SINGLE STORY DISASTER RELIEF HOUSING UNIT USING AIC COMPOSITE PANELS

1. INTRODUCTION

A single story disaster relief housing unit using AIC composite panels is proposed. The objective of this report is to determine the safe sustainable ground acceleration of the unit in the event of an earthquake. The design and the structural details are shown in the Appendix. The structural parameters of the unit have been developed through an extensive full scale load testing program and reported in AES Report No. AIC-09-1 dated 3/25/09. Therefore, the analyses made in this Report are conducted with reference to Report AIC-09-1.

2. PANEL PRODUCT

The panel is a composite structural member consisting of a structural foam core sandwiched between two structural steel skins. The panels are manufactured by the laminating process in accordance with the established Quality Control Manual. The 4" deep panel is used in the analysis.

3. HOUSING UNIT

The major features of the housing unit are listed below.

a. Unit width = 29'-0".

b. Unit length = 29'-0"

c. Roof slope = 6 : 12.

d. Eaves/End Wall height = 8'-10.25"= 8.854'.

e. Ridge height = 16’-11.25”= 16.938’.

f. Roof panel length = 17’-3.25” = 17.271’

g. Length of roof = 31’

h. Height of roof mass center = 12’-10.75” = 12.896’.

i. Total wall panel weight = 3685#

j. Total roof panel weight = 3080#

k. Total light gauge steel weight = 3250#

l. Total weight of fasteners = 340#

m. Total dead weight of unit = 10355#

4. CALCULATION OF MASSES

a. Building Surface Areas

Wall Area below Eaves:

A1 = 4 sides x 8.854’ x 29’ = 1027.1 sq. ft.

Roof Area:

A2 = 2 sides x 17.271’ x 31’ = 1070.8 sq. ft.

End Wall Area above Eaves:

A3 = 2 sides x 29’ x (16.938’ – 8.854’) / 2 = 234.4 sq. ft.

Total Building Surface Area:

At = A1 + A2 + A3 =2332.3 sq. ft.

b. Dead Weight Distributions and Centroid Heights

Unit Dead Weight = 10355 / 2332.3 = 4.44 psf

Wall Areas below Eaves:

W1 = 4.44 x 1027.1 = 4560.3 #

H1 = 8.854 / 2 = 4.427’ (centroid height)

Roof Areas:

W2 = 4.44 x 1070.8 = 4754.4 #

H2 = 12.896’

End Wall Areas above Eaves:

W3 = 4.44 x 234.4 = 1040.7 #

H3 = 8.854 + (16.938 – 8.854) / 3 = 11.549’

5. EARTHQUAKE ANALYSES GOVERNED BY BASE SHEAR

The following equation is obtained by expressing the allowable ground acceleration as a function of the gravitational acceleration.

a = n g -- (1)

where a = allowable ground acceleration (ft/sec^2)

n = multiplier

g = gravitational acceleration (ft/sec^2)

The total base shear generated by the ground acceleration is given by the following equation.

V = M a = M (n g) = n W = 10355 n --------------------------------- (2)

where V = total base shear (#)

M = total mass of the unit.

W = total weight of the unit (#)

Based on Report AIC-09-1, the allowable diaphragm shear is 300 plf. The allowable total base shear is calculated below.

Va = 2 (walls) x 29’ x 300 plf = 17400 # ---------------------------- (3)

Equating Eq. 2 to Eq. 3 and solving for “n” yields:

n = 1.68 -- (4)

6. EARTHQUAKE ANALYSES GOVERNED BY OVERTURNING MOMENT

The total base uplifting force is calculated below.

P = n (W1 H1 + W2 H2 + W3 H3) / 29’

= n (4560.3 x 4.427 + 4754.4 x 12.896 + 1040.7 x 11.549) / 29

P = 3224.8 n --- (5)

Based on Report AIC-09-1, the allowable base uplifting load is 480 plf. The total allowable base uplifting is calculated below.

Pa = 480 x 29 = 13920 -- (6)

Equating Eq. 5 to Eq. 6 and solving for “n” yields:

n = 4.32 -- (7)

7. CONCLUSION

Comparing Eq. 4 to Eq. 7, the design is governed by the earthquake generated base shear and it can safely sustain a horizontal ground acceleration of 1.68 times the gravitational acceleration (i.e. 54.1 ft/sec^2) with a safety factor of 3.0. This means that the base connection of the shear wall diaphragm will reach the yielding condition at a horizontal ground acceleration of 162.3 ft/sec^2. However, this shear yielding condition will only cause a sliding displacement of the shear wall without endangering the collapse of the building. This means that in case of extraordinary earthquake beyond the design limit, it is still safe to stay inside the housing unit. This unusual safety feature is mainly due to the very high strength/weight ratio of the composite foam panel system.

Appendix A: Design Drawings & Structural Details

AES

ADVANCED ENGINEERING SERVICES

SUITE 505-A
McKNIGHT PARK DRIVE
PITTSBURGH, PA 15237
(412) 367 - 7990

ADDENDUM #1 TO Report No. AIC-09-1

Prepared for

OceanSafe Housing
3255 Bayshore
Greenport, NY 11944

and

Advanced Insulation Concepts, Inc.
8055 Production Ave.
Florence, KY 41042

By

Raymond M.L. Ting, Ph.D., P.E.
Advanced Engineering Services
505A McKnight Park Drive
Pittsburgh, PA 15237

November 25, 2009

Reference: Mr. Greg Horeczko's e-mail to Mr. Basilice dated 10/19/09

This Addendum is to address Items 4 & 7 in the above reference e-mail.

<u>Item 4. Concentrated Load</u>

RE #1: FETI Test Report T311-09 (Concentrated Load Tests)

RE #2: Original AES Report AIC-09-1

DATA ANANLYSIS ON RE #1

$L = 8' = 96"$ (test span) $Ic = 2.042\ in^4/ft$ (4" panel)

$Gc = 267.6 + 1.112 \times 8^2 = 338.8$ psi (Eq. A8 in RE #2)

$P = 300$ # (concentrated load at mid-span)

Using one foot width property, the mid-span deflection is calculated below.

$k = E\ Ic / (Ac\ Gc\ L^2)$

$= 29 \times 10^6 \times 2.042 / (48 \times 338.8 \times 96^2) = 0.395$

$Y = [300 \times 96^3 (1 + 12 \times 0.395)] / (48 \times 29 \times 10^6 \times 2.042) = 0.536"$

$Yt = (0.343 + 0.348 + 0.346)/3$

$= 0.346"$ (Ave. mid-span deflection in RE #1)

$Be = 0.536 / 0.346 = 1.55'$ (effective panel width in resisting the 300# load)

The value of Be is a function of the transverse panel stiffness and can be conservatively assumed to be linearly related to the panel depth as stated in the following equation based on the 4" panel tests.

$Be = 0.3875\ D$

$Pe = P / Be$

where Be = effective panel width in resisting a midspan concentrated load (ft)

D = panel depth (")

Pe = equivalent midspan concentrated load for one foot width of panel (#)

P = applied midspan concentrated load (#)

ANALYSIS FOR COMBINED DEAD LOAD & A MIDSPAN CONCENTRATED LOAD

Fu1 = 36.939 – 1.9095 D (Eq. B3 in RE #2)

Fa = Fu1 / 2.5 (allowable bending stress with safety factor of 2.5)

Ma = Fa S1 = Rc [Wd L^2/ 8 + Pb L / (4 Be)] (allowable moment)

The allowable midspan concentrated load governed by bending stress, Pb, can be calculated from the above equation.

Vup = 18.533 – 0.909 D (Eq. B6 in RE #2)

Va = Vup / 3.0 (allowable shear stress with safety factor of 3.0)

Ra = Va Ac = Rc [Wd L/ 2 + Pv L / (2 Be)] (allowable reaction)

The allowable midspan concentrated load governed by shear stress, Pv, can be calculated from the above equation.

Under the effect of dead load plus a 300# midspan concentrated load, the midspan deflection can be calculated by the following equation.

Y = Rc [Wd L^4 (0.625 + 6 k) + Pc L^3(1 + 12 k)/Be] / (48 E Ic)

The following Load-Span Tables are generated from the above equations. The data limit the allowable concentrated load to the minimum of 300#.

THE FOLLOWING DATA ARE BASED ON THE FOLLOWING CONDITIONS
ROOF LOAD: DEAD LOAD + MIDSPAN CONCENTRATED LOAD
SAFETY FACTORS:
SAFETY FACOTOR FOR SHEAR = 3.00
SAFETY FACTOR FOR BENDING = 2.50

ALLOWABLE LOAD-SPAN TABLE FOR AIC PANELS

D (")	L (FT)	WD(PSF)	PAB(#)	PAV(#)	YP(")
10.	16.00	3.66	802.6	14340.0	.124 (L/1550.)
10.	17.00	3.66	740.7	14311.4	.136 (L/1505.)
10.	18.00	3.66	685.2	14285.6	.149 (L/1453.)
10.	19.00	3.66	634.8	14262.1	.163 (L/1396.)
10.	20.00	3.66	588.8	14240.3	.180 (L/1336.)
10.	21.00	3.66	546.7	14219.8	.198 (L/1274.)
10.	22.00	3.66	507.7	14200.5	.218 (L/1210.)
10.	23.00	3.66	471.6	14182.0	.241 (L/1146.)
10.	24.00	3.66	437.9	14164.2	.266 (L/1083.)
8.	14.00	3.28	679.2	9616.3	.160 (L/1051.)
8.	15.00	3.28	622.7	9586.9	.176 (L/1025.)
8.	16.00	3.28	572.9	9561.5	.193 (L/ 994.)
8.	17.00	3.28	528.6	9539.3	.213 (L/ 960.)
8.	18.00	3.28	488.8	9519.5	.234 (L/ 921.)
8.	19.00	3.28	452.7	9501.6	.259 (L/ 881.)
8.	20.00	3.28	419.8	9485.1	.286 (L/ 839.)
6.	10.00	3.07	613.8	5797.3	.191 (L/ 628.)
6.	11.00	3.07	546.6	5744.5	.214 (L/ 618.)
6.	12.00	3.07	491.1	5703.6	.238 (L/ 606.)
6.	13.00	3.07	444.3	5671.1	.264 (L/ 591.)
6.	14.00	3.07	404.1	5644.6	.293 (L/ 574.)
6.	15.00	3.07	369.2	5622.4	.325 (L/ 554.)
6.	16.00	3.07	338.4	5603.4	.360 (L/ 533.)
4.	8.00	2.86	371.1	2856.8	.327 (L/ 293.)
4.	9.00	2.86	318.2	2789.8	.380 (L/ 284.)

D =PANEL DEPTH.
L = PANEL SPAN.
WD = DEAD WEIGHT OF PANEL.
PAB = ALLOWABLE MIDSPAN LOAD GOVERNED BY BENDING.
PAV = ALLOWABLE MIDSPAN LOAD GOVERNED BY SHEAR.
YP = MIDSPAN DEFLECTION UNDER A 300# MIDSPAN LOAD + DEAD LOAD.

Item 7. Temperature Differential on Panel Facings

In this design application, all wall and roof panels are simply supported structure. Under the effect of temperature differential between the two panel facings, the panel will undergo stress-free thermal bow. Therefore, there will be no detrimental effect on the structural integrity of the panel due to temperature differential. The requirement in Section 4.11 of AC04 is fulfilled.