STONE & WEBSTER ENGINEERING CORPORATION

CLIENT & PROJECT	PAGE 1 OF 16
PRIVATE FUEL STORAGE FACILITY - PRIVATE FUEL STORAGE,LLC	PLUS / PGS OF ATTACHMENTS

CALCULATION TITLE

DEVELOPMENT OF SOIL IMPEDANCE FUUNTIONS FOR CANISTER TRANSFER BUILDING

QA CATEGORY (X)

X I - NUCLEAR SAFETY RELATED

__ II __ III __ OTHER

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.02	STRUCTURAL	SC-4	NA	300B

APPROVALS - SIGNATURE & DATE			REV. NO. OR NEW CALC. NO	SUPERSEDES CALC. NO. OR REV. NO.	CONFIRMATION REQUIRED (X)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
B.E. Ebbeson B.E. EBBESON 6/16/98	S. Chen 6/18/98	F. Ogden (*) F. OGDEN 6/18/98	0	NA		X

* IOV CHECKLIST IN FILE Q2.9

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CALCULATION SHEET

J.O./W.O./CALCULATION NO	REVISION	PAGE
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B.E. EBBESON 6-15-98	S. Chen 6/18/98	F. Gelen

SUBJECT/TITLE
Development of Soil Impedance Functions for Canister Transfer Building

QA CATEGORY/CODE CLASS
I

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(Revisions, Additions, Deletions, Etc.)

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B.E. EBBESON 6-15-98	S Chen 6/18/98	F. Ogden

SUBJECT/TITLE	QA CATEGORY/CODE CLASS
Development of Soil Impedance Functions for Canister Transfer Building	I

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Page No.	Description
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SUBJECT/TITLE	QA CATEGORY/CODE CLASS
Development of Soil Impedance Functions for Canister Transfer Building	I

OBJECTIVE:

The purpose of this calculation is to develop soil impedance functions to simulate the stiffness and damping effects provided by the soil beneath the Canister Transfer Building. These results will be used in the seismic analysis of the Canister Transfer Building, which will be performed in Calculation 05996.02-SC-5 (Ref. 1).

CALCULATION METHOD & ASSUMPTIONS:

The SWEC computer program REFUND (Ref. 2) is used to calculate the impedance functions. This program assumes that the building foundation is a rigid rectangular mat on the surface of a layered soil column. Since the building mat is not rectangular, an equivalent rectangle of similar area and moment of inertia is used. This approximation is consistent with the guidelines given in ASCE 4-86 (Ref. 3). The building mat is assumed to be 5 feet thick, and the assumption of a rigid mat is consistent with ASCE 4-86. The soil properties used in the analysis are obtained from Table 2 of Section 4 of the PSFS Design Criteria (Ref. 4). Soil shear modulus values are increased by 50% and reduced by 33% to account for uncertainties in the analysis, as suggested in ASCE 4-86. Three sets (nominal, upper bound, and lower bound) will be developed. Resulting impedance functions, in the form of stiffness and damping matrices are contained in the computer output, and also stored on disk files for reformatting for use in the seismic analysis. Plots for the nominal soil case were developed for information, and are shown on pages 11-16.

SOURCES OF DATA AND EQUATIONS:

See the next page for a list of references used in this calculation.

CONCLUSION:

The soil impedance functions, in the form of stiffness and damping matrices, have been developed and are suitable for use in the seismic analysis.

The impedance functions have been stored on the SWEC mainframe computer system with the following data set names:

STRUCTRL.BEE.NOMINAL	(Nominal soil case)
STRUCTRL.BEE.UPPER	(Upper Bound soil case)
STRUCTRL.BEE.LOWER	(Lower Bound soil case)

References:

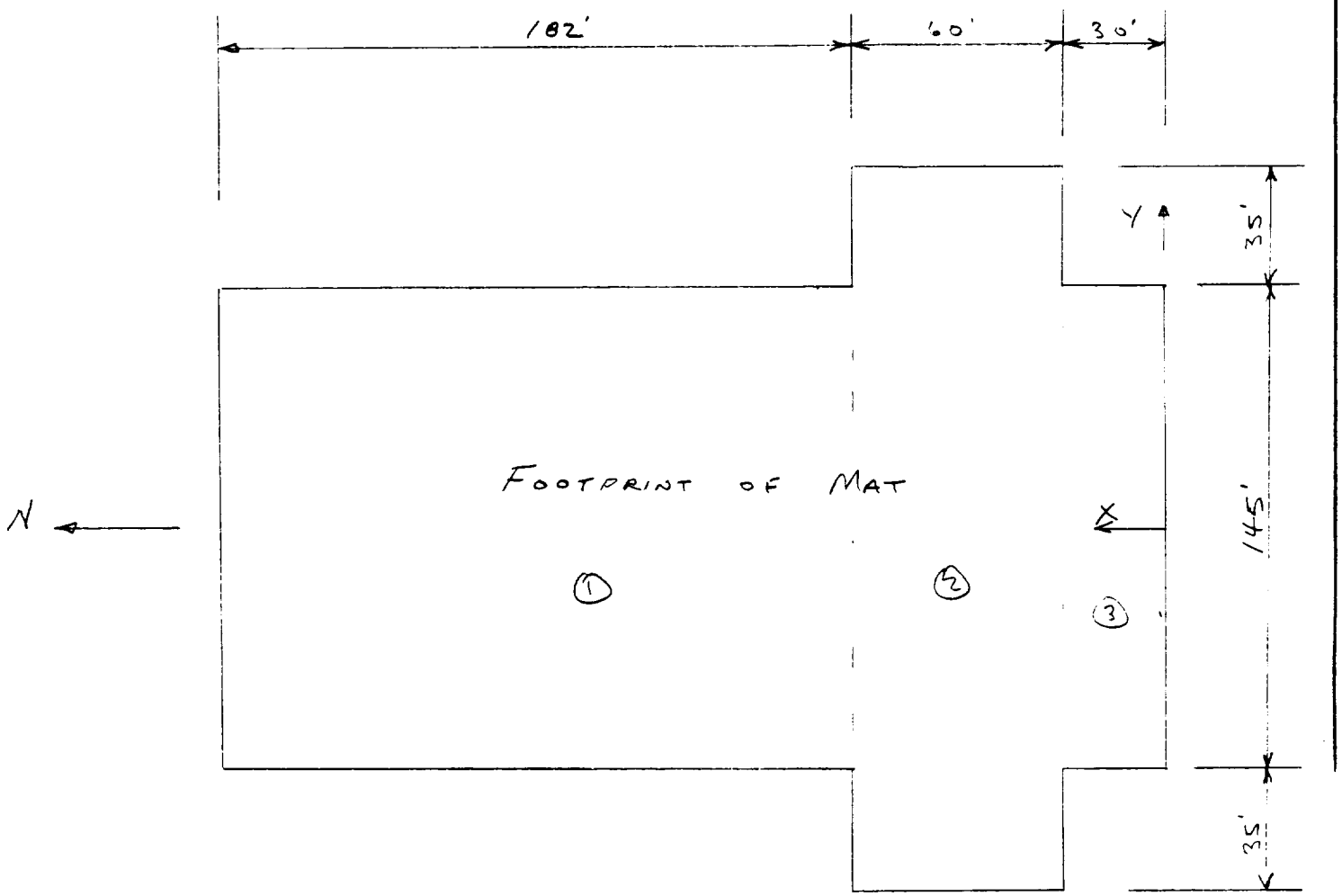
1. Calculation 05996.02-SC-5, Rev. 0, 'Seismic Analysis of Canister Transfer Building'

2. SWEC Computer Program REFUND, ST-232, Version 0, Level 1.

3. ASCE 4, 'Standard for Seismic Analysis of Safety-Related Nuclear Structures', 1986, American Society of Civil Engineers.

4. Private Fuel Storage Facility Design Criteria, Revision 2, June 20, 1997, Stone & Webster Engineering Corporation, Denver, Colorado.

DETERMINE EQUIVALENT RECTANGULAR DIMENSIONS



PIECE	AREA	$\bar{X}$	A * $\bar{X}$
1	26390	181	4776590.
2	12900	60	774000.
3	4350	15	65250
	43640		5615840.

$$\bar{X} = \frac{5615840}{43640} = 128.69'$$

$$I_x = \frac{1}{12}\left(182(145)^3 + 60(215)^3 + 30(145)^3\right) = 1.036 \times 10^8$$

$$I_y = \frac{1}{12}\left(145(182)^3 + 215(60)^3 + 145(30)^3\right) + 26390\,(181 - 128.69)^2 + 12900\,(128.69 - 60)^2 + 4350\,(128.69 - 15)^2 = 2.663 \times 10^9 \text{ ft}^4$$

It will not be possible to find an equivalent rectangle of length a and width b which will have all three parameters (A, IX, IY) equal to those of the actual shape.

A. Matching A & IX

$$ab = 43640$$

$$\frac{1}{12} a b^3 = 1.036 \times 10^8$$

$$a = 259'$$

$$b = 169'$$

B. Matching A & IY

$$ab = 43640$$

$$\frac{1}{12} b a^3 = 2.663 \times 10^8$$

$$a = 271'$$

$$b = 161$$

Use a rectangle 265' x 165'

$$A = (265)(165) = 43725 \approx 43640$$

$$IX = \frac{1}{12}(265)(165)^3 = .992 \times 10^8 \approx 1.036 \times 10^8$$

$$IY = \frac{1}{12}(165)(265)^3 = 2.559 \times 10^8 = 2.663 \times 10^8$$

∴ USE RECTANGLE 265' x 165'. ALL PARAMETERS (A, IX, IY) ARE WITHIN 4 % OF ACTUAL VALUES

USE 23 SEGMENTS IN X DIR (11.5')

USE 15 SEGMENTS IN Y DIR (11')

SOIL PROPERTIES

PROPERTIES WILL BE TAKEN FROM TABLE 2 OF SECTION 4 OF REF. 4. ASSUMING THAT THE TOP 5' WILL BE EXCAVATED FOR THE FOUNDATION, THE TOP 5' WILL BE EXCLUDED. FROM EXAMINING THE VALUES IN TABLE 4, FOUR MACROLAYERS WILL REASONABLY REPRESENT THE SUBGRADE TO 600', WHERE THE MODEL WILL STOP DUE TO THE HIGH SHEAR MODULUS

MACROLAYER	THICKNESS ft.	DENS. kcf	SHEAR WAVE VEL. fps	DAMP.	ν
1	10.	.081	500.	.10	.433
2	15.	.081	325.	.12	.433
3	90.	117	1830.	.05	.433
4	480.	.130	2200.	.08	.49

① WILL HAVE 2 SUBLAYERS (5' EA.)

② WILL HAVE 3 SUBLAYERS (5' EA)

③ WILL HAVE 5 SUBLAYERS (18' EA)

④ WILL HAVE 8 SUBLAYERS (60' EA)

FREQUENCY INTERVAL

Use 0.5 Hz interval from 0 to 15 Hz

COMPUTER LOG

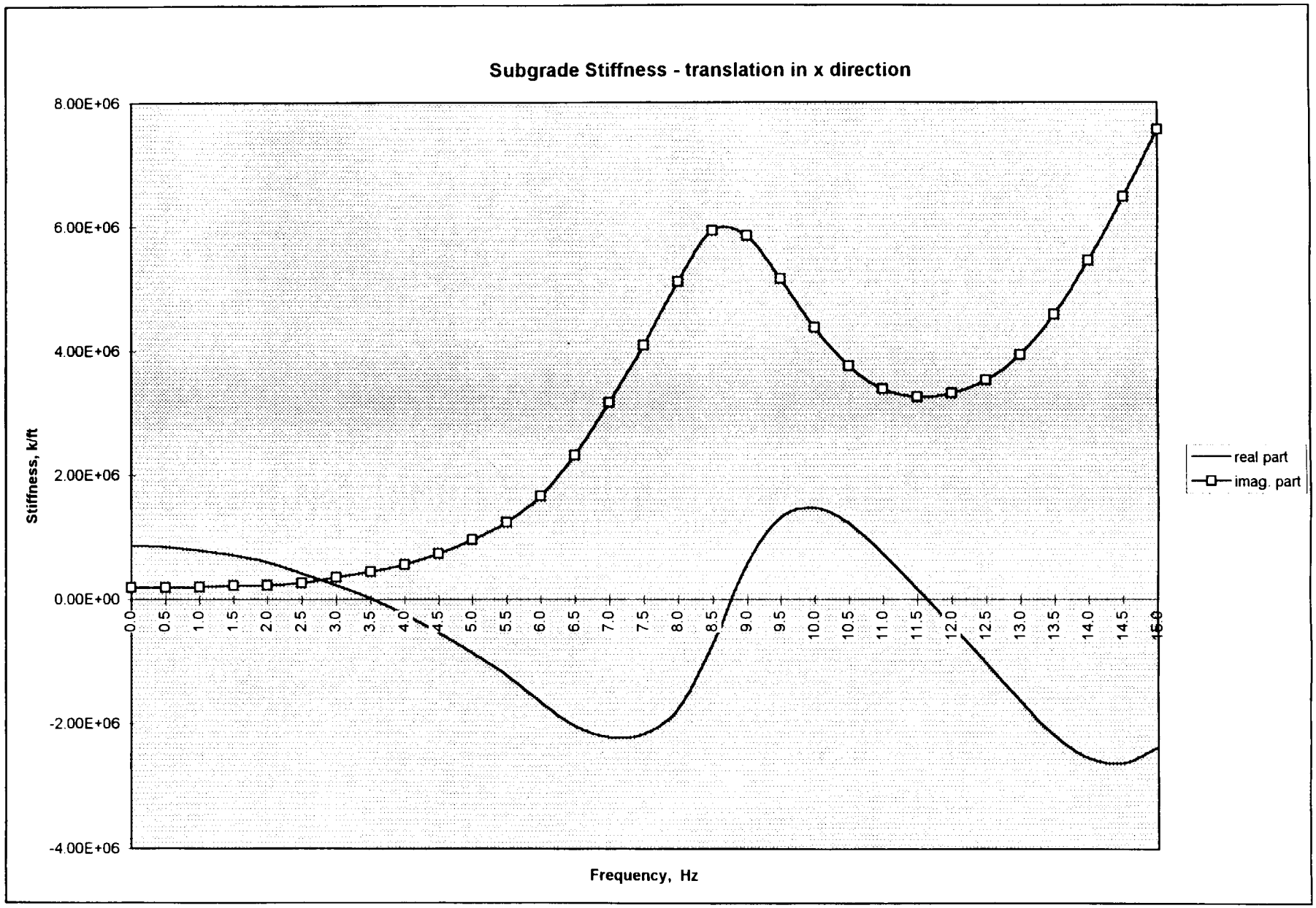
NOMINAL SOIL CASE RUN R0302C41 JOB 4036
dd 6/15/98

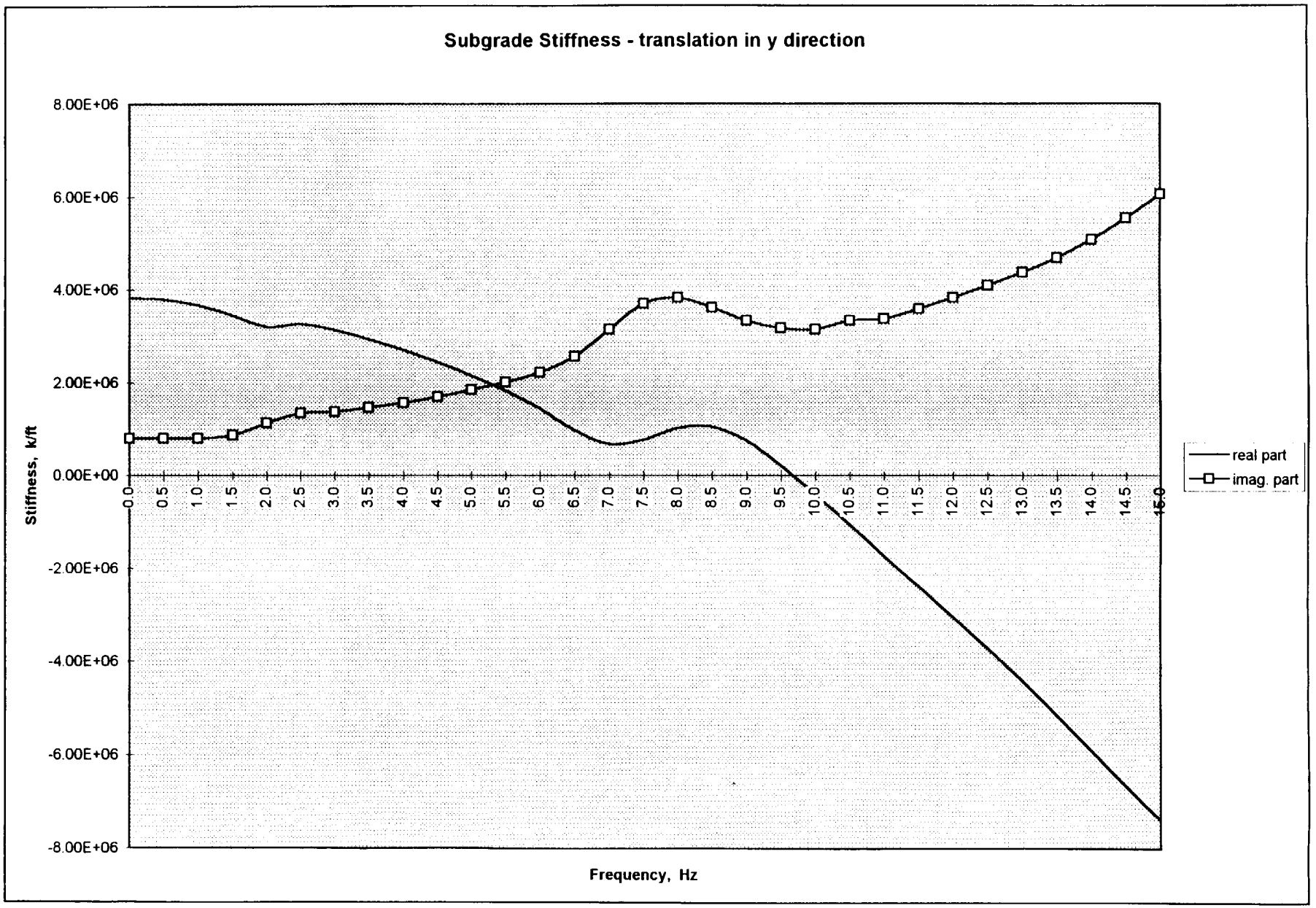
UPPER BOUND SOIL CASE RUN R0302C42 JOB 8624
dd 6/17/98

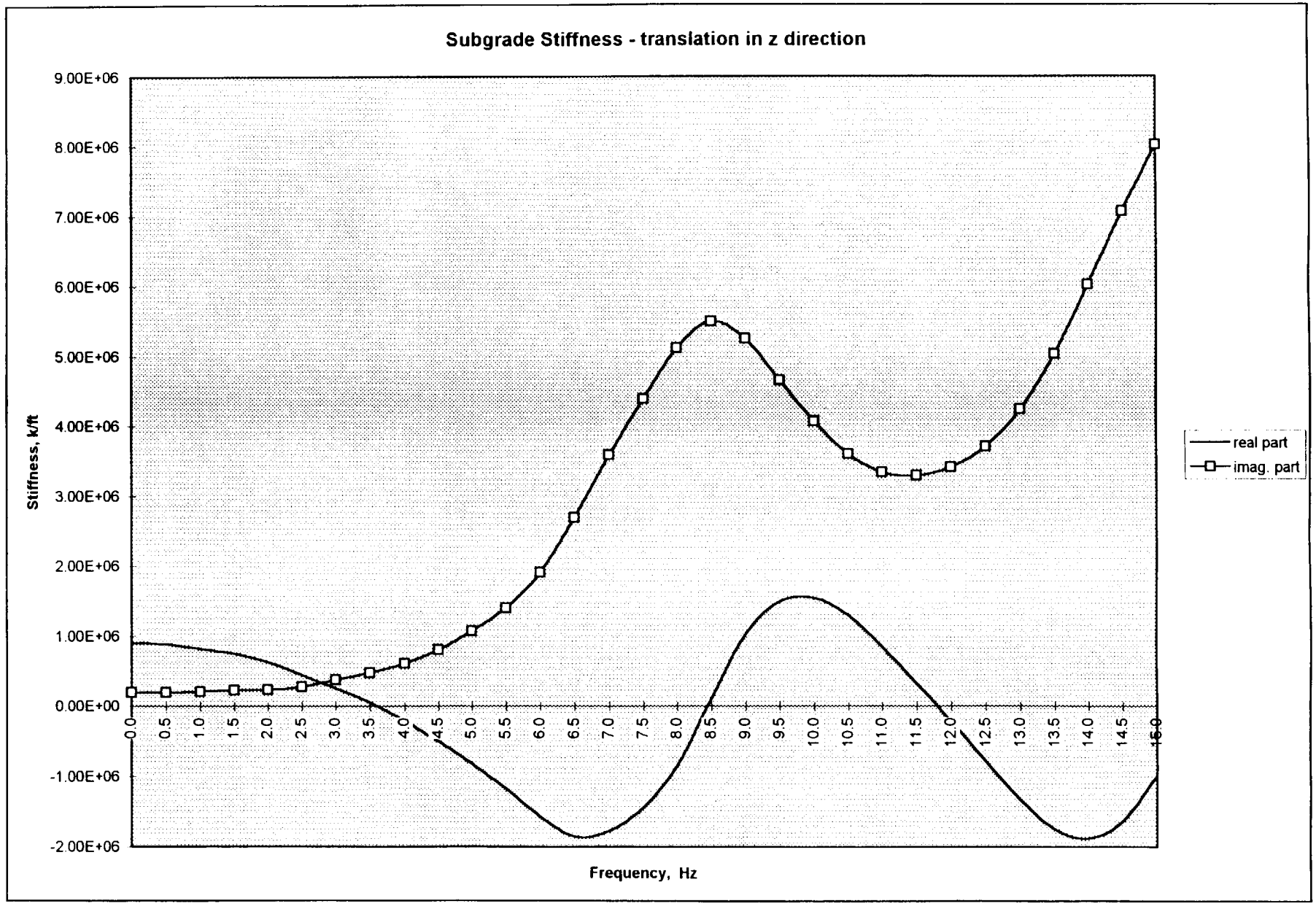
LOWER BOUND SOIL CASE RUN R0302C43 JOB 8625
dd 6/17/98

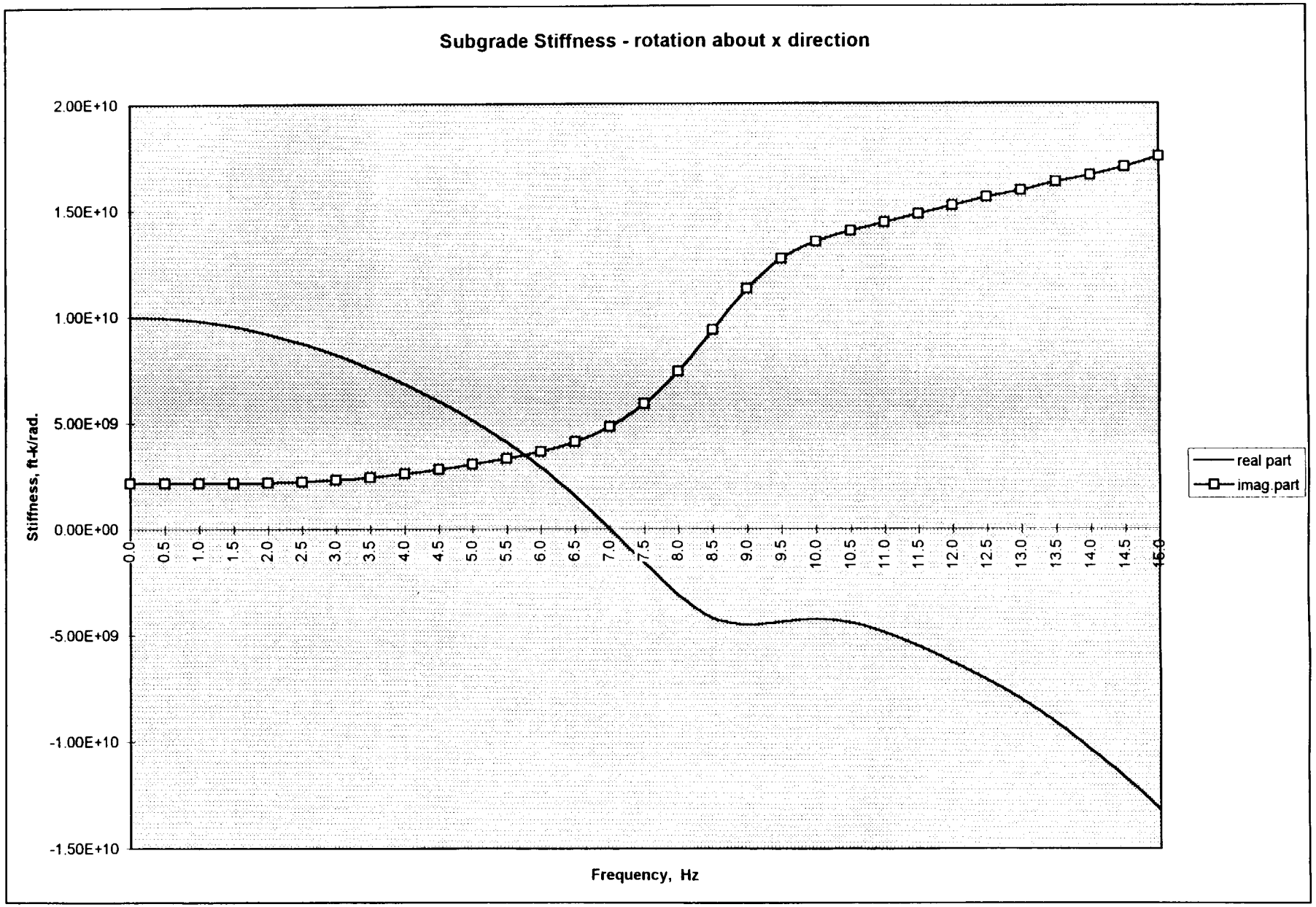
COORDINATE SYSTEM

For REFUND input X is the N-S direction and Y is the E-W direction. Output is in the convention of X being the N-S direction, Z being the E-W direction and Y being vertical, which is consistent with the seismic analysis sign convention.


Subgrade Stiffness - translation in x direction
8.00E+06
6.00E+06
4.00E+06
2.00E+06
0.00E+00
-2.00E+06
-4.00E+06
Stiffness, k/ft
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Frequency, Hz
real part
imag. part


Subgrade Stiffness - translation in y direction
8.00E+06
6.00E+06
4.00E+06
2.00E+06
0.00E+00
-2.00E+06
-4.00E+06
-6.00E+06
-8.00E+06
Stiffness, k/ft
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Frequency, Hz
real part
imag. part


Subgrade Stiffness - translation in z direction
9.00E+06
8.00E+06
7.00E+06
6.00E+06
5.00E+06
4.00E+06
3.00E+06
2.00E+06
1.00E+06
0.00E+00
-1.00E+06
-2.00E+06
Stiffness, k/ft
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Frequency, Hz
real part
imag. part


Subgrade Stiffness - rotation about x direction
2.00E+10
1.50E+10
1.00E+10
5.00E+09
0.00E+00
-5.00E+09
-1.00E+10
-1.50E+10
Stiffness, ft-k/rad.
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
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12.0
12.5
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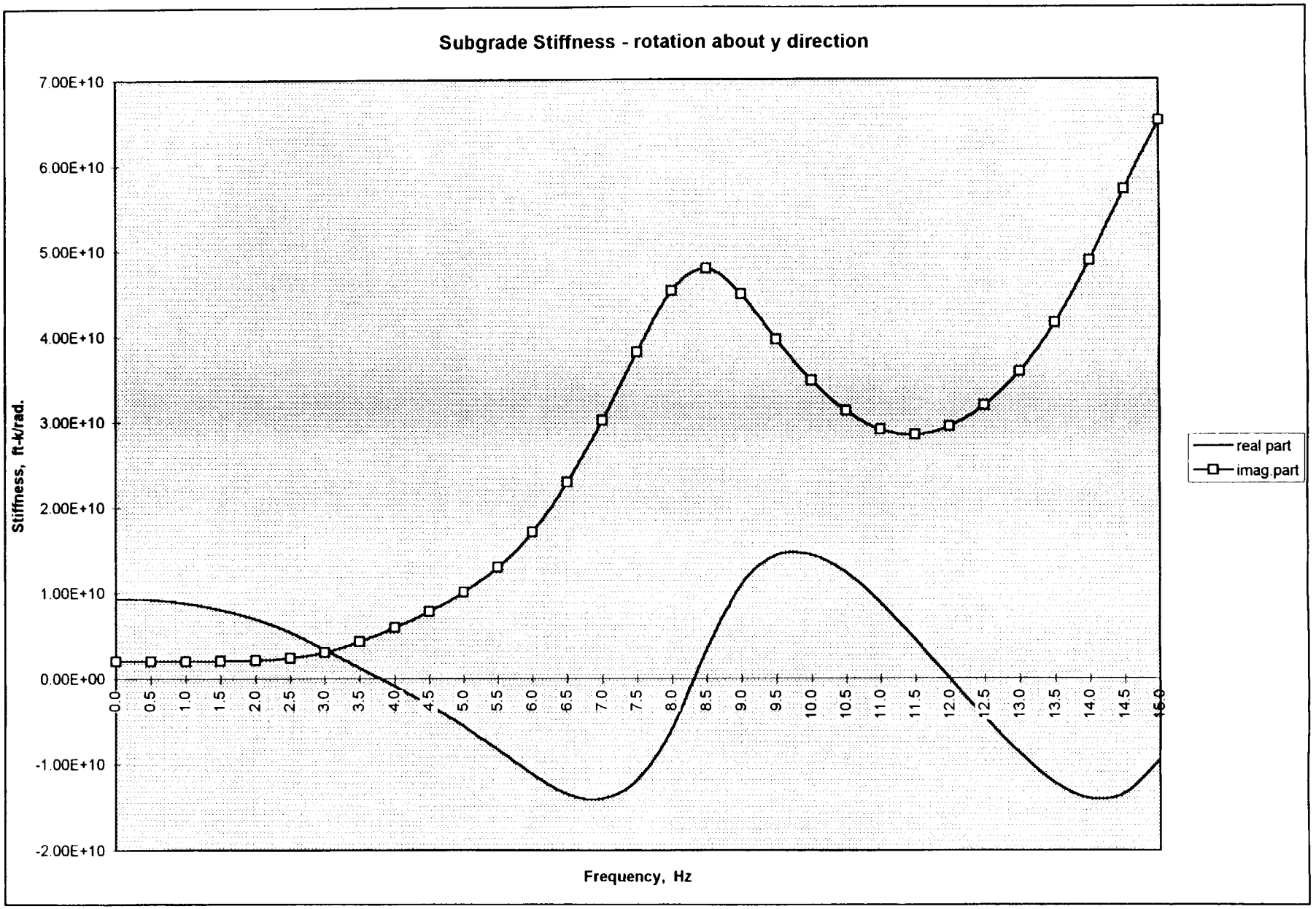
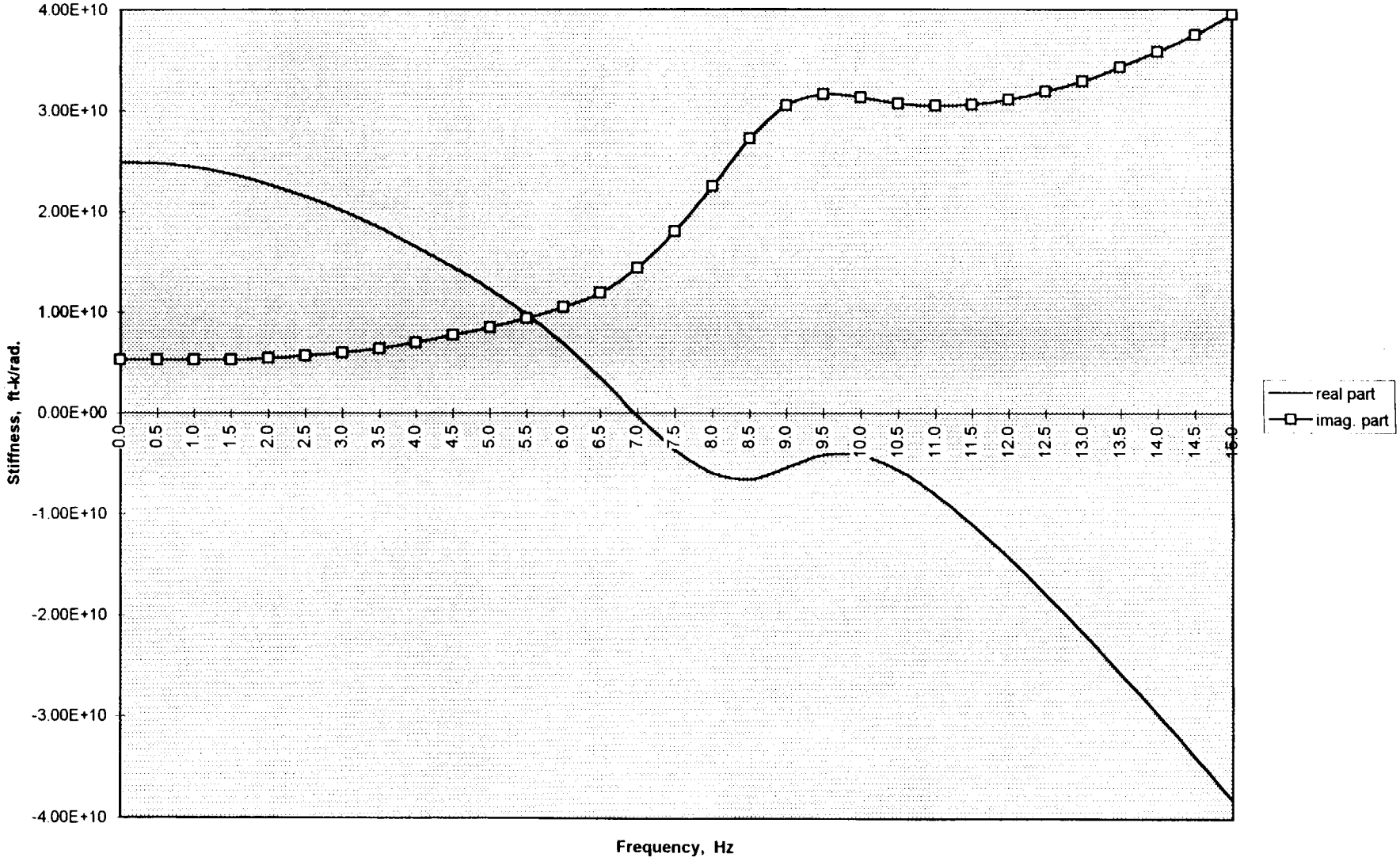
13.5
14.0
14.5
15.0
Frequency, Hz
real part
imag.part


Subgrade Stiffness - rotation about y direction
Stiffness, ft-k/rad.
7.00E+10
6.00E+10
5.00E+10
4.00E+10
3.00E+10
2.00E+10
1.00E+10
0.00E+00
-1.00E+10
-2.00E+10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Frequency, Hz
real part
imag.part

Subgrade Stiffness - rotation about z direction



COMPUTER RUNS

for

Calculation No. 05996.02 STRUCTURAL-SC-4

DEVELOPMENT OF SOIL IMPEDANCE FUNCTIONS FOR CANISTER TRANSFER BUILDING