NSF International

December 22, 2004

TEST REPORT

Stress and Acoustic Analysis
of
I-Rock Composite Beams
for use as
Highway Noise Barriers

Client:	I-Rock Industries, Inc.
Client Number :	1L410
Program:	Tox Group
Performing Laboratory:	NSF International 789 Dixboro Road Ann Arbor, MI, 48105-0140 USA
Product:	I-Rock Composite Beams
Date of Testing:	December 3, 2004 – December 8, 2004
Overall Study Result:	**COMPLETE**

Director of Engineering: _______ **Date:** 12/22/04

Test Engineer: David Ortiz **Date:** 12/22/04

Report Number PA#215126

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STUDY PERSONNEL

STUDY DIRECTOR:

Robert Frayer, PE	Director of Engineering

Professional personnel involved:

Ted Bailey, PE	Structural Engineer
David Orton, M.S.	Test Engineer

Background and Executive Summary

I-Rock Industries, Inc. (the "Client") has contracted NSF International (NSF) to evaluate the Client's composite beams for use as highway noise barriers for structural integrity and acoustic transmission (ASTM E90).

According to the stress calculations of licensed engineer, Ted Bailey, a 12 ft I-Rock Composite Beam with an 8.5"x 5.25" cross-section under a 35 psf wind load would have a strength safety factor of 3.8 and an angular deflection of 3 degrees.. The vertical steel supports, as prescribed in the attached drawing from I-Rock (see Appendix A), would experience a bending stress that exceeds the yield strength of common steel under a 35 psf wind load (see T. Bailey's report in Appendix C).

Acoustic analysis of the composite beam wall structure found the Sound Transmission Class (STC) to be 31 in both configurations (solid and perforated).

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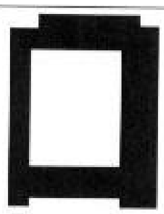
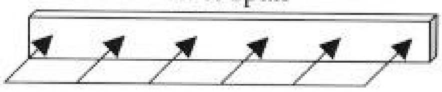
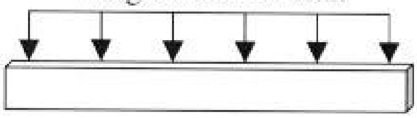
Table of Results

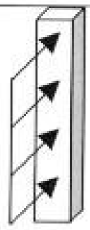
Geometric Properties of Composite Beam

	Results	
 (see Appendix B for detailed dimensions)	Total Height	8.5"
	Total Width	5.5"
	Height exposed to wind	8"
	Moment of Inertia I_{xx}	202 in^4
	Moment of Inertia I_{yy}	96 in^4

Stress Analysis of Composite Beam

	Results	
12 ft span  35 psf Wind Load ≈ 23.3 lb/ft	Max Bending Stress	140 psi
	Flexural Strength	537 psi
	Safety Factor	3.8
	Max Angular Deflection at ends	3 degrees
	Max Shear Stress at ends	5 psi
Weight load 351 lb/ft 	Compressive Stress	13 psi
	Compressive Strength	2107 psi
	Safety Factor	162

Stress Analysis of Steel I-Beam

	Results	
420 lb/ft  Equivalent Load from 35 psf Wind on 12 ft span and 20 ft column	Max Bending Moment	84,000 ft-lbs
	Max bending stress in 6x6 beam	77.9 ksi
	Yield strength of common steel	33 ksi
	(6x6 Beam Fails)	
	Recommended section modulus of I-Beam	>50 in^3

Sound Absorption (ASTM E90)

	STC (Sound Transmission Class)
Solid Wall	31
Perforated Wall	31

1.0 Stress Analysis

(See Appendix C for report from Ted E. Bailey, PE)

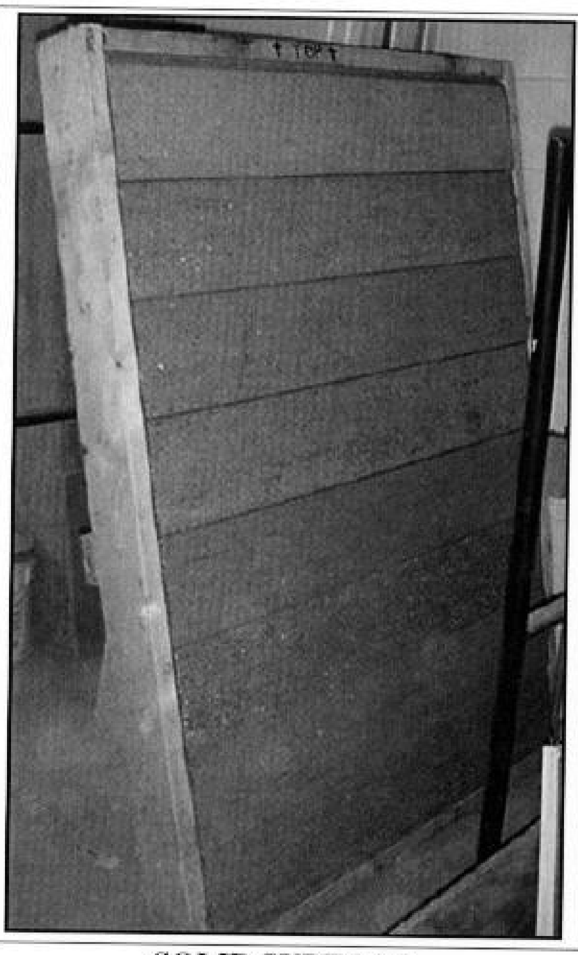
2.0 Sound Transmission Testing

2.1 Introduction

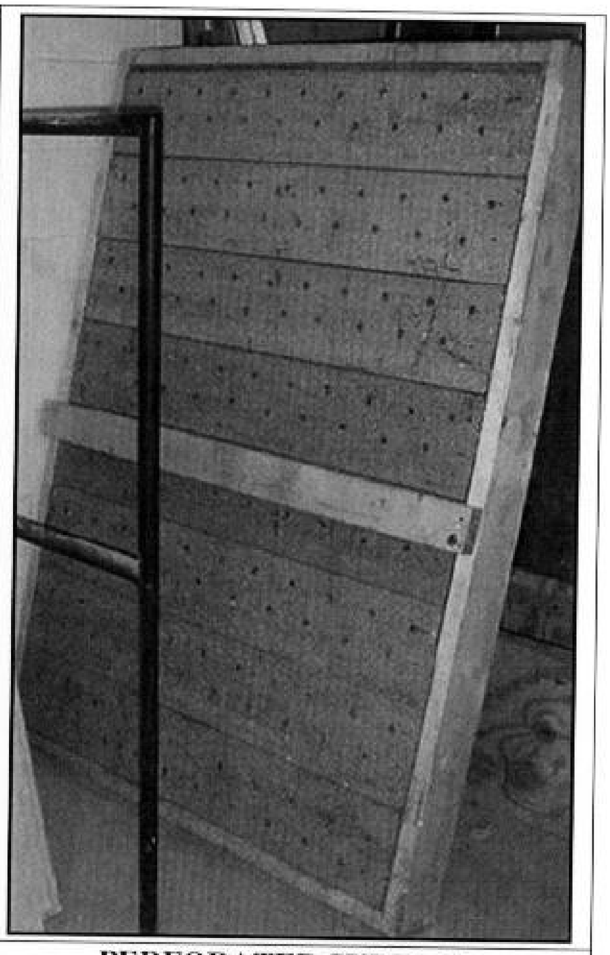
This report presents the results of sound transmission testing conducted on I-Rock Composite Sound Barrier samples, per ASTM E90 / NIST-accredited.

2.2 Sample Description

The sample, as supplied as an assembly by I-Rock Industries, measured 48" x 66.5" x 5.5", weighed approximately 400lbs, and consisted of 8 hollow composite beam sections (see Appendix B for dimensioned cross-section). The sample was made with a solid surface on one side and a perforated surface on the other side. The Perforated Wall surface contained 21 holes per section, a total of 168 holes. The holes were 5/8" nominally in diameter and passed halfway through the section thickness.



SOLID SURFACE



PERFORATED SURFACE

2.3 Test Procedure

2.3.1 Sound Transmission Test

ASTM:E90(04), "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements," was followed in every respect. The I-Rock panel was tested both with the solid surface towards the sound source and with the perforated surface towards the sound source. The STC value was obtained by applying the Transmission Loss (TL) values to the STC reference contour of ASTM:E413(04), "Determination of Sound Transmission Class." The actual transmission loss at each frequency was calculated by following the equation:

$$TL = NR + 10 \log S - 10 \log A_2$$

where:

TL = Transmission Loss (dB)
NR = Noise reduction (dB)
S = Surface area common to both sides (sq.ft.)
A_2 = Sound absorption of the receiving room with sample in place (sabins)

2.3.2 OITC Procedure

ASTM:E1332(03), "Determination of Outdoor-Indoor Transmission Class," was followed in every respect. The OITC was calculated by using the sound transmission loss values in the 80 to 4000 Hz range as measure in accordance with ASTM:E90(04). These transmission loss data are then used to determine the A-weighted sound level reduction of the specimen for the reference source specified in Table 1 of ASTM:E1332(03). The appropriate calculations were made to determine the OITC value. The source room has a volume of 2948 ft^3 and the termination room has a volume of 5825 ft^3.

The temperatures and relative humidity of the termination room met the requirements of the standard during and after the test. All frequencies met the requirement for 95% confidence established by the standard.

2.4 Equipment

Manufacturer	Model	Description	S/N
Norwegian Electronics	NE830	Real Time Analyzer	11511
Bruel & Kajar	3923	Rotating Microphone Boom	815424
Norsonic	1230	Pressure Condenser Microphone	26361
Bruel & Kajar	4192	Pressure Condenser Microphone	2360314

2.5 Results

The sample achieved an **STC of 31** with 30 deficiencies when the ***Solid Surface*** was pointed towards the noise source.

The sample achieved an **STC of 31** with 30 deficiencies when the ***Perforated Surface*** was pointed towards the noise source.

APPENDIX A

ACOUSTIC GRAPHS

Filename	
Test #6	**ASTM E90 - Laboratory Sound Transmission Class**

Project Folder	Client	Product	Model #	Quantity	Comment
63711-NSF	NSF International	Sound Barrier	I-Rock Composite	1	Solid Wall Towards Noise

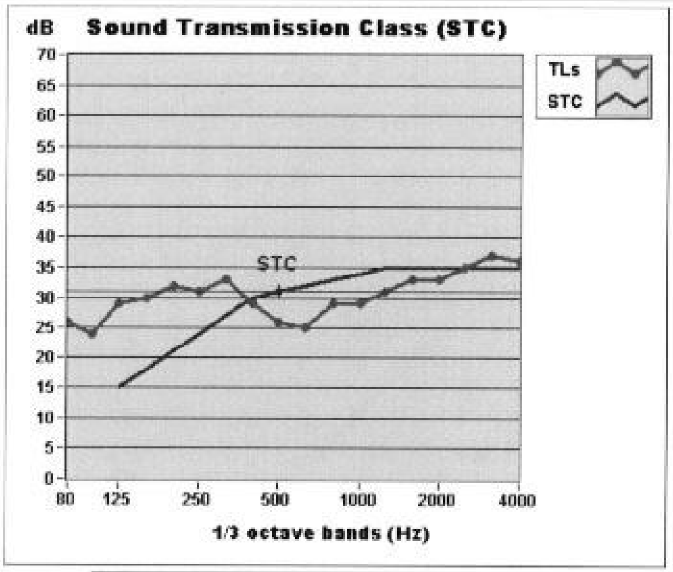
Sample Size - Wt.	Sample Description
48.0 in x 66.5 in x 5.5 in - 400 lbs	I-Rock Composite Sound Barrier '04 : Solid Wall towards noise source. : Size: 48" x 66-1/2" :

Time Stamp
Fri, Dec 03, 2004 - 11:52 AM

TLs - sample TL values (dB)
95% CI - 95% Confidence interval (dB)
def - STC deficiencies (dB)

F (Hz)	TLs	95% CI	def
80	26	2.8	-
100	24	1.6	-
125	29	2.2	0
160	30	1.7	0
200	32	0.6	0
250	31	0.5	0
315	33	0.4	0
400	29	0.4	1
500	26	0.2	5
630	25	0.2	7
800	29	0.3	4
1000	29	0.2	5
1250	31	0.2	4
1600	33	0.2	2
2000	33	0.3	2
2500	35	0.2	0
3150	37	0.3	0
4000	36	0.4	0

Temp (°C)	R.H. (%)	ATM (mbar)
20.3	59	984



STC = 31 def: 30
OITC: 29

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Filename: Test #1

ASTM E90 - Laboratory Sound Transmission Class

Project Folder	Client	Product	Model #	Quantity	Comment
63711-NSF	NSF International	Sound Barrier	I-Rock Composite	1	Perforated Wall towards Noise

Sample Size - Wt.: 48.0 in x 66.5 in x 5.5 in - 400 lbs

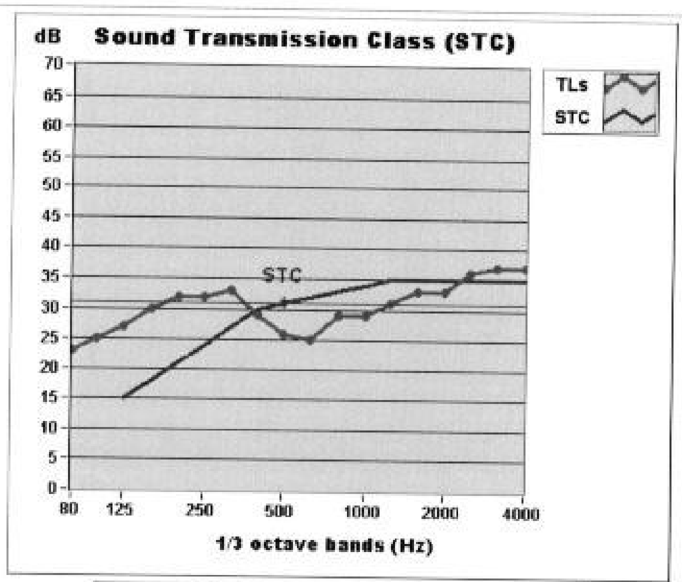
Sample Description: I-Rock Composite Sound Barrier - '04 : Perforated Wall Towards Noise Source. : Size: 48" x 66-1/2" :

Time Stamp: Fri, Dec 03, 2004 - 9:49 AM

TLs - sample TL values (dB)
95% CI - 95% Confidence Interval (dB)
def - STC deficiencies (dB)

F (Hz)	TLs	95% CI	def
80	23	2.8	-
100	25	1.6	-
125	27	2.2	0
160	30	1.7	0
200	32	0.6	0
250	32	0.5	0
315	33	0.4	0
400	29	0.4	1
500	26	0.2	5
630	25	0.2	7
800	29	0.3	4
1000	29	0.2	5
1250	31	0.2	4
1600	33	0.2	2
2000	33	0.3	2
2500	36	0.2	0
3150	37	0.3	0
4000	37	0.4	0

Temp (°C)	R.H. (%)	ATM (mbar)
20.3	59	984



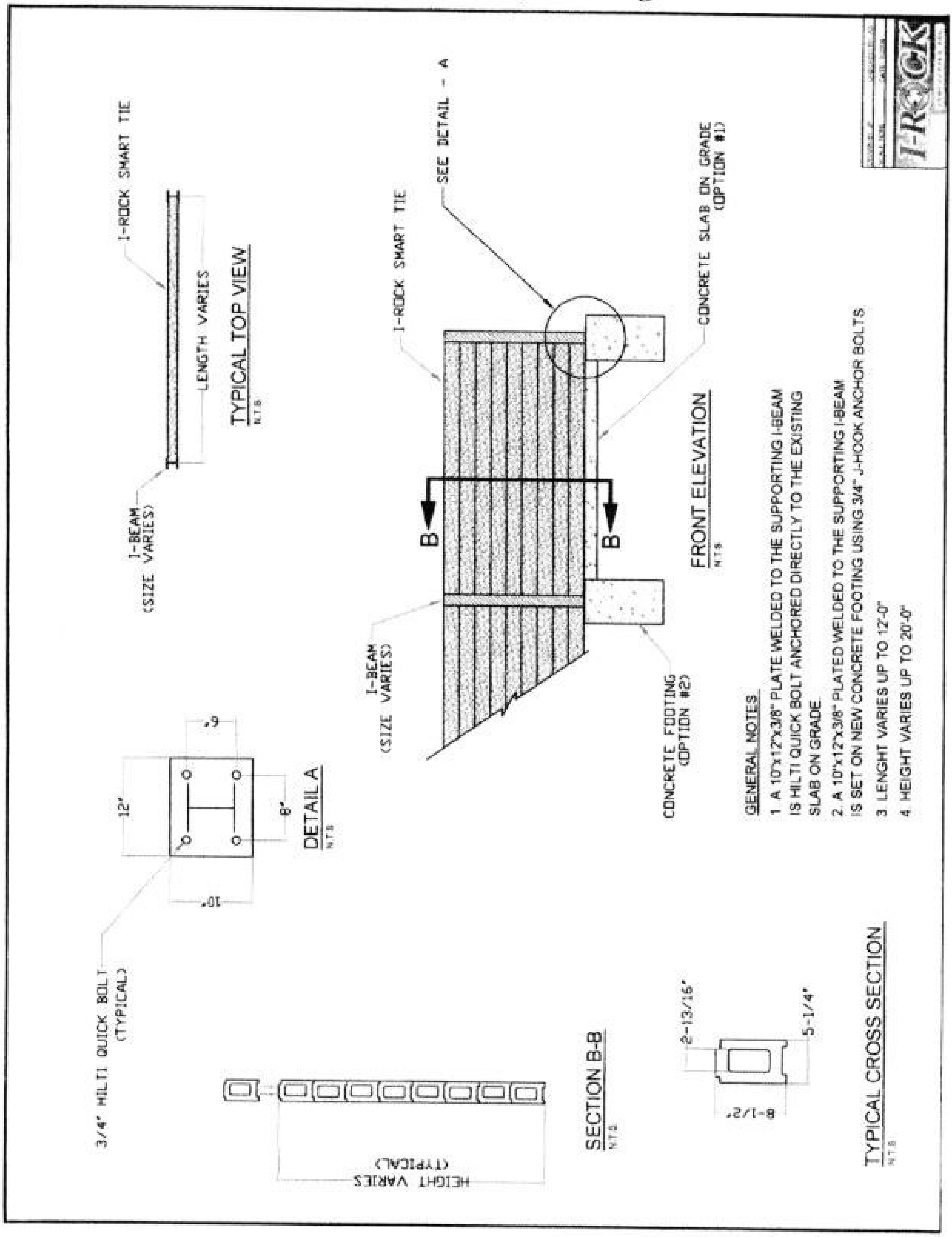
STC = 31 def: 30

OITC: 29

APPENDIX B

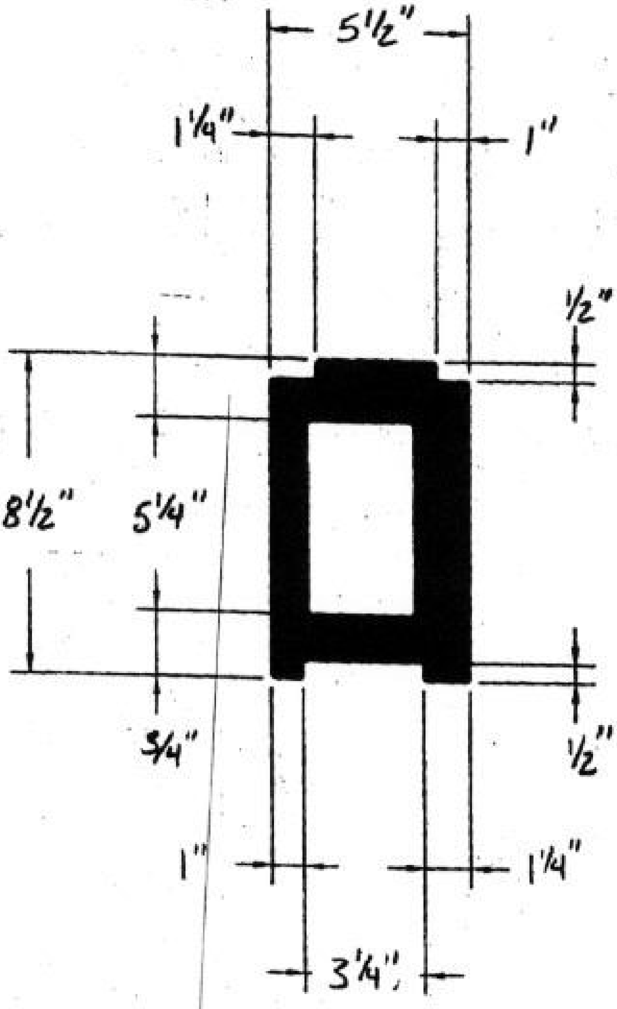
DRAWINGS

I-Rock Assembly Drawing



December 22, 2004

I-Rock Cross-Section Drawing



SMART-TIE CUT SECTION
SCALE: 3:1

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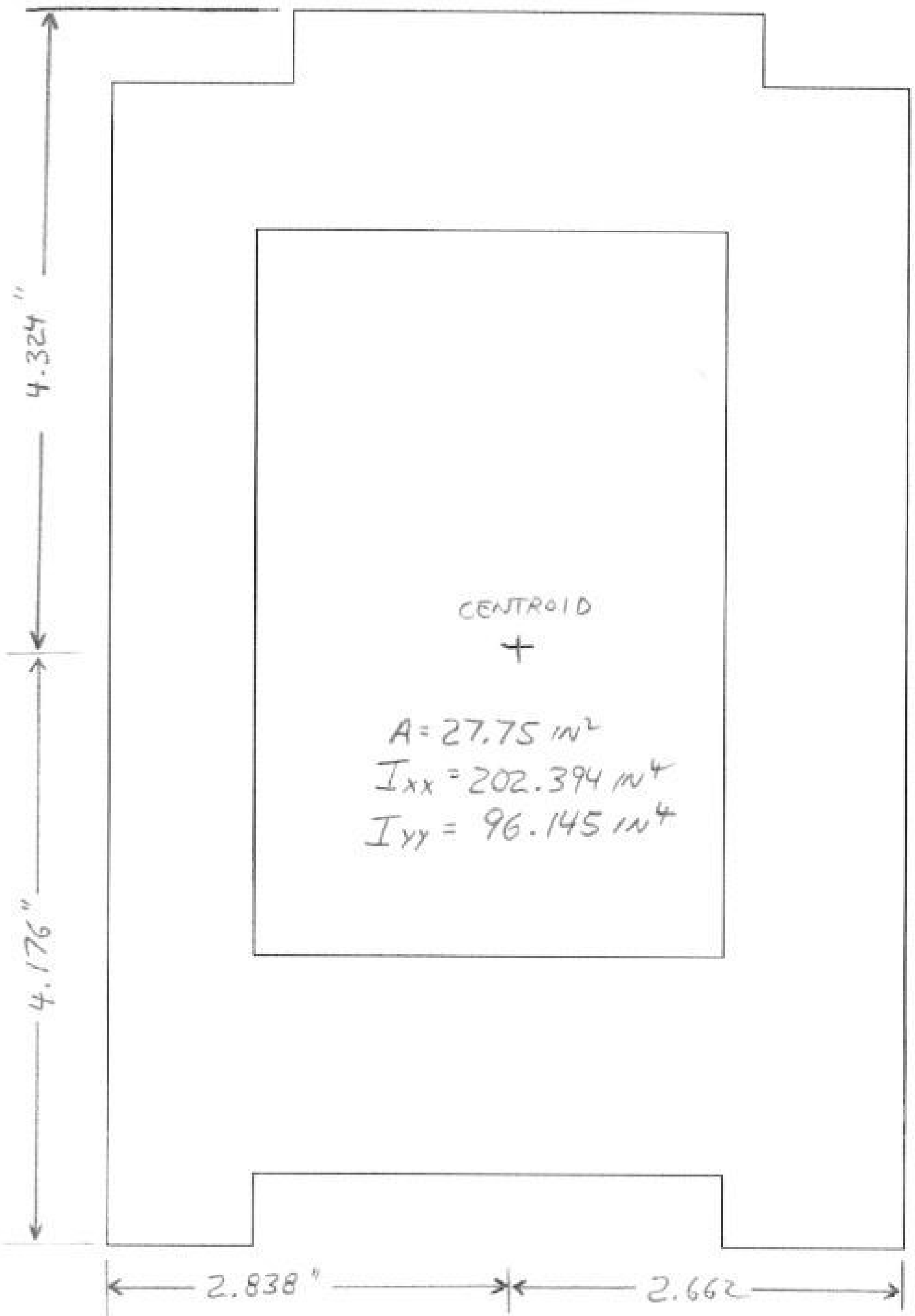
Moment of Inertia Drawing

SECTION PROPERTIES GENERATED USING VELLUM 2.70
SCALE 1/1



APPENDIX C

STRUCTURAL ANALYSIS REPORT

Ted E. Bailey
P. O. Box 6076
Ann Arbor, MI 48106
17 December 2004

Robert W. Frayer
NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105

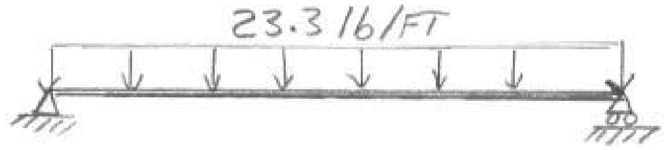
Subject: Stress Analysis Of Composite Beams To Be Used In A Noise Barrier

Dear Bob,

I have completed my analysis of the composite material beams that are to be used as structural members on a proposed Noise Barrier. The maximum bending stresses at the mid point of the composite beam, the shear stresses of the composite beam at the Steel I-beam support and the compressive stresses of the composite beam due to gravity loading are all within acceptable limits, assuming the geometry and material properties in the attached data sheets are correct and that there are no cracks or manufacturing defects in the composite beams. The assumed 6X6 Steel I-beam is not adequate for a wind loading of 35 PSF. A Steel I-beam with a section modulus of at least 50 in^3 would be required to satisfy the stress requirements for the Steel I-beam used in this application.

I used the attached data sheets for assumed geometry and material properties. The area and inertial properties of the beam were calculated using the Vellum CAD computer program. The cross sectional area was calculated to be 27.75 in^2. The calculated moment of inertia (I) values for the composite beam cross section were determined to be 96 in^4 and 202 in^4.

A simple model was created to determine the maximum bending stresses for a simply supported composite beam with a span of12 feet and a uniform loading of 23.3 lb/ft. This loading is equivalent to a wind load of 35 PSF. The ends of a simply supported beam can support shear loading but cannot carry a moment. The simple support assumption is conservative for the determination of bending stresses. In addition, the composite beams interlock from top to bottom and analyzing each composite beam without interlocking is also conservative.

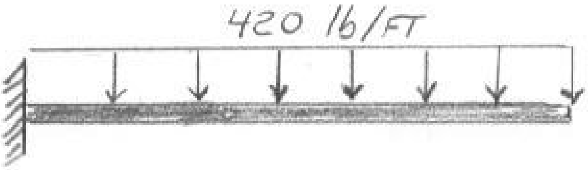


A flexural modulus of 45,600 PSI and a flexural strength of 537 PSI was used for this analysis. These values were obtained from the attached data sheets. The maximum Shear Load at the mid point of the beam was determined to be 140 lb. The maximum bending moment at the center of the beam was 420 ft-lb. If the beam had been rigidly supported at both ends, the bending stress would have been only 280 ft-lb. The maximum tensile bending (flexural) stress in the composite beam located at the outer edge of the beam at the midpoint was calculated to be 140 PSI. Because the flexural strength of the composite material is 537 PSI, there is a safety factor of 3.8 for this load condition. The angular deflection of the composite beam at the I-beam support with free rotation was 3 degrees. This is low and rotation is not expected to be a problem.

Shear loading at the end supports of a composite beam under wind loading of 35 PSF was determined. Three inches of each end of a composite beam were assumed to be simply supported within the channels formed by vertical Steel I-beams. The shear area was calculated to be 27.75 in^2. The calculated shear load on each end was 140 lb. Therefore, the shear stress at each end is only 5 PSI. This is very low and shear failure of the composite beams within the Steel I-beam channels is unlikely.

The compressive stresses due to gravity loading on the bottom composite beam was determined using the assumption that the beams were stacked to a height of 20 feet. The weight on each bottom beam segment is 351 lb/ft. The compressive stress on the beam is only 13 PSI. This is very much less than the compressive strength of 2107 PSI that is published in the attached data sheets. Compressive load failure is unlikely to occur on these composite beams.

The bending strength of the vertical steel I-beams were determined with the assumption that the steel I-beams are 20 feet in length, that they are fixed at one end by the concrete base and that the fixed beam has a uniform loading of 420 lb/ft (equivalent to a wind loading of 35 PSF). From my AISC manual, I selected a 6X6 light column beam with a weight of 20 lb/ft, an area of 5.88 in^2, a web thickness of 0.25 inch and a Moment of Inertia in the bending direction of 38.8 in^4. The Section Modulus for this beam was calculated to be approximately 13 in^3. The dimensions for this I-beam are similar to the I-Beam depicted on the attached drawing.



The calculated maximum bending moment at the base of the I-beam under maximum load conditions was 84,000 ft-lb. The maximum bending stress in the steel beam at the base of the I-beam near the concrete support was calculated to be 77.9 KSI. This is approximately 4 times higher than the maximum stresses recommended in Timoshenko "Mechanics of Materials". If common grade steels with a yield strength of 33 KSI are used, then it is recommended that an I-beam be selected that has a Section Modulus of at least 50 in^3. An I-beam with a Section Modulus of less than 50 in^3 can be used if the I-beam is made out of a higher strength steel.

Sincerely Yours,

Ted E. Bailey

Ted Bailey