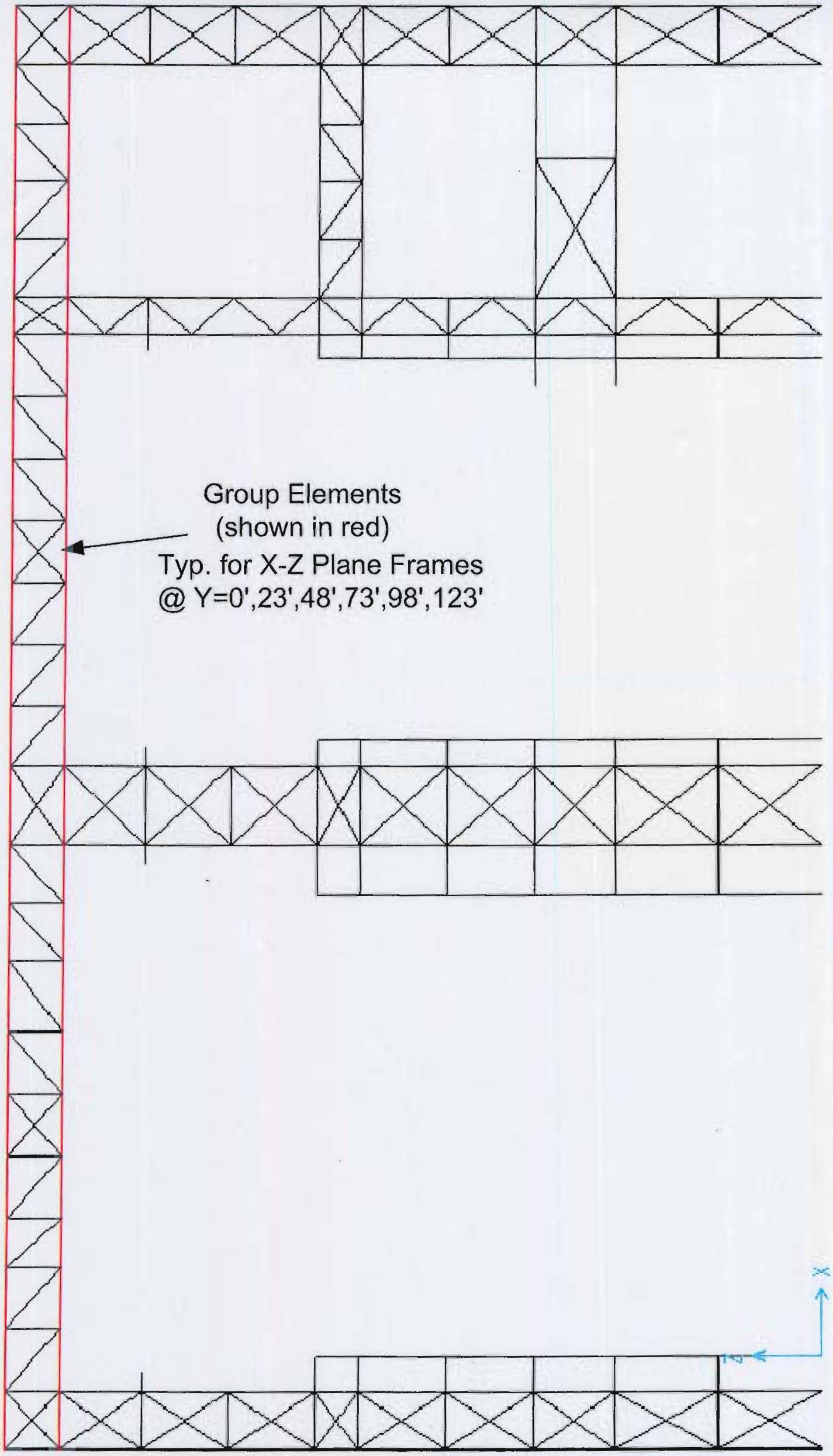


FIG. 6.4.31

SAP2000 Model - Group "ROOFTRUST"

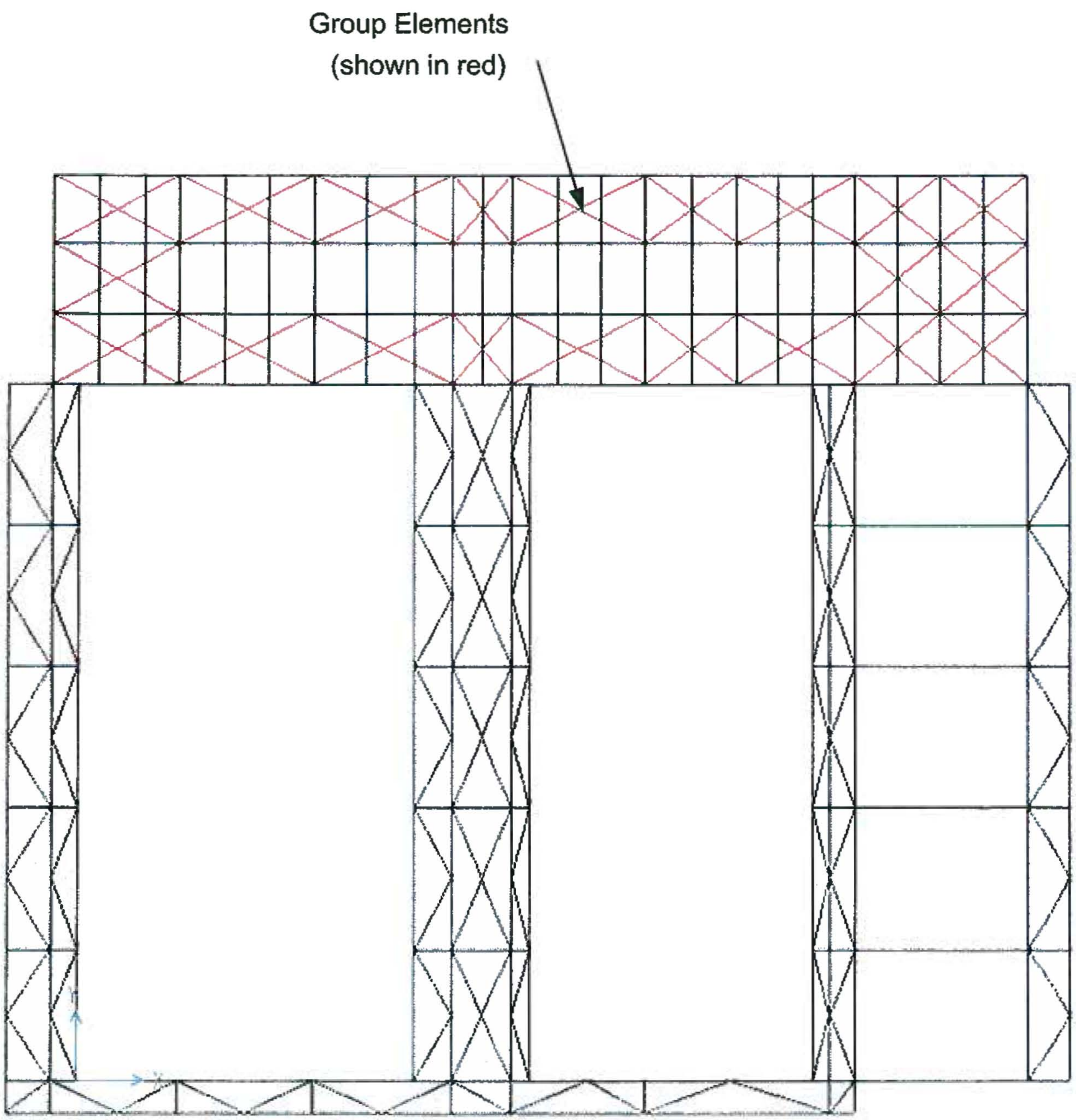


FIG. 6.4.32
SAP2000 Model - Group "LOWERROOFHX"
X-Y Plane @ Z = 65ft

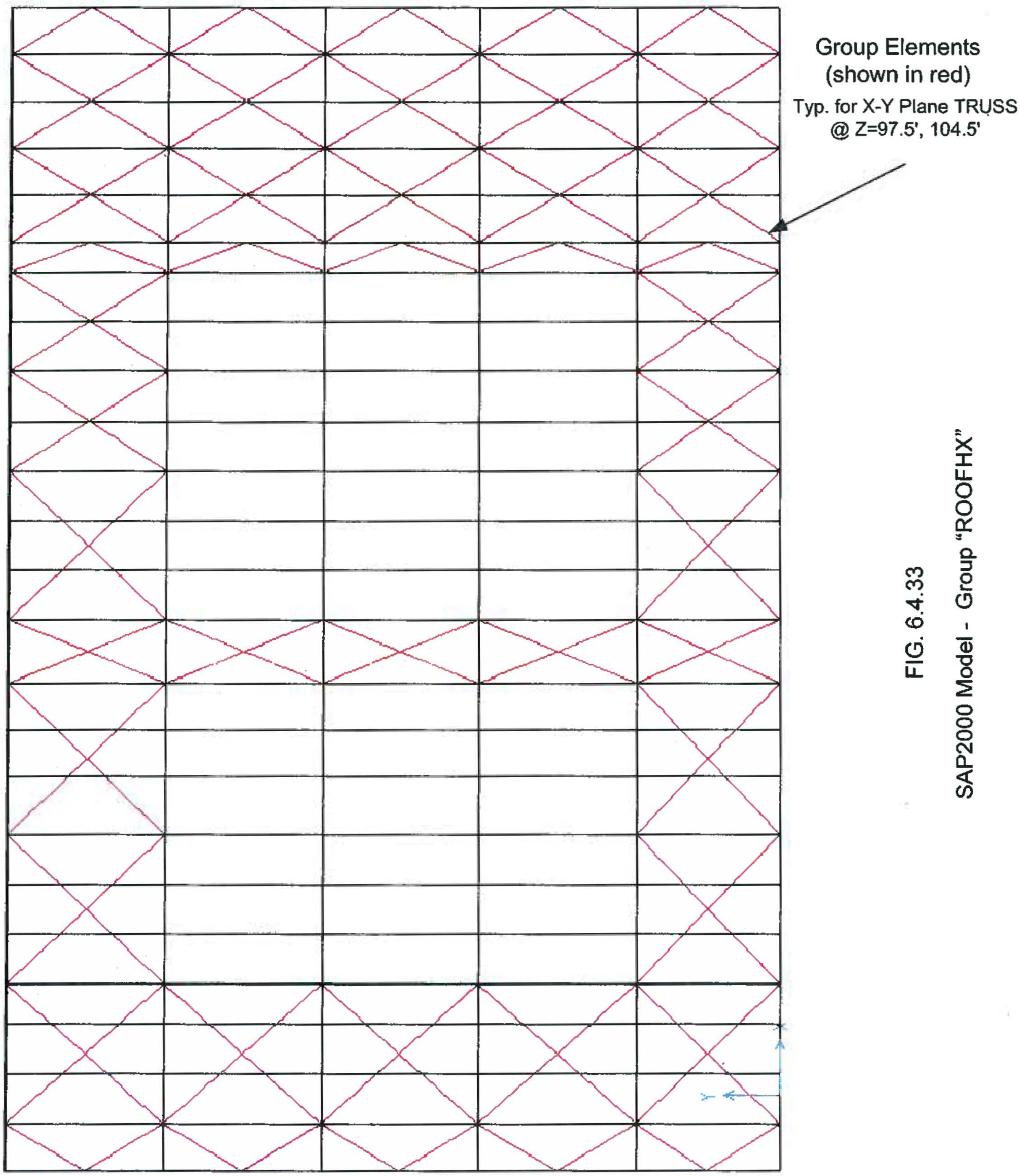


FIG. 6.4.33
SAP2000 Model - Group "ROOFHX"

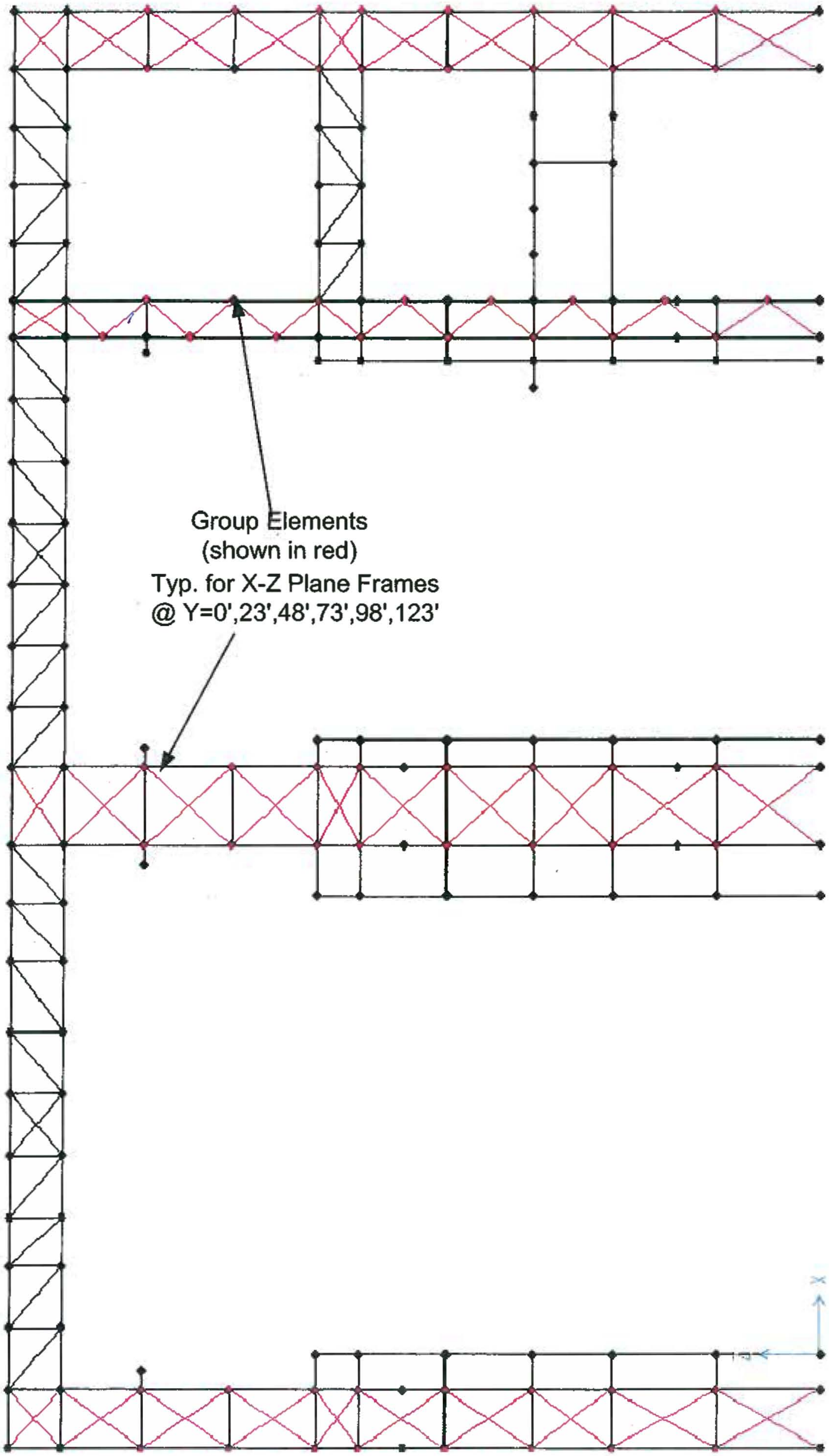


FIG. 6.4.34

SAP2000 Model - Group “SMALLVX”

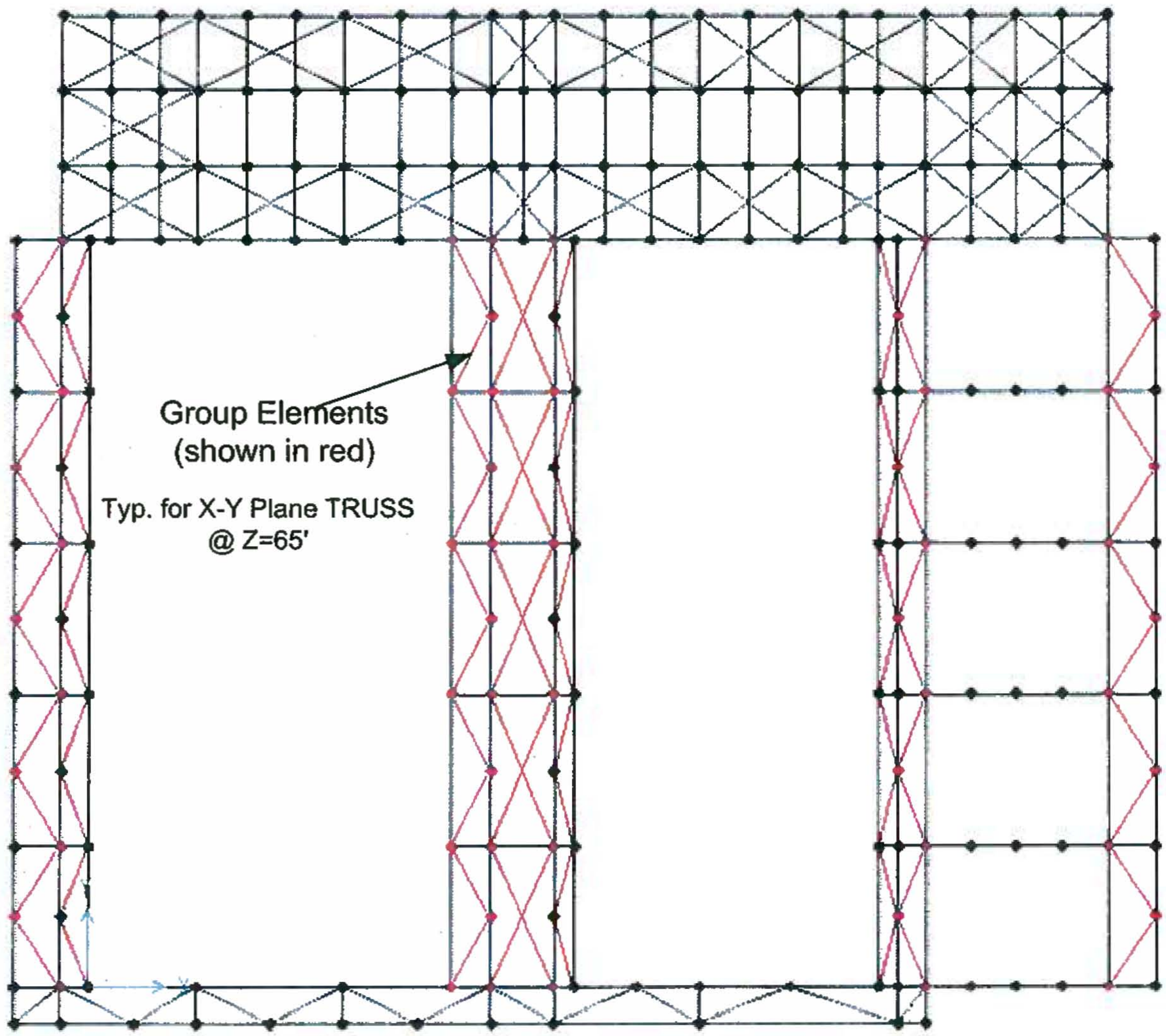


FIG. 6.4.35

SAP2000 Model - Group "SMALLHX@65"

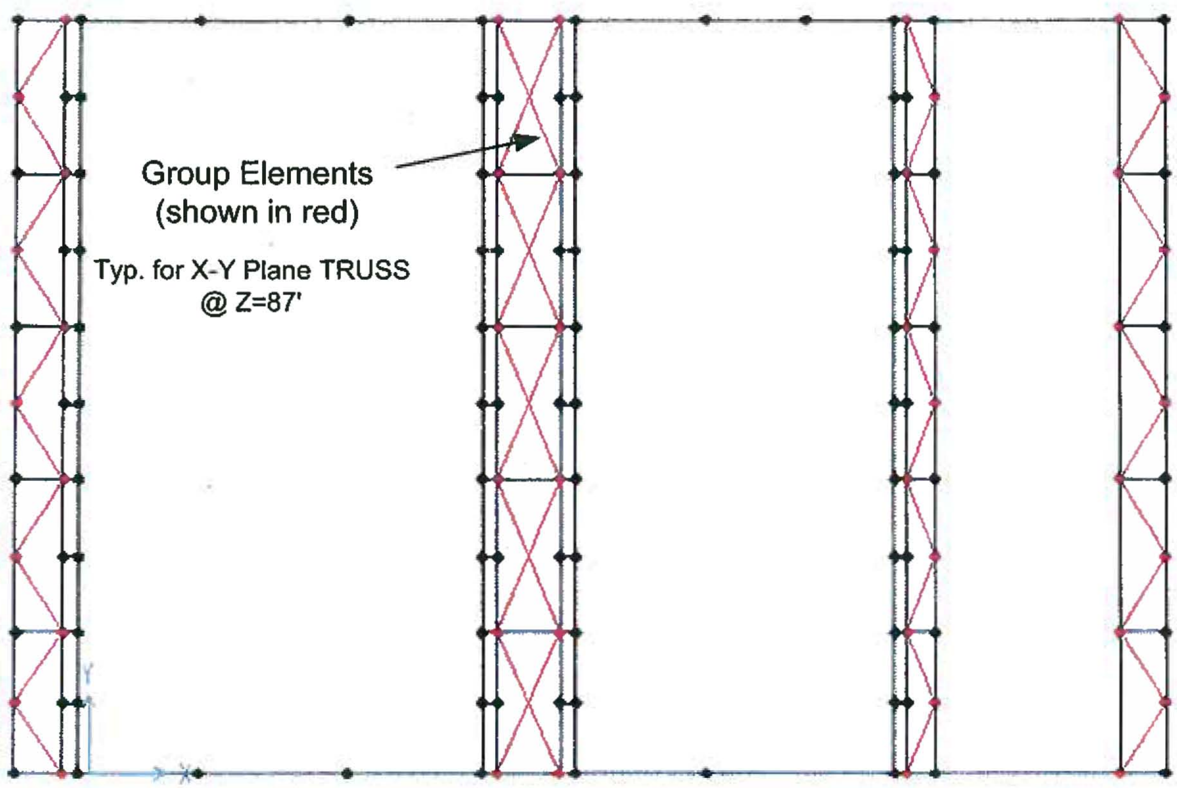


FIG. 6.4.36

SAP2000 Model - Group "SMALLHX@87"

ATTACHMENT B

STEEL BUILT-UP SECTION PROPERTIES

BUILT-UP (B.U.) SECTION PROPERTIES

Basic Formulas: Ref .2.2.23

$I = bd^3/12$ Rectangular solid section w/ neutral axis at center

$Ix_{BU} = Ixw + Ix_{plates}$ $Sx = Ix/Cy$ $r_x = (Ix/A)^{1/2}$

$Iy_{BU} = Iyw + (A_{plate} \times d_1^2)$ $Sy = Iy/Cy$ $r_y = (Iy/A)^{1/2}$

Torsional constant formula for basic sections:

$J = 1/3(bt^3)$ Rectangular solid section with 't' thickness

$J = 2t1 \times t2 \times b^2h^2/(b \times t2 + h \times t1)$ Rectangular box hollow section where:

b = centroidal distance between 2 plates with t2 thickness

h = centroidal distance between 2 plates with t1 thickness

Columns at Col. E.6/10, J/10, and K/10 (Ref Figure 1-A)

W36x393 with Plate 2 in x 33.4 in each side

b = 16.83 in d = 37.8 in Width and depth of W36

t1 = 2.20 in t2 = 1.22 in Flange and web thickness of W36

H = 35.6 in Mean height of W36

t3 = 2 in h = 33.4 in Thickness and depth of plate

$Ixw = 27500\ in^4$ $Iyw = 1750\ in^4$ Axis X and Y moment of inertia of W36

$Zxw = 1660\ in^3$ $Zyw = 325\ in^3$ Plastic section modulus of W36

$Aw = 115\ in^2$ Cross-sectional area of W36

Built-Up Section properties

$A = 115\ in^2 + 2(2in \times 33.4in) = 248.6\ in^2$ Cross-sectional area of B.U. section

$Ix = 27500in^4 + 2 \times 2in \times (33.4in)^3/12 = 39920\ in^4$ B.U. X-axis moment of inertia

$Iy = 1750in^4 + 2[2in \times 33.4in \times (8.415in)^2]$ B.U. Y-axis moment of inertia

$= 11210\ in^4$

$Sx = 39920in^4/18.9in = 2112.2\ in^3$ B.U. X-axis section modulus

$Sy = 11210in^3/9.42in = 1190\ in^3$ B.U. Y-axis section modulus

$Avy = 2 \times 2in \times 33.4in + 37.8in \times 1.22in = 179.7\ in^2$ Shear area parallel to web and plates

$Avx = 2 \times 2.2in \times 16.83in = 74.05\ in^3$ Shear area parallel to W36 flanges

$r_x = (39920\ in^4/248.6\ in^2)^{1/2} = 12.67\ in$ X-axis radius of gyration

$r_y = (11210in^4/248.6in^2)^{1/2} = 6.71\ in$ Y-axis radius of gyration

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2/(b \times t3 + H \times t1) + 1/3(h \times t2^3)$

$J = 2 \times 2.2in \times 2in \times (16.83in)^2 \times (35.6in)^2/(16.83in \times 2in + 35.6in \times 2.2in)$

$+ 1/3[33.4in \times (1.22in)^3$

$J = 28230\ in^4$

Plastic Section Modulus Ref.2.2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

$Zx = Zx/w + 2x(1/4)(t3 \times h^2)$

$Zx = 1660in^3 + 2x(1/4)[2in \times (33.4in)^2] = 2775\ in^3$

$Zy = Zy/w + 2x(t3 \times h) \times b/2$

$Zy = 325in^3 + 2x(2in \times 33.4in) \times 16.83in/2 = 1449\ in^3$

<u>Crane Runway Girder @ TOS El 64'-6"</u> **Crane Rail 1 (Ref. Figure 1-B)**

W36x300 with Plate 1½" x 33.38" each side

b = 16.65 in d = 36.74 in Width and depth of W36

t1 = 1.68 in t2 = 0.94 in Flange and web thickness of W36

H = 35.06 in Mean height of W36

t3 = 1.5 in h = 33.38 in Thickness and depth of plate

$Ix/w = 20300\ in^4$ $Iy/w = 1300\ in^4$ Axis X and Y moment of inertia of W36

$Zx/w = 1260\ in^3$ $Zy/w = 241\ in^3$ Plastic section modulus of W36

$Aw = 88.3\ in^2$ Cross-sectional area of W36

Built-Up Section properties

$A = 88.3\ in^2 + 2(1.5in \times 33.38in) = 188.44\ in^2$ Cross-sectional area of B.U. section

$Ix = 20300in^4 + 2 \times 1.5in \times (33.38in)^3/12 = 29598\ in^4$ B.U. X-axis moment of inertia

$Iy = 1300in^4 + 2[1.5in \times 33.38in \times (8.32in)^2]$ B.U. Y-axis moment of inertia

$= 8232\ in^4$

$Sx = 29598in^4/18.37in = 1611\ in^3$ B.U. X-axis section modulus

$Sy = 8232in^3/9.08in = 907\ in^4$ B.U. Y-axis section modulus

$Avy = 2 \times 1.5in \times 33.38in + 36.74in \times 0.94in$ Shear area parallel to web and plates

$= 134.7\ in^2$

$Avx = 2 \times 1.68in \times 16.65in = 46\ in^3$ Shear area parallel to W36 flanges

$r_x = (29598\ in^4/188.44\ in^2)^{1/2} = 12.53\ in$ X-axis radius of gyration

$r_y = (8232in^4/188.44in^2)^{1/2} = 6.61\ in$ Y-axis radius of gyration

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2/(b \times t3 + H \times t1) + 1/3(h \times t2^3)$

$J = 2 \times 1.68in \times 1.5in \times (16.65in)^2 \times (35.06in)^2/(16.65in \times 1.5in + 35.06in \times 1.68in)$

$+ 1/3[33.38in \times (0.94in)^3$

$J = 20485\ in^4$

Plastic Section Modulus Ref.2.2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

$Zx = Zx/w + 2x(1/4)(t3 \times h^2)$

$Zx = 1260in^3 + 2x(1/4)[1.5in \times (33.38in)^2] = 2095\ in^3$

$Zy = Zy/w + 2x(t3 \times h) \times b/2$

$Zy = 241 in^3 + 2x(1.5in \times 33.38in) \times 16.65in/2 = 834 in^3$

Crane Runway Girder @ TOS El 43'-8", 53'-4", 86'-0" (Ref: Figure -1C)

W30x191 with Plate 1" x 28.31" each side

b = 15.04 in	d = 30.68 in	Width and depth of W36
t1 = 1.185 in	t2 = 0.71 in	Flange and web thickness of W36
H = 29.5 in		Mean height of W36
t3 = 1 in	h = 28.31 in	Thickness and depth of plate
$Ix/w = 9170 in^4$	$Iy/w = 673 in^4$	Axis X and Y moment of inertia of W36
$Zx/w = 673 in^3$	$Zy/w = 138 in^3$	Plastic section modulus of W36
$Aw = 56.1 in^2$		Cross-sectional area of W36

Built-Up Section properties

$A = 56.1 in^2 + 2(1in \times 28.31in) = 112.72 in^2$ Cross-sectional area of B.U. section

$Ix = 9170in^4 + 2 \times 1in \times (28.31in)^3/12 = 12951 in^4$ B.U. X-axis moment of inertia

$Iy = 673in^4 + 2[1in \times 28.31in \ x(7.52in)^2]$ B.U. Y-axis moment of inertia

$= 3875 in^4$

$Sx = 12951in^4/15.34in = 844 in^3$ B.U. X-axis section modulus

$Sy = 3875in^3/8.02in = 483.2 in^3$ B.U. Y-axis section modulus

$Avy = 2 \times 1in \times 28.31in + 30.68in \times 0.71in$ Shear area parallel to web and plates

$= 78.40 in^2$

$Avx = 2 \times 1.185in \times 15.04in = 35.64 in^3$ Shear area parallel to W36 flanges

$r_x = (12951in^4/112.72\ in^2)^{1/2} = 10.72$ in X-axis radius of gyration

$r_y = (3875in^4/112.72in^2)^{1/2} = 5.86$ in Y-axis radius of gyration

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2/(b \times t3 + H \times t1) + 1/3(h \times t2^3)$

$J = 2 \times 1.185in \times 1in \times (15.04in)^2 \times (29.5in)^2/(15.04in \times 1in + 29.5in \times 1.185in)$

$+ 1/3[28.31in \times (0.71in)^3$

$J = 9330\ in^4$

Plastic Section Modulus Ref.2.2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

$Zx = Zx/w + 2x(1/4)(t3 \times h^2)$

$Zx = 673in^3 + 2x(1/4)[1in \times (28.31in)^2] = 1074\ in^3$

$Zy = Zy/w + 2x(t3 \times h) \times b/2$

$Zy = 138in^3 + 2x(1in \times 28.31in) \times 15.04in/2 = 564\ in^3$

<u>**Column at Col. 4/G and 4/J**</u> (Ref: Figure 1-D)

2 @ W36x260 with Plate 1.5in x 42.5 on each side welded to outside face of W36 flanges

$b_f = 16.55$ in	$d_w = 36.26$ in	Width and depth of W36
$t_f = 1.44$ in	$t_w = 0.84$ in	Flange and web thickness of W36
b=28 in		Spacing between 2 – W36, c/c of webs
H1 = 35.15 in		Mean depth of W36 between flanges
H2 = 37.76 in		Mean distance between centerline of 2 plates
$H_{Avg} = 36.32$ in		2 – 1½" plates are welded to the outside face of the 1.44" thick flanges of 2-W36 shapes. H_{Avg} is

the distance between centerlines of the combined thickness of flange & plate.

t2 = 1.5 in | h = 42.5 in | Thickness and depth of plate

$Ix/w = 17300\ in^4$ | $Iy/w = 1090\ in^4$ | Axis X and Y moment of inertia of W36 each

$Zx/w = 1080\ in^3$ | $Zy/w = 204\ in^3$ | Plastic section modulus of W36 each

$Aw = 76.5\ in^2$ | Cross-sectional area of W36 each

Built-Up Section properties

$A = 2 \times 76.5\ in^2 + 2(1.5in \times 42.5in) = 280.5\ in^2$ Cross-sectional area of B.U. section

$Iy = [2x1090\ in^4 + 2 \times 76.5\ in^2(14in)^2]$ B.U. X-axis moment of inertia

$+ 2 \times 1.5in \times (42.5in)^3/12 = 51360\ in^4$

$Ix = 2 \times 17300in^4 + 2[1.5in \times 42.5in \times (18.88in)^2]$ B.U. Y-axis moment of inertia

$= 80048\ in^4$

$Sy = 51360in^4/22.275in = 2306\ in^3$ B.U. X-axis section modulus

$Sx = 80048in^4/19.63in = 4078\ in^3$ B.U. Y-axis section modulus

$Avy = 2 \times .84in \times 36.26in = 60.9\ in^2$ Shear area parallel to web and plates

$Avx = 2 \times 1.44in \times 16.55in + 2 \times 1.5in \times 42.5in$ Shear area parallel to W36 flanges

$= 175.2\ in^2$

$r_y = (51360in^4/280.5in^2)^{1/2} = 13.5\ in$ X-axis radius of gyration

$r_x = (80048in^4/280.5in^2)^{1/2} = 16.9\ in$ Y-axis radius of gyration

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2_{Avg}/(b \times t3 + H_{Avg} \times t1)$

$J = 2 \times 2.94in \times .84in \times (28in)^2 \times (36.32in)^2 / (28in \times .84in + 36.32in \times 2.94in)$

$J = 39202\ in^4$

Subtract the torsional value of the gap between the flanges.

b_{gap} = 28in – 16.55in = 11.45 in Flange t_f = 1.44 in

Jgap = (t_f x b^2_{gap} x H_1^2)/(b_{gap} + H_1)

Jgap = 1.44in x $(11.45in)^2$ x $(34.82in)^2$ / (11.45in + 34.82in) = 4947 in^4

Jnet = 39202in^3 – 4947in^3 = 34255in^4

Plastic Section Modulus Ref.2.2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

Zy = 2Aw x b/2 + 2x(1/4)(t2 x h^2)

Zy = 2 x 76.5 in^2 x 28in/2 + 2x(1/4)[1.5in x $(42.5in)^2$] = 2425 in^3

Zx = 2 x Zx/w + 2 x (t2 x h) x H2/2

Zx = 2 x 1080in^3 + 2 x (1.5in x 42.5in) x 37.76in/2 = 4567 in^3

<u>**Column at Col. 4/C**</u> Refer to similar B.U. section sketch for Col. 4/G and 4/J **(Ref : Figure 1-E)**

2 @ W24x250 with Plate 1in x 39 in on each side welded to outside face of W24 flanges

b_f = 13.18 in	d_w = 26.34 in	Width and depth of W24
t_f = 1.89 in	t_w = 1.04 in	Flange and web thickness of W24
b=28 in		Spacing between 2 – W24
H1 = 24.45 in		Mean depth of W36 between flanges
H2 = 27.34		Mean distance between the 2 plates
H_{Avg} = 25.45 in		2 – 1 plates are welded to the outside face of the 1.89" thick flanges of 2-W36 shapes. H_{Avg} is the distance between centerlines of the combined thickness of flange & plate.
t2 = 1 in	h = 39 in	Thickness and depth of plate
Ix/w = 8490 in^4	Iy/w = 724 in^4	Axis X and Y moment of inertia of W24 each
Zx/w = 744 in^3	Zy/w = 171 in^3	Plastic section modulus of W24 each
Aw = 73.5 in^2		Cross-sectional area of W24 each

Built-Up Section properties

$A = 2 \times 73.5\ in^2 + 2(1in \times 39in) = 225\ in^2$ Cross-sectional area of B.U. section

$Iy = [2x724\ in^4 + 2 \times 73.5\ in^2(14in)^2]$ B.U. X-axis moment of inertia

$+ 2 \times 1in \times (39in)^3/12 = 40146\ in^4$

$Ix = 2 \times 8490in^4 + 2[1in \times 39in\ x(13.67in)^2]$ B.U. Y-axis moment of inertia

$= 31555\ in^4$

$Sy = 40146in^4/20.59in = 1950\ in^3$ B.U. X-axis section modulus

$Sx = 31555in^4/14.17in = 2227\ in^3$ B.U. Y-axis section modulus

$Avy = 2 \times 1.04in \times 26.34in = 54.78\ in^2$ Shear area parallel to web and plates

$Avx = 2 \times 1.89in \times 13.18in + 2 \times 1in \times 39in$ Shear area parallel to W24 flanges

$= 127.8\ in^2$

$r_y = (40146in^4/225in^2)^{1/2} = 13.35\ in$ X-axis radius of gyration

$r_x = (31555in^4/225in^2)^{1/2} = 11.84\ in$ Y-axis radius of gyration

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2_{Avg}/(b \times t3 + H_{Avg} \times t1)$

$J = 2 \times 2.89in \times 1.04in \times (28in)^2 \times (25.45in)^2 / (28in \times 1.04in + 25.45in \times 2.89in)$

$J = 29730\ in^4$

Subtract the torsional value of the gap between the flanges.

$b_{gap} = 28in - 13.18in = 14.82\ in$ Flange $t_f = 1.89$ in

$Jgap = (t_f \times b^2_{gap} \times H_1^2)/(b_{gap} + H_1)$

$Jgap = 1.89in \times (14.82in)^2 \times (24.45in)^2 / (14.82in + 24.45in) = 6320\ in^4$

$Jnet = 29730in^4 - 6320in^4 = 23410in^4$

Plastic Section Modulus Ref.2 2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

$Zy = 2Aw \times b/2 + 2x(1/4)(t2 \times h^2)$

$Zy = 2 \times 73.5\ in^2 \times 28in/2 + 2x(1/4)[1in \times (39in)^2] = 2818\ in^3$

$Zx = 2 \times Zx/w + 2 \times (t2 \times h) \times H2/2$

$Zx = 2 \times 744in^3 + 2 \times (1in \times 39in) \times 27.34in/2 = 2554\ in^3$

Column at Col. 5/G and 5/J

(See sketch for Built-Up Section and components)

W36x328 properties

$b_f = 16.63$ in	$d_w = 37.09$ in	Width and depth of W36
$t_f = 1.85$ in	$t_w = 1.02$ in	Flange and web thickness of W36
$Ix/w = 22500\ in^4$	$Iy/w = 1420\ in^4$	Axis X and Y moment of inertia of W36 each
$Zx/w = 1380\ in^3$	$Zy/w = 265\ in^3$	Plastic section modulus of W36 each
$Aw = 96.4\ in^2$		Cross-sectional area of W36 each

W36x260 properties

$b_f = 16.55$ in	$d_w = 36.26$ in	Width and depth of W36
$t_f = 1.44$ in	$t_w = 0.84$ in	Flange and web thickness of W36
$Ix/w = 17300\ in^4$	$Iy/w = 1090\ in^4$	Axis X and Y moment of inertia of W36 each
$Zx/w = 1080\ in^3$	$Zy/w = 204\ in^3$	Plastic section modulus of W36 each
$Aw = 76.5\ in^2$		Cross-sectional area of W36 each

Plus: 2-Side Plates 2in x 45in

1-Bottom Plate 2in x 36.26in

Built-Section properties

$A = 96.4in^2 + 76.5in^2 + 2(2in \times 45in) + 2in \times 36.26in$ Total Built-Up Section area

= 425.42 in^2

Locate Neutral X – axis

Moment of section areas at the bottom of bottom plates

W36s:	96.4in^2 x 20.55in	=	1981. in^3
	76.5in^2 x 39.51in	=	3022.5 in^3
Plates:	2in x 36.26in x 1in	=	72.5 in^3
	2(2in x 45in) x 23.89in	=	4300. in^3
Σ Moment Areas			9376 in^3

Y_{bot} = 9376 in^3/425.42 in^2 = 22.04 in

Y_{top} = 47.78in – 22.04in = 25.74 in

Compute Ix:

W36x260:	1090 in^4 + 76.5 in^2(17.46in)^2	=	24411.0 in^4
W36x328:	22500 in^4 + 96.4 in^2(1.5in)^2	=	22717.0 in^4
2 Side Plates:	2 x (2in)(45in)^3/12 + 2 x (2in x 45in)(1.85in)^2	=	30991.0 in^4
1 Bottom Plate:	36.26in x (2in)^3/12 + (2in x 36.26in)(21.04in)^2	=	32103.0 in^4
	Ix	=	110222.0 in^4

Max. Sx = Ix /Y_{bot}

Max. Sx = 110222 in^4/22.04 = 5001.0 in^3

Min. Sx = Ix /Y_{top}

Min. Sx = 110222 in^4/25.74 = 4282.0 in^3

Shear Area: Ax = (.84in)(33.38in) + 2((1.85in)(16.63in)) = 89.5 in^2

Ay = 2((2 in)(45 in) + (1.44 in)(16.55 in)) + (1.02 in)(33.39 in) = 262 in^2

Compute Iy:

W36x260:		=	17300.0 in^4
W36x328:		=	1420.0 in^4
2 Side Plates:	2 x (45in)(2in)^3/12 + 2 x (2in x 45in)(19.13in)^2	=	66592.0 in^4
1 Bottom Plate:	2in x (36.26in)^3/12	=	7945.0 in^4
	Iy	=	93257.0 in^4

Sy = 93257.0 in^4 / 20.13 = 4633.0 in^3

Torsional Constant Ref.2.2.23

$J = 2t1 \times t3 \times b^2H^2/(b \times t3 + H \times t1) + 1/3(h \times t2^3)$

The basic torsional constant equation for a rectangular box section per the above reference.

The **torsional constant** of the Built-Up section is computed based on the parts of a formed rectangular box section defined as follows (See sketch):

Part 1: A semi-uniform rectangular box consisting of a U-shaped 2 inch plates and closed on the 4[th] side with the web thickness of W36x260 ($t1_w = 0.84$ in).

For the top and bottom plates, use the average plate thickness, $t1 = ½(t1_w + t1_b) = 1.42$ in

$J1 = 2t1 \times t3 \times b^2H^2/(b \times t3 + H \times t1)$

$J1 = 2 \times 1.42in \times 2in \times (38.26in)^2 \times (38.51in)^2/(38.26in \times 2in + 38.51in \times 1.42in)$

$J1 = 93981\ in^3$

Part 2: Included parts of the 2 W36 flanges that are welded inside the semi-uniform rectangular box in Part 1.

$J2 = 2t1_f \times t3_f \times b_f^2\, h_f^2/(b_w \times t3_f + h \times t1_f)$

$J2 = 2 \times 1.85in \times 1.44in \times (16.63in)^2 \times (8.7in)^2/(34.82in \times 1.44in + 35.24in \times 1.85in)$

$J2 = 967\ in^3$

Part 3: The web of W36x328 at the centerline Y-axis of the Built-Up box section.

$J3 = 1/3(h_w \times t2^3)$

$J3 = 1/3[33.39in \times (1.02in)^3]$

$J3 = 12\ in^3$

Torsional Constant $J = J1 + J2 + J3 = 94{,}960\ in^4$

Plastic Section Modulus Ref.2.2.24

Plastic section modulus, is the arithmetical sum of the static moments about the neutral axis of the parts of the cross-section above and below, or left and right, of that axis.

About the neutral X-axis:

From	W36x260 =	$76.5in^2 \times 17.46$ in	$= 1335.7\ in^3$
	W36x328 =	$(16.63in \times 1.85in)(16.12in + 19.12in)$	$=1084.2\ in^3$

	(1.02in x 15.2in) x 7.6in + (1.02in x 18.19in) x 9.1in		= 286.7 in^3
2in Bot Plate =	(2in x 36.26in) x 21.04in		= 1525.8 in^3
		Zx	= 4232.4 in^3

About the Y-axis (symmetrical):

From	W36x260			= 1080 in^3
	W36x328			= 265 in^3
	2in Bot. Plate	¼ x 2in x $(36.26in)^3$		= 657 in^3
	2 Side Plates	2(2in x 45in) x 38.26in/2		= 3443 in^3
			Zy	= 5445 in^3

COLUMNS @ COL E-6/10, J/10 & K/10 with W36 x 393

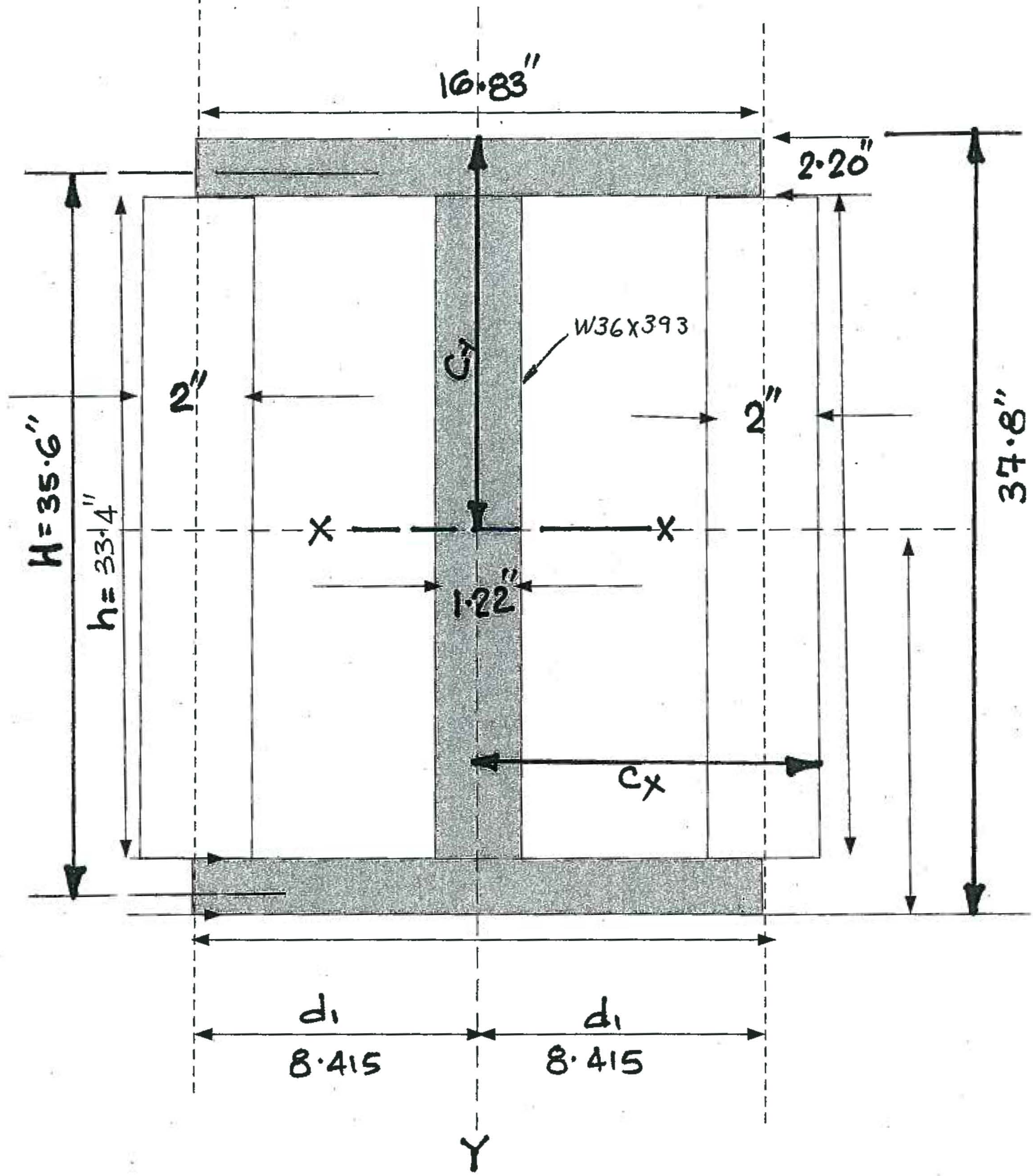


Figure - 1A

(REF PG NO B-2)

CRANE RAIL GIRDER @ TOS EL 64'-6", CRANE RAIL 1 WITH W 36 X 300

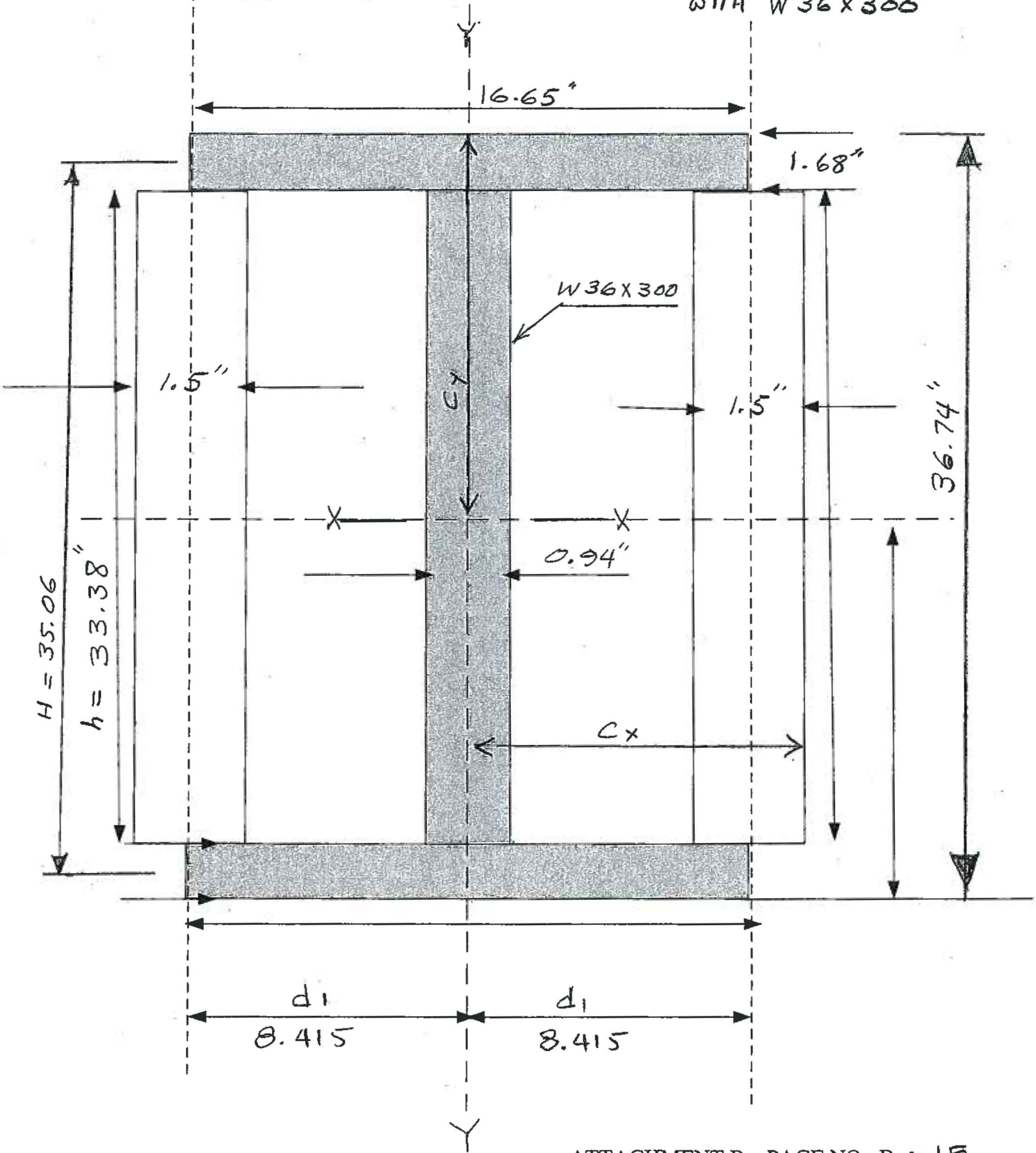


Figure 1B

(REF. PG NO - B-3)

CRANE RUNWAY GIRDER @ TOS EL 43'-8", 53'-4", 86'-0"
WITH W30X191

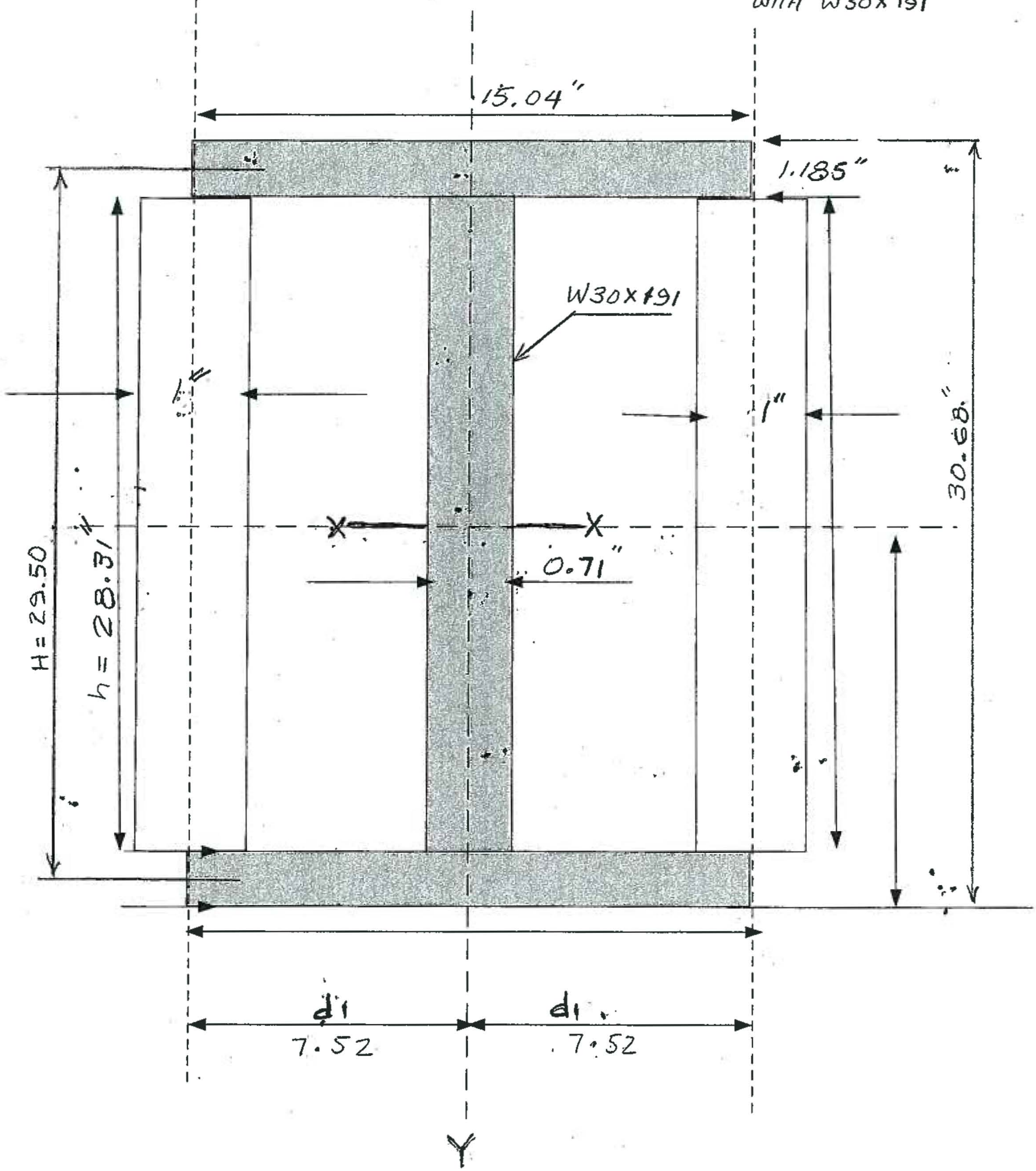


Figure: 1C

(REF. PG NO. B-5)

COLUMNS @ COL 4/G & 4 J WITH 2 X WF 36X260

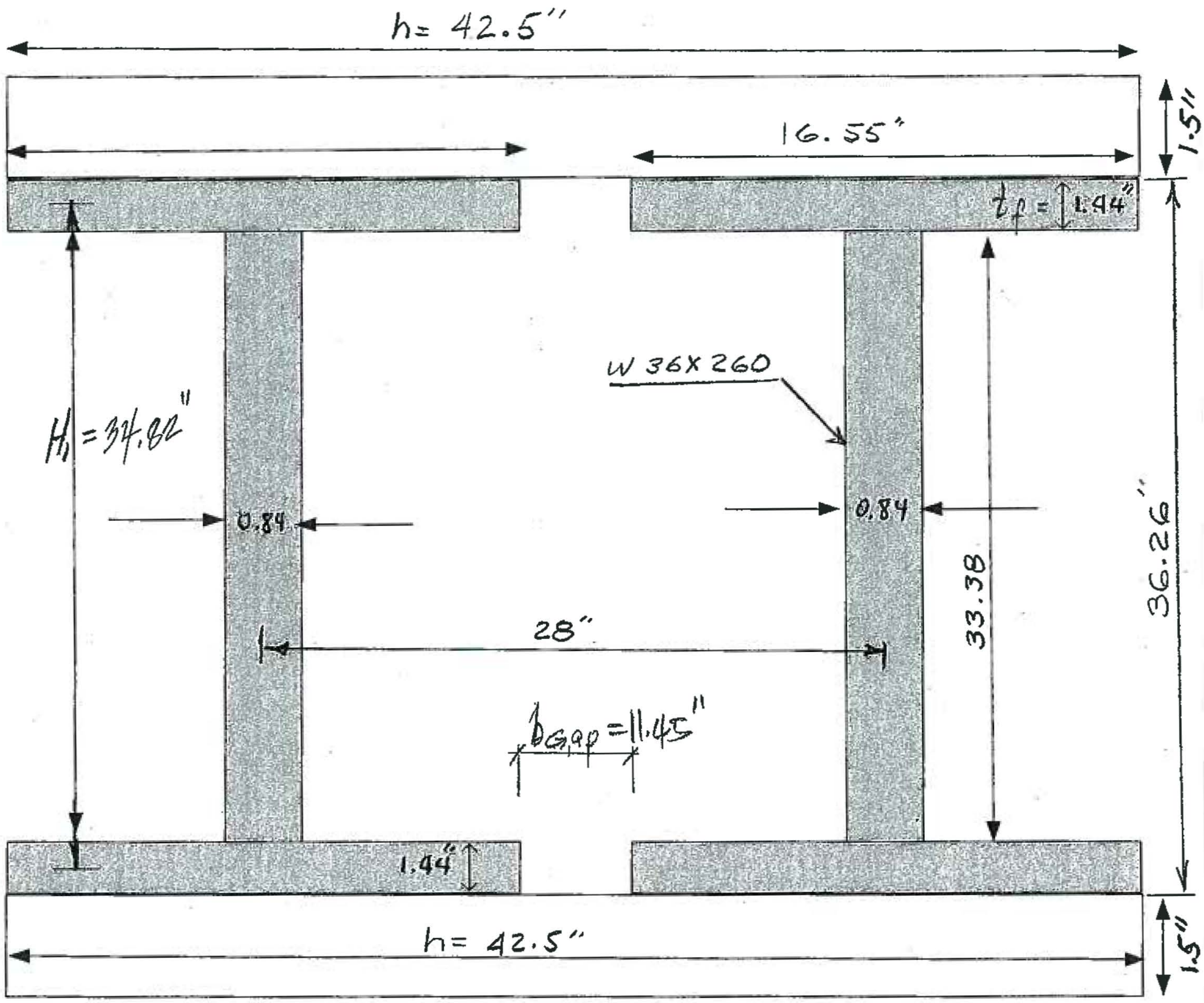
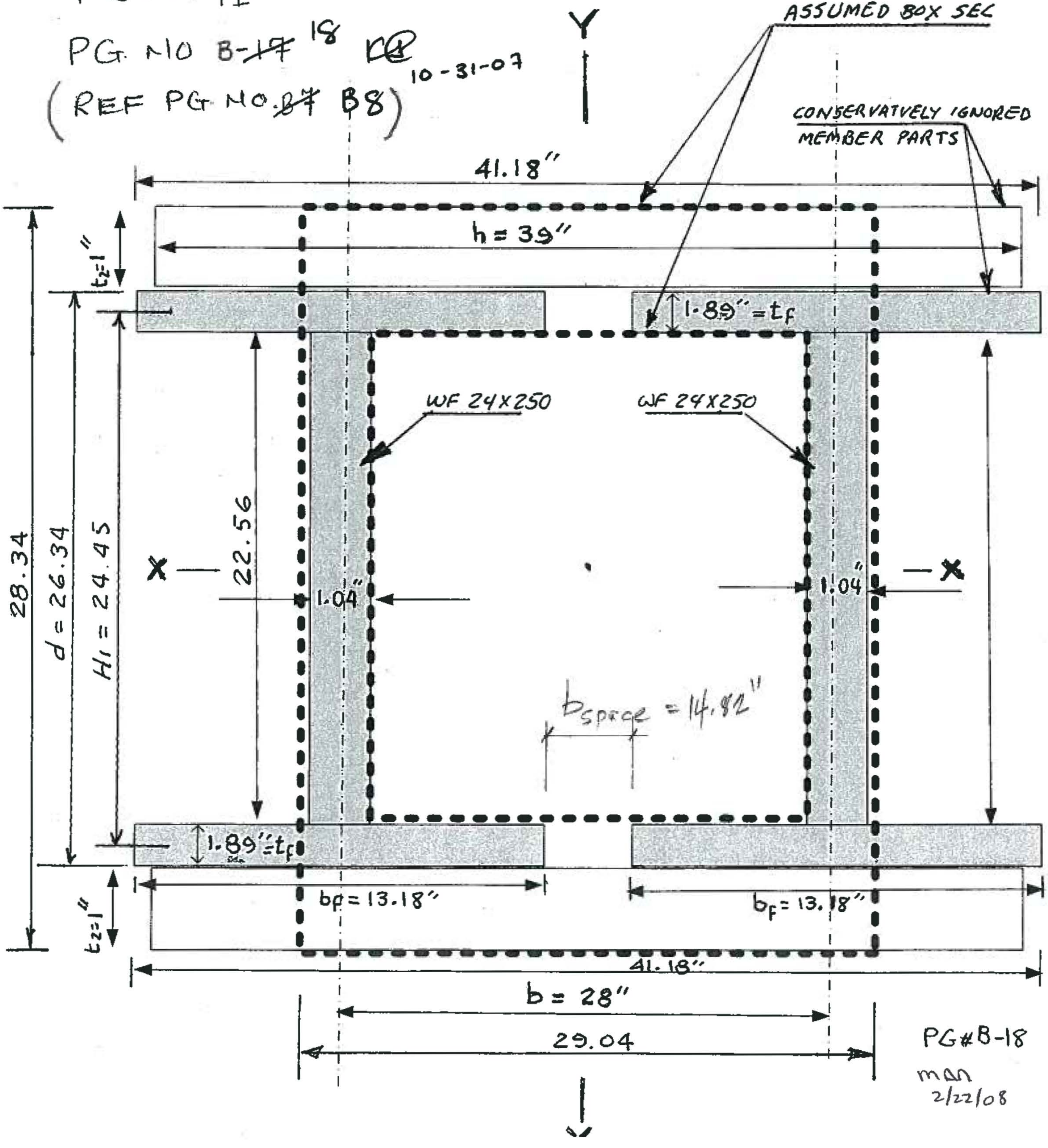


Figure 1D

(REF PG. NO -B- 6)
Attachment B

COLUMN @ COL 4C WITH 2X WF 24X250

Attachment B
Figure: 1E
PG. NO B-~~17~~ 18 KC 10-31-07
(REF PG. NO. ~~B7~~ B8)



PG#B-18
man 2/22/08

COLUMNS @ COL LINES 5G & 5J WITH W36X260 & W36X328

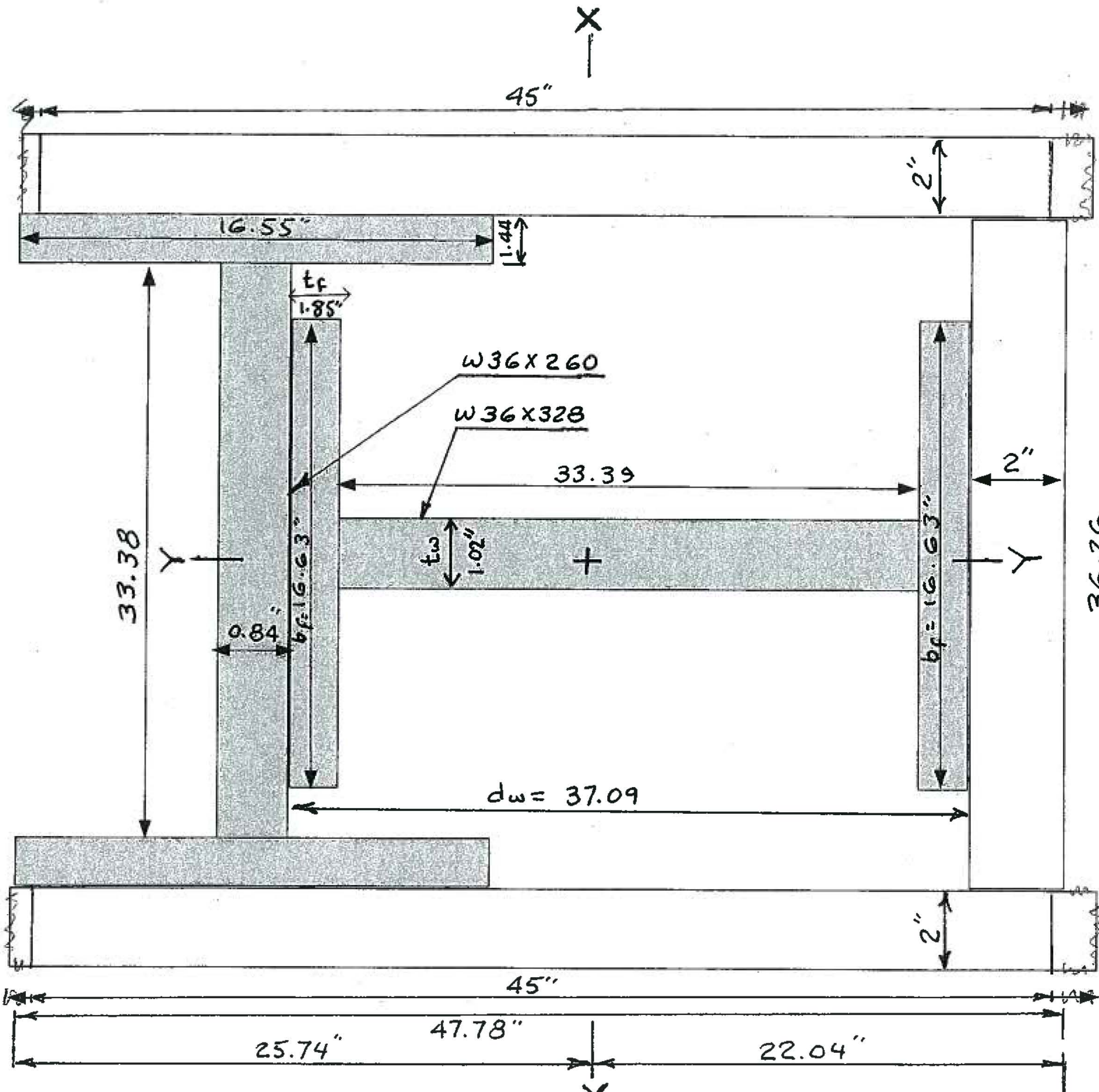
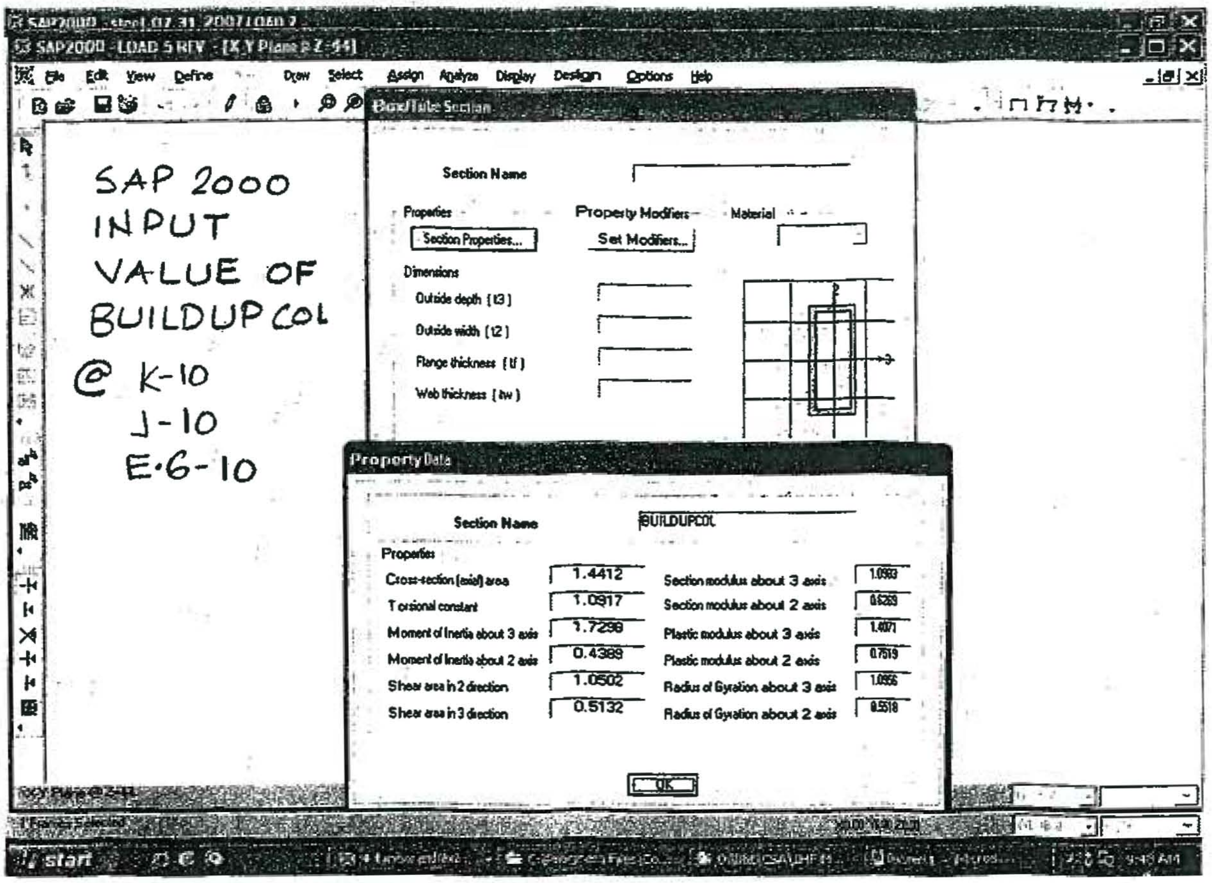


Figure:- 1F.

(REF PG # B-10)

PG B-19
MAD 2/22/08



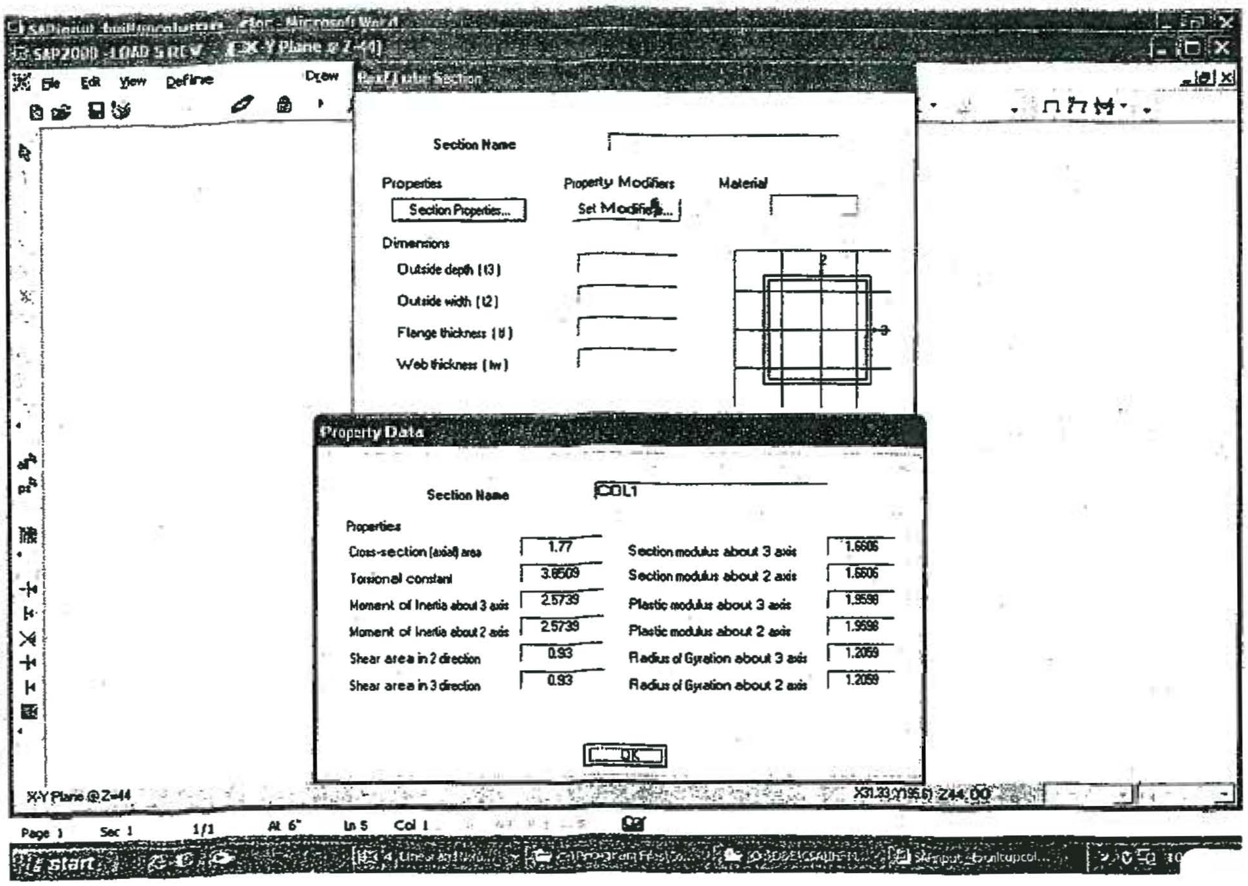
Actual Properties. — — — — — — — Ref PG. NO B_2-B_3 & Figure NO. 1A

<u>BUILDUP COL</u> (FIG 1-A)

CROSS SECTION AREA AXIAL	1.7264	FT^2	SECTION MODULUS ABOUT 3 AXIS	1.2223	FT^3
TORSIONAL CONSTANT	1.3614	FT^4	SECTION MODULUS ABOUT 2 AXIS	0.6886	FT^3
MOMENT OF INERTIA ABOUT 3 AXIS	1.9251	FT^4	PLASTIC MODULUS ABOUT 3 AXIS	1.6059	FT^3
MOMENT OF INERTIA ABOUT 2 AXIS	0.5406	FT^4	PLASTIC MODULUS ABOUT 2 AXIS	0.8385	FT^3
SHEAR AREA IN 2 DIRECTION	1.2479	FT^2	RADIUS OF GYRATION ABOUT 3 AXIS	1.0558	FT * ← LESS THAN SAP
SHEAR AREA IN 3 DIRECTION	0.5142	FT^2	RADIUS OF GYRATION ABOUT 2 AXIS	0.5592	FT

* ACTUAL SEC. Properties less by 5% (NO significant impact)

KP 10/26/07.

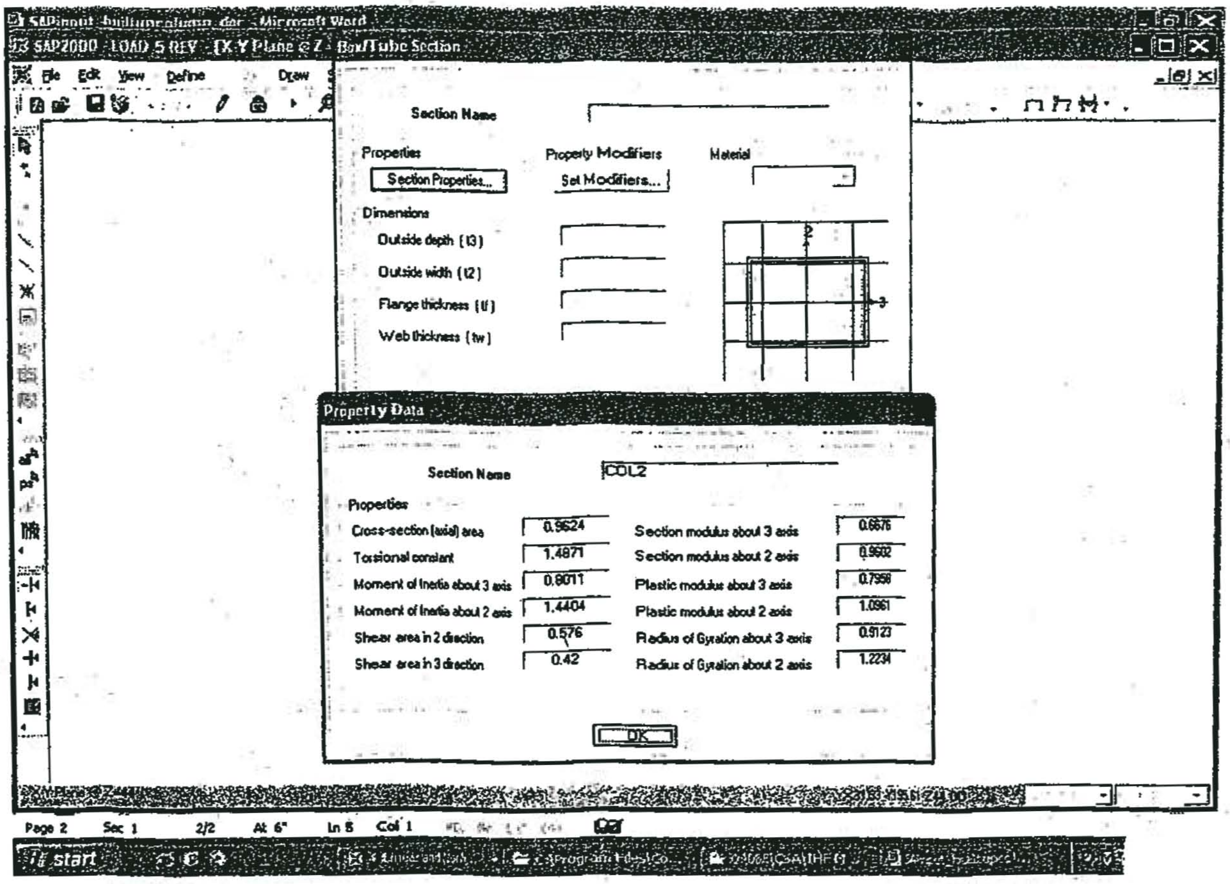


ACTUAL PROPERTIES — — — — — REF PG NO B11-B12 & FIGURE NO 1F

COL 1 (FIG 1-F)

CROSS SECTION AREA AXIAL	2.9543	FT^2	SECTION MODULUS ABOUT 3 AXIS	2.894	FT^3
TORSIONAL CONSTANT	4.5795	FT^4	SECTION MODULUS ABOUT 2 AXIS	2.68	FT^3
MOMENT OF INERTIA ABOUT 3 AXIS	4.4973	FT^4	PLASTIC MODULUS ABOUT 3 AXIS	3.1510	FT^3
MOMENT OF INERTIA ABOUT 2 AXIS	5.3155	FT^4	PLASTIC MODULUS ABOUT 2 AXIS	2.4493	FT^3
SHEAR AREA IN 2 DIRECTION	1.819	FT^2	RADIUS OF GYRATION ABOUT 3 AXIS	2.69	FT
SHEAR AREA IN 3 DIRECTION	0.62	FT^2	RADIUS OF GYRATION ABOUT 2 AXIS	1.709	FT

$$r = \left(I_x / A_x\right)^{1/2}$$



KC
10-26-07

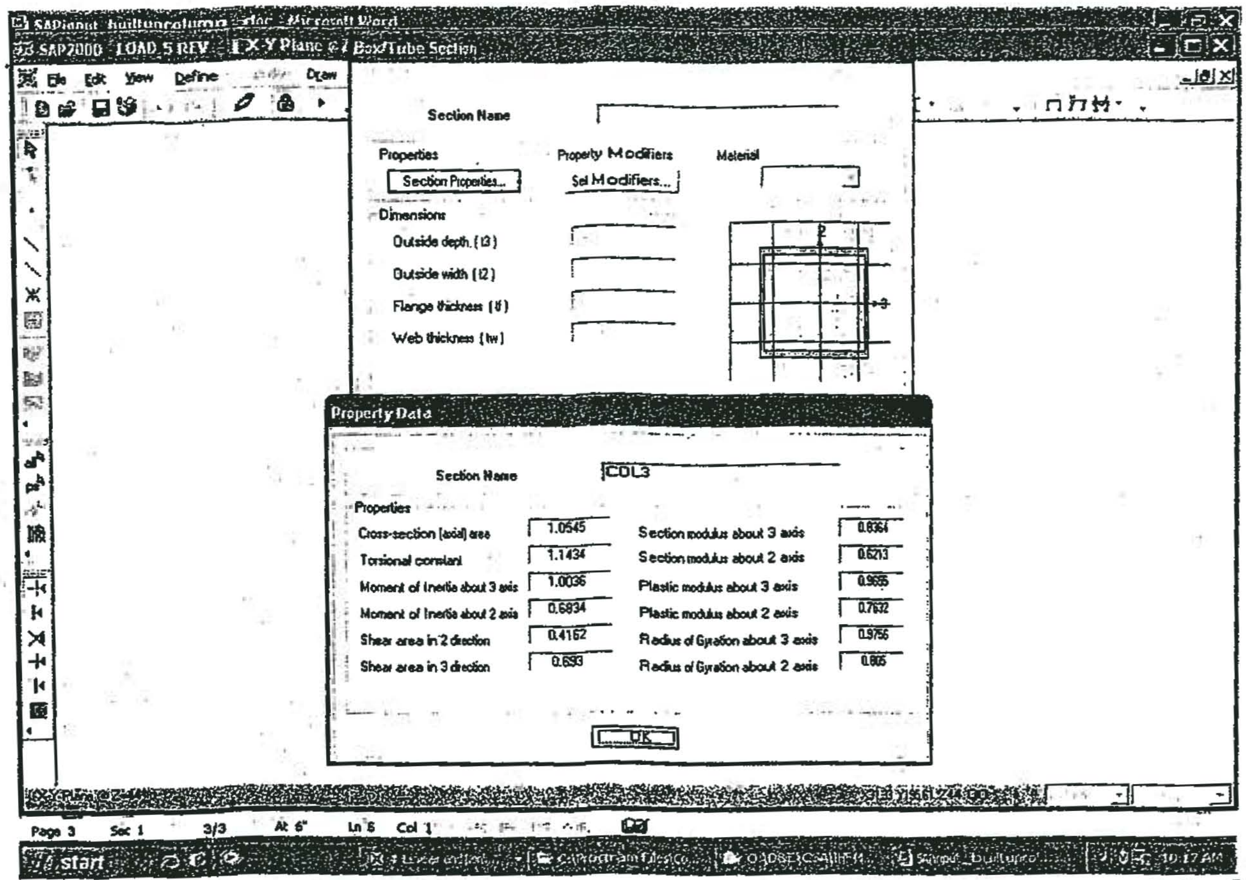
ACTUAL PROPERTIES ------- REF PG NO. B7-B8 & FIGURE NO 1-D

COL 2 (G4 & J4)

CROSS SECTION AREA AXIAL	1.9479	FT^2	SECTION MODULUS ABOUT 3 AXIS	2.3599	FT^3
TORSIONAL CONSTANT	1.6519	FT^4	SECTION MODULUS ABOUT 2 AXIS	1.3345	FT^3
MOMENT OF INERTIA ABOUT 3 AXIS	3.8603	FT^4	PLASTIC MODULUS ABOUT 3 AXIS	2.6429	FT^3
MOMENT OF INERTIA ABOUT 2 AXIS	2.478	FT^4	PLASTIC MODULUS ABOUT 2 AXIS	1.4034	FT^3
→* SHEAR AREA IN 2 DIRECTION	0.4229	FT^2	RADIUS OF GYRATION ABOUT 3 AXIS	1.4083	FT
SHEAR AREA IN 3 DIRECTION	1.2167	FT^2	RADIUS OF GYRATION ABOUT 2 AXIS	1.1250	FT

CB
10/26/07

* Actual section property is less by 27%



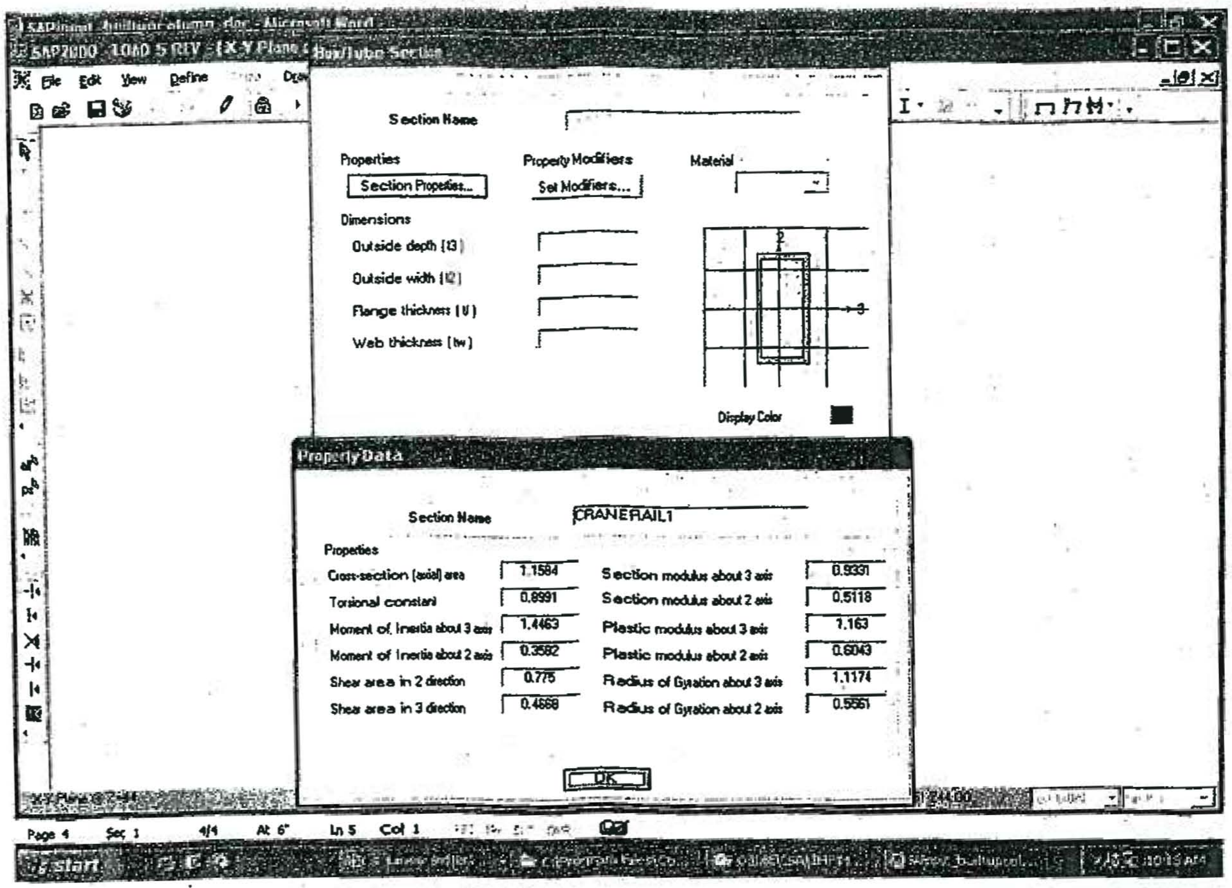
ACTUAL PROPERTIES - - - - - - - - - REF PG. NO ~~7,8,9~~ B-7, B-8, B-9 IC 10-26-07
E FIGURE NO 1-E

COL 3 (C-4)

CROSS SECTION AREA AXIAL	1.5625	FT²	SECTION MODULUS ABOUT 3 AXIS	1.1285	FT³
* TORSIONAL CONSTANT	1.1289	FT⁴	SECTION MODULUS ABOUT 2 AXIS	1.2888	FT³
MOMENT OF INERTIA ABOUT 3 AXIS	1.9360	FT⁴	PLASTIC MODULUS ABOUT 3 AXIS	1.6308	FT³
MOMENT OF INERTIA ABOUT 2 AXIS	1.5217	FT⁴	PLASTIC MODULUS ABOUT 2 AXIS	1.4780	FT³
SHEAR AREA IN 2 DIRECTION	0.3804	FT²	RADIUS OF GYRATION ABOUT 3 AXIS	1.1125	FT
SHEAR AREA IN 3 DIRECTION	0.8275	FT²	RADIUS OF GYRATION ABOUT 2 AXIS	0.9867	FT

IC 10/26/07

* Actual Sec. properties less by 2%.
No insignificant impact.



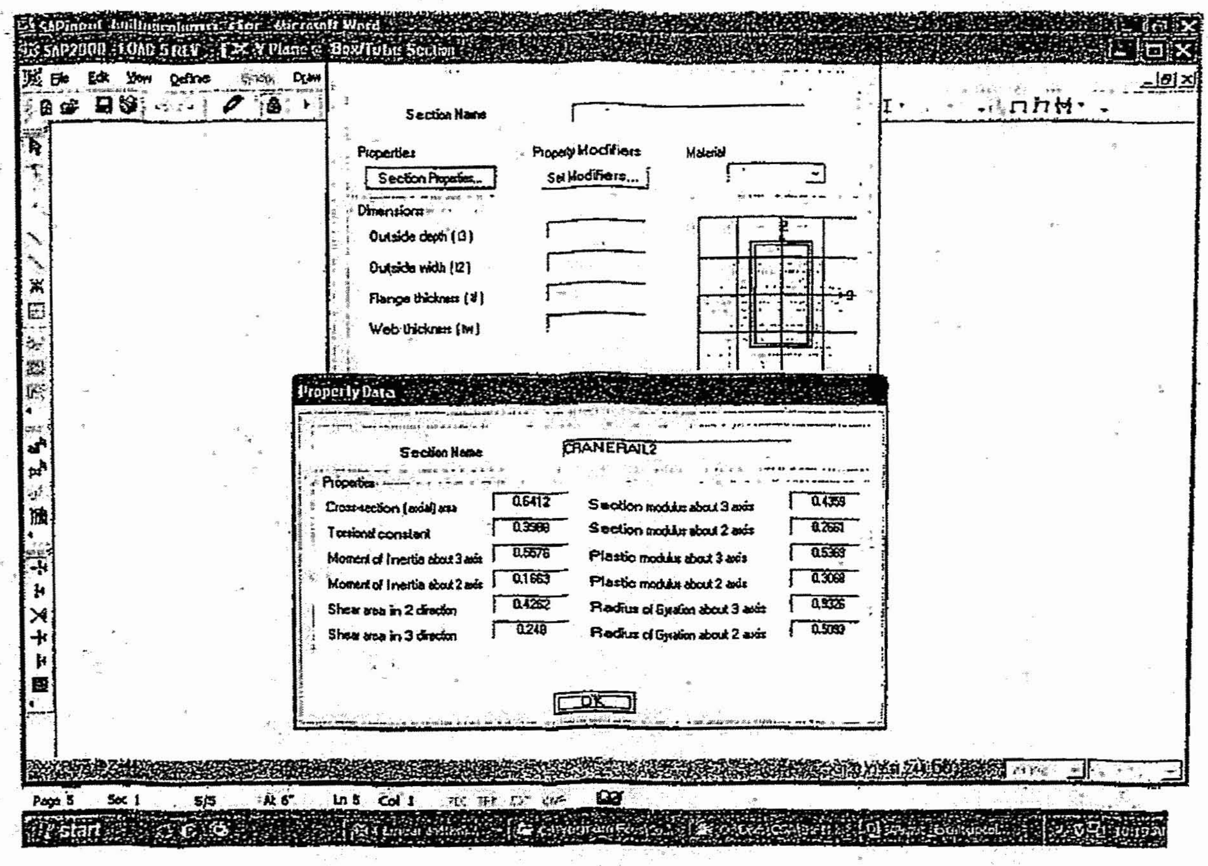
ACTUAL PROPERTIES ———— REF PG NO ~~2,3~~ B4-B3 & FIGURE NO 1-B

MAA 2-22-08 KP 10-21-07

CRANERAIL 1 (FIG 1-B)

CROSS SECTION AREA AXIAL	1.3086 FT²	SECTION MODULUS ABOUT 3 AXIS	0.9323 FT³ * ← LESS THAN SAP (MAA 2/22/08)
TORSIONAL CONSTANT	0.9879 FT⁴	SECTION MODULUS ABOUT 2 AXIS	0.5249 FT³
* LESS THAN SAP 2% (MAA 2/22/08) MOMENT OF INERTIA ABOUT 3 AXIS	1.4274 FT⁴	PLASTIC MODULUS ABOUT 3 AXIS	1.2124 FT³
MOMENT OF INERTIA ABOUT 2 AXIS	0.3970 FT⁴	PLASTIC MODULUS ABOUT 2 AXIS	0.4826 FT³ * ← LESS THAN
SHEAR AREA IN 2 DIRECTION	0.9354 FT²	RADIUS OF GYRATION ABOUT 3 AXIS	1.0442 FT } * LESS THAN SAP
* LESS THAN SAP SHEAR AREA IN 3 DIRECTION	0.3194 FT²	RADIUS OF GYRATION ABOUT 2 AXIS	0.5508 FT }

* ACTUAL MOM OF INERTIA/3 AXIS LESS THAN SAP BY 2%.
* ACTUAL SHEAR IN 3 DIRECTION LESS THAN SAP BY 32%.
* ACTUAL SEC. MOD. ABOUT 3 AXIS LESS THAN SAP BY 1%.
* ACTUAL PLASTIC MODULUS ABOUT 2 AXIS LESS THAN SAP BY 21%.
* ACTUAL RADIUS OF GYRATION ABOUT 3 AXIS LESS THAN SAP BY 7%.
* ACTUAL RADIUS OF GYRATION ABOUT 2 AXIS LESS THAN SAP BY 1%.

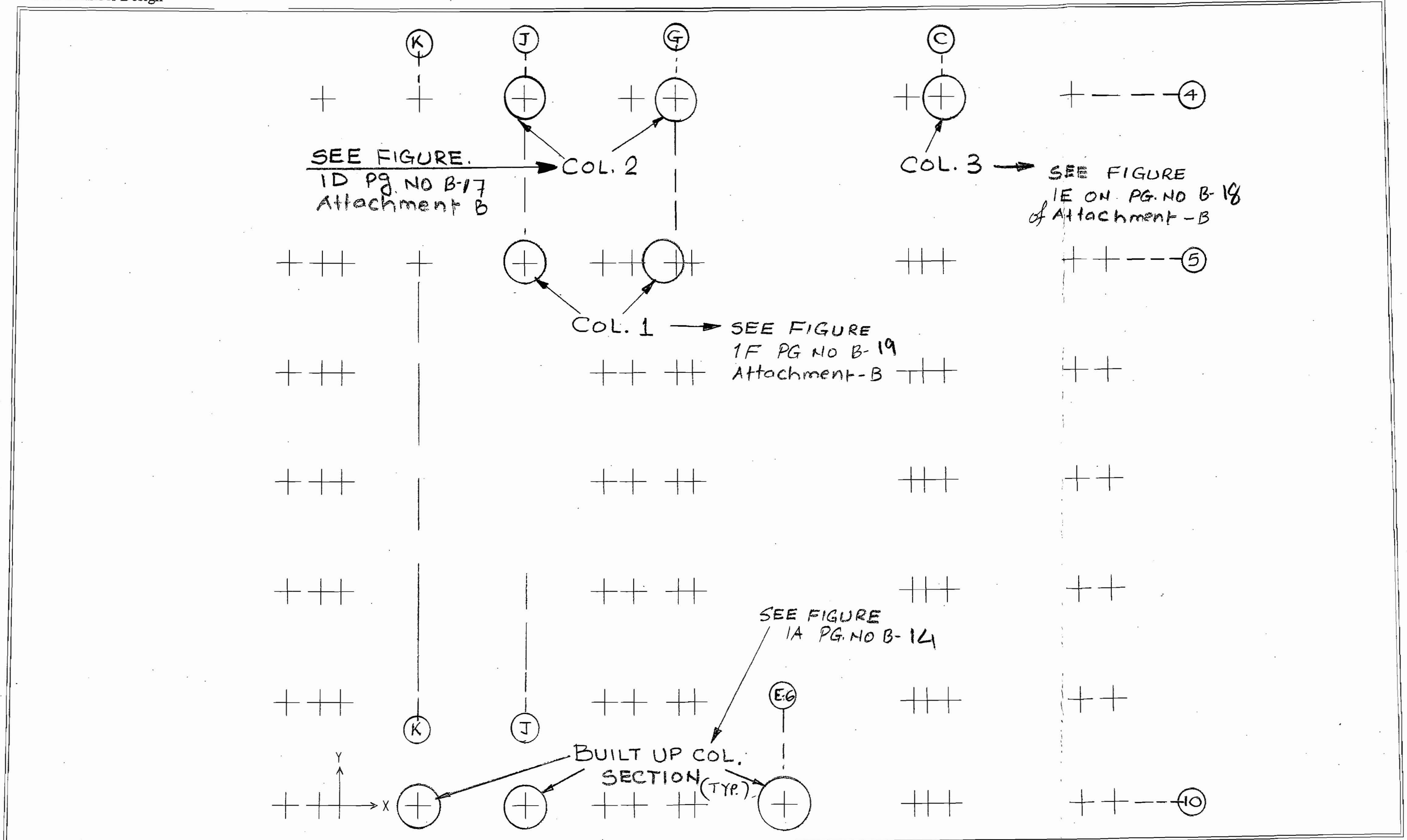


ACTUAL PROPERTIES ------------ REF PG NO ~~4,~~ B6. B-5
& FIGURE NO 1-C KB 10-26-07

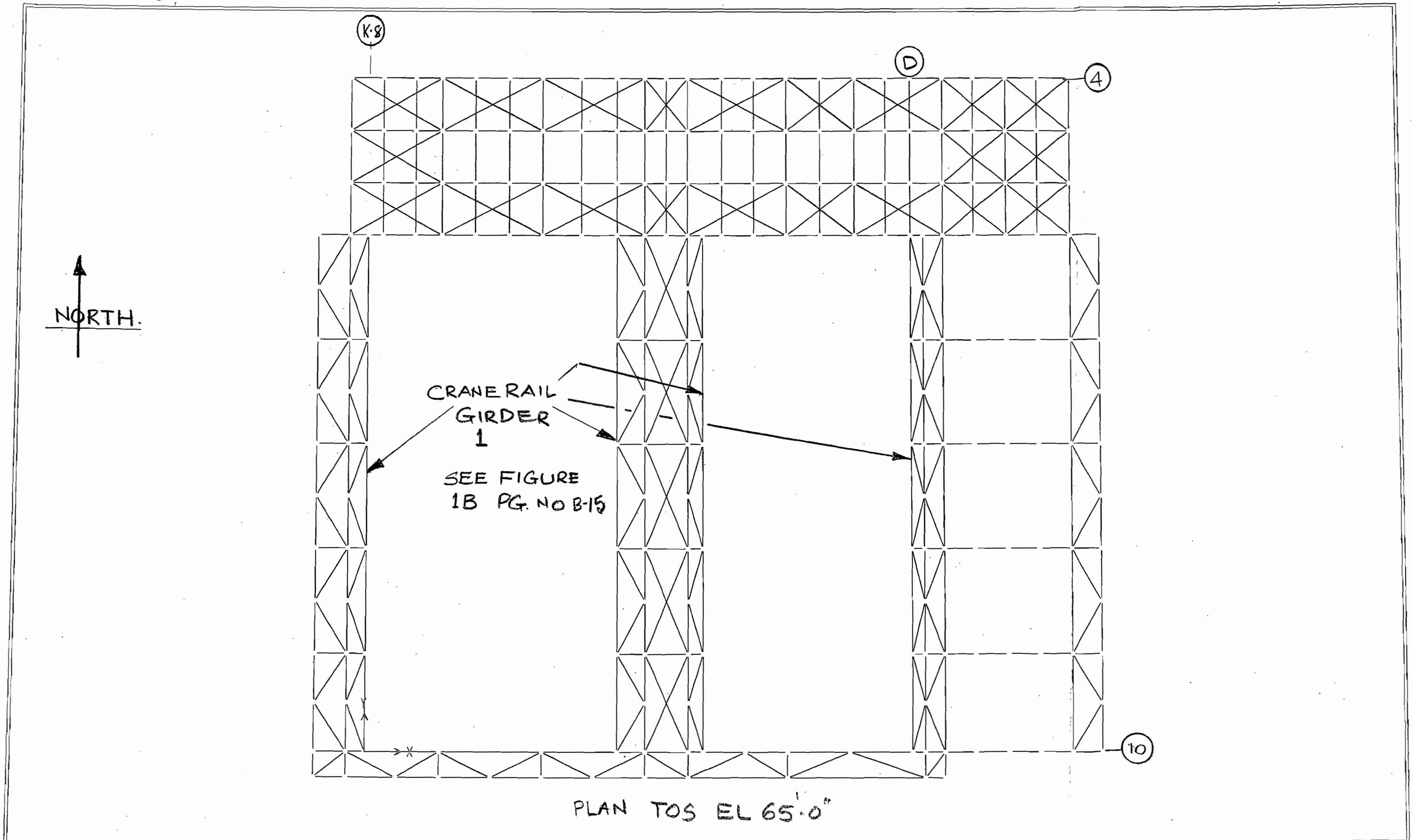
CRANERAIL 2 (FIG 1-C)

CROSS SECTION AREA AXIAL	0.7828	FT^2	SECTION MODULUS ABOUT 3 AXIS	0.4884	FT^3
TORSIONAL CONSTANT	0.4499	FT^4	SECTION MODULUS ABOUT 2 AXIS	0.2796	FT^3
MOMENT OF INERTIA ABOUT 3 AXIS	0.6246	FT^4	PLASTIC MODULUS ABOUT 3 AXIS	0.6215	FT^3
MOMENT OF INERTIA ABOUT 2 AXIS	0.1869	FT^4	PLASTIC MODULUS ABOUT 2 AXIS	0.3264	FT^3
SHEAR AREA IN 2 DIRECTION	0.5444	FT^2	RADIUS OF GYRATION ABOUT 3 AXIS	0.8933	FT } LESS THAN SAP *
* → SHEAR AREA IN 3 DIRECTION (SLIGHTLY LESS THAN SAP)	0.2475	FT^2	RADIUS OF GYRATION ABOUT 2 AXIS	0.4883	FT } *

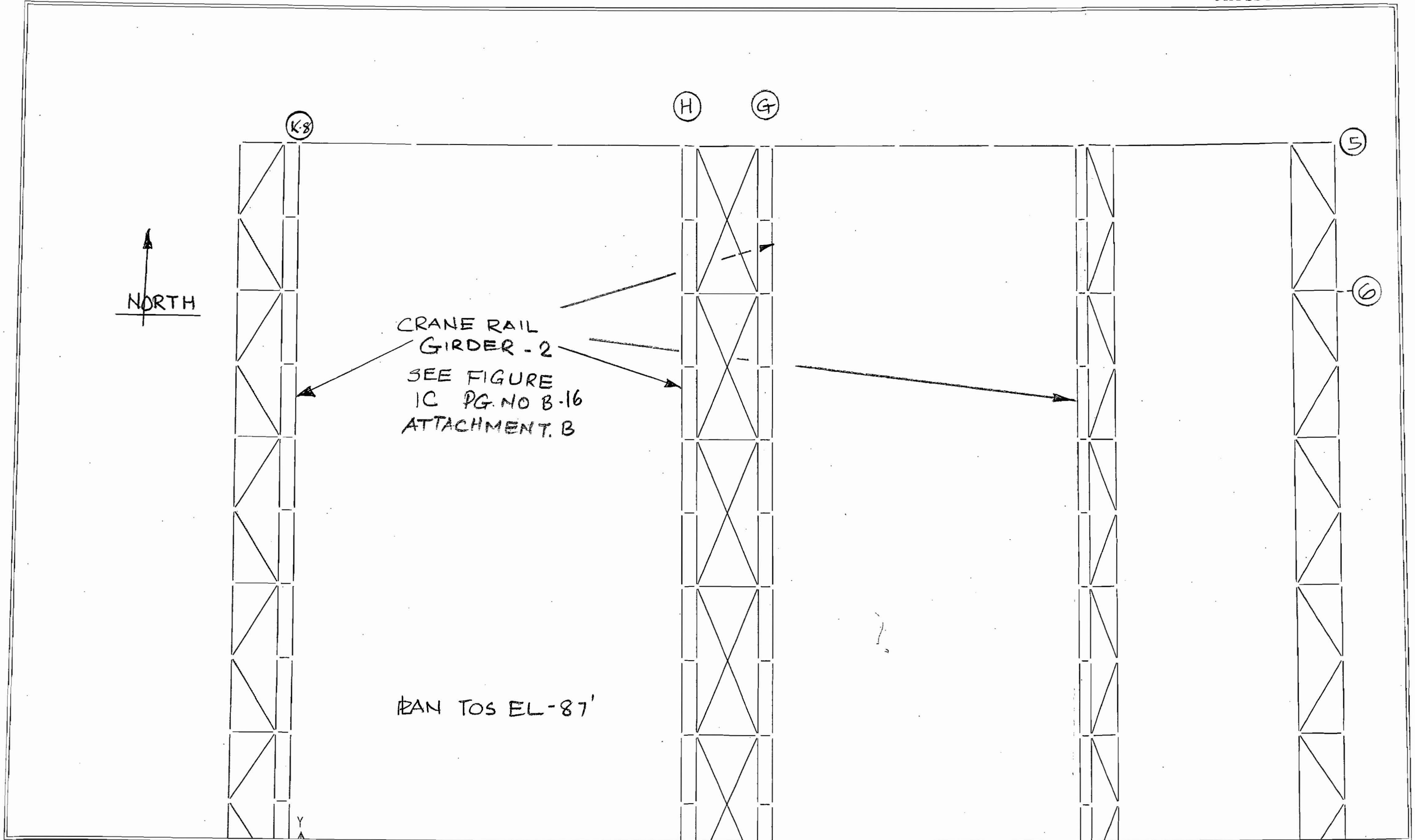
* ACTUAL SHEAR AREA IN 3 DIR LESS THAN SAP BY 1%.
* ACTUAL RAD. OF GYRATION ABOUT 3 AXIS LESS THAN SAP BY 4%.
* ACTUAL RAD OF GYRATION ABOUT 2 AXIS LESS THAN SAP BY 4%.



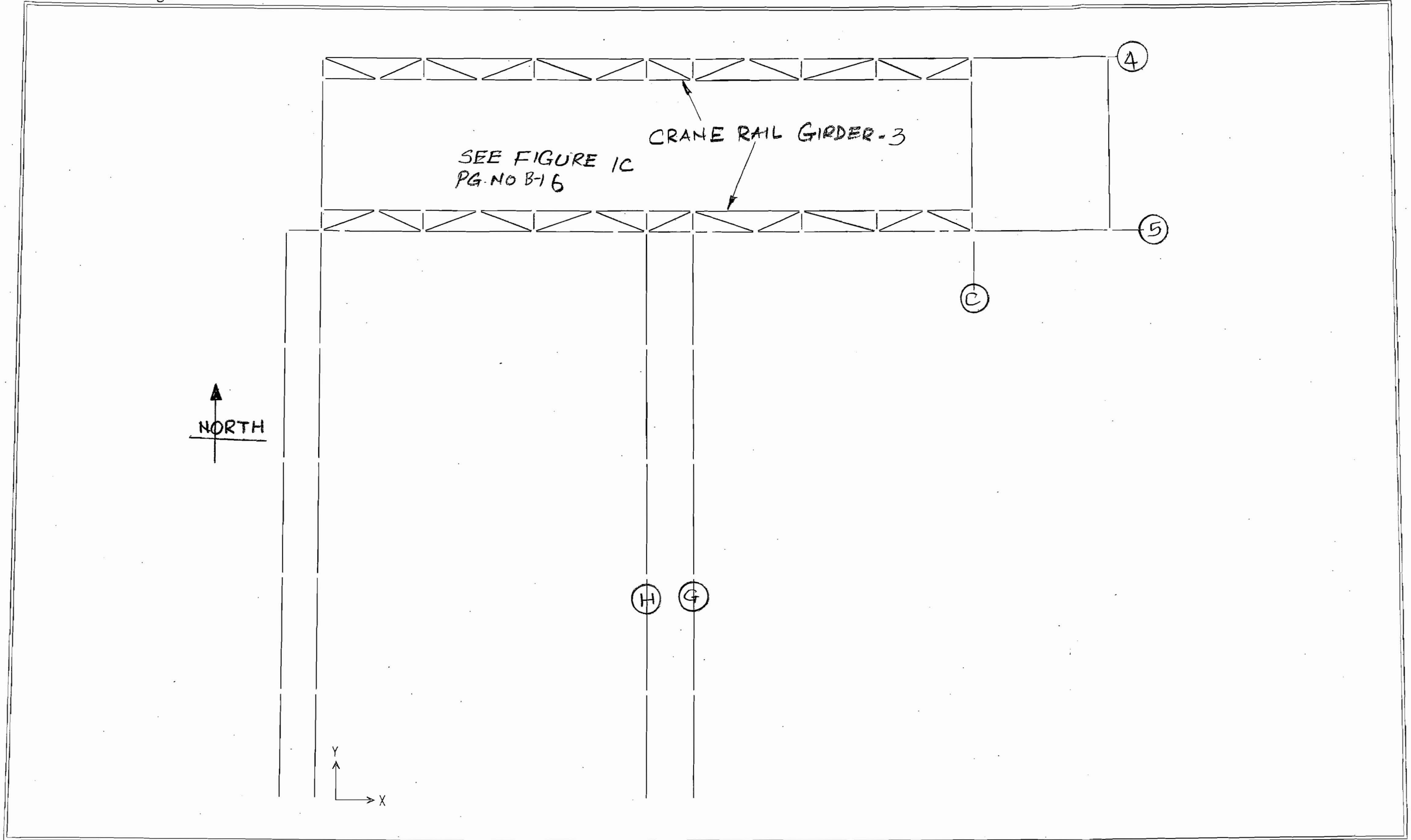
SAP2000 v9.1.4 - File:LOAD 5 REV - X-Y Plane @ Z=0 - Kip, ft, F Units



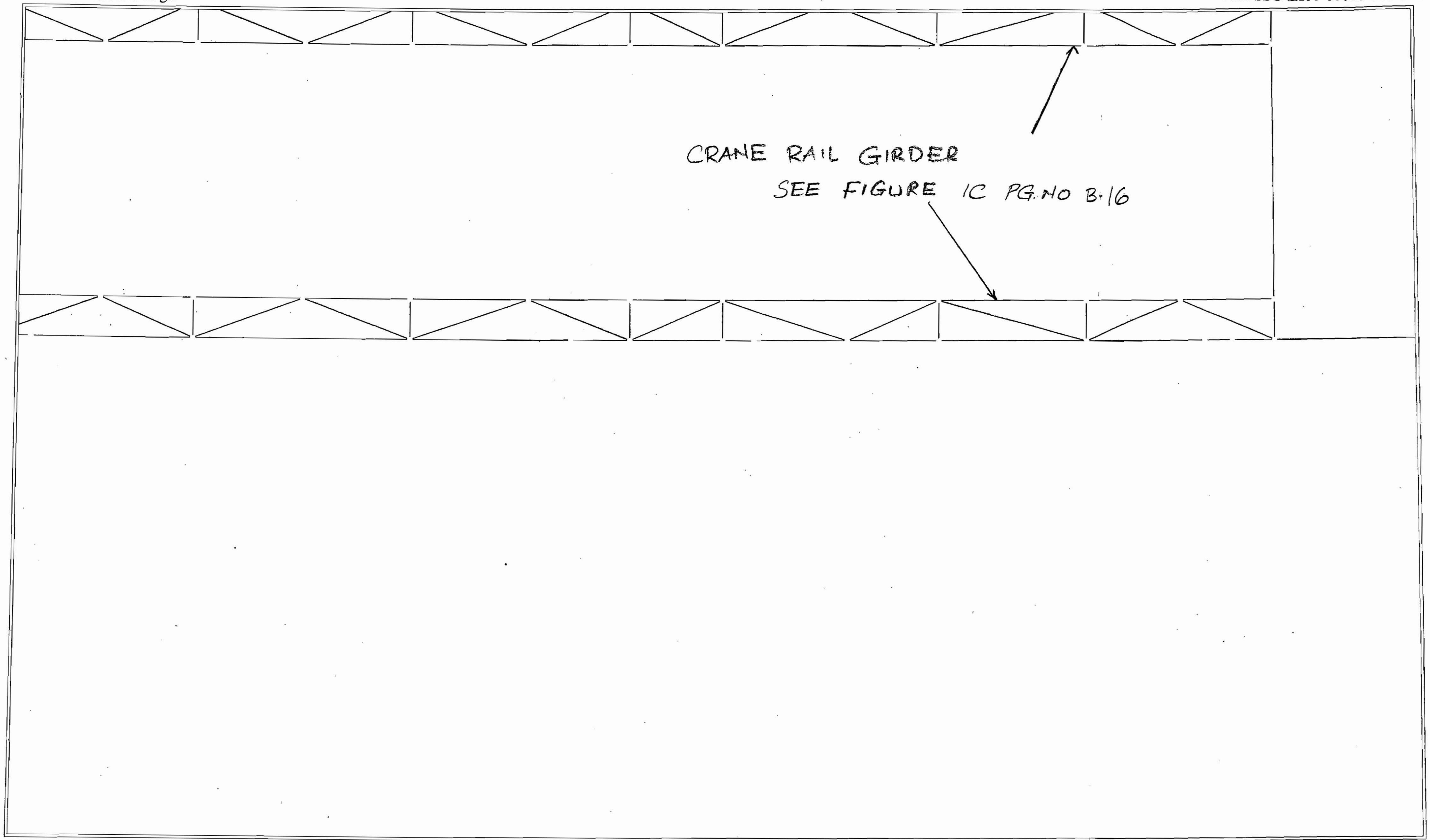
SAP2000 v9.1.4 - File:LOAD 5 REV - X-Y Plane @ Z=65 - Kip, ft, F Units



SAP2000 v9.1.4 - File:LOAD 5 REV - X-Y Plane @ Z=87.25 - Kip, ft, F Units



SAP2000 v9.1.4 - File:LOAD 5 REV - X-Y Plane @ Z=53.75 - Kip, ft, F Units



SAP2000 v9.1.4 - File:LOAD 5 REV - X-Y Plane @ Z=44 - Kip, ft, F Units