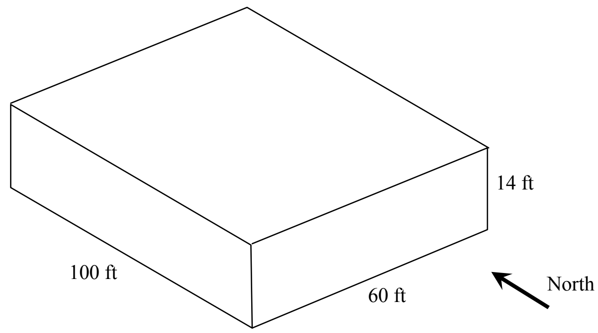
White Paper
Trial Design Problem 01-06

June 19, 2007

1.0 Introduction



Is the code written for practicing design engineers or for researchers? Are practicing design engineers able to keep up with the fast pace of code changes? Is the code being properly and consistently applied in practice? The trial design problems, developed by the Design Practices Committee of the Structural Engineering Institute (SEI), are intended to evaluate these questions.

The purpose of this Trial Design Problem 01-06 was to:

a. Investigate how practicing engineers interpret and apply current seismic and wind loading provisions.
b. Investigate the consistency of engineering judgment used for development of lateral design loads by practicing engineers.
c. Promote dialog and continuing education among practicing engineers related to seismic and wind lateral loading provisions.
d. Identify and promote needed improvements in the ASCE 7 lateral load code requirements.

2.0 Demographics of Participants

There were a total of 54 participants submitting solutions for this trial design problem. We would like to sincerely thank those engineers who took the time to submit a solution. The average time to develop a solution for the trial design was 1 hour. A break down of the demographics of the participants is as follows:

Highest Educational Degree	46% Bachelors	48% Masters	6% Unknown	
Years Experience	31% 0-4 Years	30% 5-10 Years	22% 11-20 Years	17% 21+ Years
Professional License	33% EIT Only	67% PE	28% SE	
States	31% Minnesota	13% Arizona	13% Virginia	43% Others

3.0 Evaluation of Responses

3.1 Experience Level

Experience is essential….this is the first lesson learned (or reinforced) from the trial design solutions. Education alone is not adequate to ensure practicing engineers are able to safely and consistently design buildings. As an example, the seismic base shear (V) from the published solution is 11.00 kips. A summary of the base shear results from the Trial Design Solutions is as follows:

	Seismic Base Shear (V) per Trial Design Solutions	
	0 to 4 Years Experience	**5+ Years Experience**
Low	0.5 kips	9.5 kips
Average	70.1 kips	13.1 kips
High	979.9 kips	27.8 kips
Standard Deviation	234.6 kips	3.7 kips

While having experience certainly does not eliminate all errors, having at least 5 years of experience seemed to give engineers enough judgment to recognize unreasonable answers that were grossly incorrect.

As a result of the extremely large variation in results for those with less than 5 years of experience, findings for the subsequent portions of this report will be based on data gathered from those engineers with 5+ years of experience.

3.2 Seismic Loading

3.2.1 Simplified vs. Equivalent Lateral Force Method

Both the Simplified and the Equivalent Lateral Force methods are appropriate for the trial design problem. Given the simplicity of the problem, it is interesting to observe the overwhelming selection of the Equivalent Lateral Force Method in lieu of the Simplified Method. The trend to use the Equivalent Lateral Force method seemed consistent for engineers in all areas of the country, regardless of the seismicity of the area.

	% of Total Solutions	
Seismic Method	19% Simplified	81% Equiv. Lateral Force

3.2.2 Reading the Maps

The determination of correct seismic design forces is dependant upon accurately reading the S_S and S_1 values from the ground motion maps. The variation in read values was quite surprising and typically resulted in discrepancies of 10% to 15% in seismic design forces.

	S_S				
	ASCE 7 Maps	**USGS Website**		**5-20 Years Experience**	**21+ Years Experience**
Low	0.16	0.18		0.16	0.16
Average	0.20	0.19		0.20	0.23
High	0.25	0.22		0.25	0.39
Standard Deviation	0.024 (12%)	0.018 (9%)		0.025 (12%)	0.083 (36%)

S_S and S_1 values were determined using a variety of sources including the ASCE 7-05 maps, the USGS website with latitude-longitude data, and the USGS website using zip code data. Regardless of the source, there was significant variation in values determined for the site. Somewhat surprisingly, the largest variation in values came from those engineers with more than 20 years of experience.

3.2.3 Site Class and Site Coefficient

The site class was not specified in the problem, thus requiring the engineer to select default site class D as specified by the ASCE 7-05. Remarkably, 100% of the engineers correctly selected site class D. Despite correctly selecting the site class, there were a few errors in determination of the site coefficients. For example, the site coefficient F_a from the published solution is 1.6. A summary of the results from the Trial Design Solutions is as follows:

	Site Coefficient, F_a
Low	1.4
Average	1.59
High	1.6
Standard Deviation	0.036 (2%)

3.2.4 Seismic Design Category

There were very few errors in determination of the seismic design category. The seismic design category from the published solution is B. A summary of the results from the Trial Design Solutions is as follows:

	% of Total Solutions			
Seismic Design Category	0% SDC=A	95% SDC=B	5% SDC=C	0% SDC=D

3.2.5 Response Modification Coefficient (R) and Importance Factor (I)

There was only 1 error in determining the appropriate Importance Factor, I=1.0. There were a few errors in determination of the Response Modification Coefficient, R=4. A summary of the results from the Trial Design Solutions is as follows:

	% of Total Solutions			
Response Modification Coefficient	8% R=2.5	8% R=3	81% R=4	3% R=6

3.2.6 Building Weight (W)

The weight of the building varied in the solutions depending primarily on whether ½ the weight of the walls or the full weight of the walls was used in the calculations. The published solution included the full weight of the walls, W=235.2 kips, since the effective seismic weight (W) is defined as the "total dead load". However, the use of ½ the weight of the walls is appropriate in determining seismic design forces in certain elements of the building. Given that the trial design problem did not specify the intended use of the seismic force, the variation in calculated weight is certainly understandable.

	% of Total Solutions	
Building Weight	24% ½ Wall Weight 201.6 kips	76% Full Wall Weight 235.2 kips

3.2.7 Seismic Response Coefficient (Cs) and Base Shear (V)

Given all of the variations discussed in the prior sections of this report, the results of C_S and V should not be surprising. From the published solution, C_S=0.0468 and V=11.00 kips. A summary of the results from the Trial Design Solutions is as follows:

	Site Response Coefficient, C_S	**Seismic Base Shear, V**
Low	0.042	9.5 kips
Average	0.059	13.1 kips
High	0.118	27.8 kips
Standard Deviation	0.0156 (26%)	3.72 kips (28%)

3.3 Wind Loading

3.3.1 Simplified vs. Analytical Procedure

Both the Simplified (Method 1) and the Analytical (Method 2) procedures are appropriate for the trial design problem. Given the simplicity of the problem, it is interesting that a large number of the respondents selected the Analytical procedures.

	% of Total Solutions	
Wind Method	65% Simplified Method 1	35% Analytical Method 2

3.3.2 Exposure

The Exposure was not specified in the problem, thus requiring the engineer to select the exposure per the definitions in ASCE 7-05. Since the description of the site conditions in the problem statement was vague (i.e. "building located in Phoenix, Arizona"), the published solution used Exposure C. Approximately ½ of the respondents selected Exposure B and ½ selected Exposure C. This inconsistency in the selection of the Exposure is a concern. A summary of the results from the Trial Design Solutions is as follows:

	% of Total Solutions		
Exposure	51% Exp = B	46% Exp = C	3% Exp = D

3.3.3 Adjustment Factor for Building Height and Exposure (λ)

Of those respondents that selected the Simplified Procedure, all except one properly determined λ, the adjustment factor for building height and exposure based on the Exposure. The published solution used λ=1.21 for Exposure C.

3.3.4 Topographic Factor (K_{zt}) and Importance Factor (I)

All of the respondents, except one, determined K_{zt}=1.0 and I=1.0.

3.3.5 Basic Wind Speed and Simplified Wind Pressure for Exp. B (p_{S30})

All of the respondents properly identified the Basic Wind Speed at the site equal to 90 mph. Of those respondents that selected the Simplified Procedure, all except one properly determined p_{S30}=12.8 psf for Zone A and p_{S30}=8.5 psf for Zone C.

3.3.6 Design Wind Pressure

The design wind pressure data was evaluated based on Exposure and Analysis Method used by the participants. The design wind pressure for the published solution was 15.5 psf for Zone A and 10.3 psf for Zone C based on the Simplified Method (Method 1) and Exposure C. A summary of the results from the Trial Design Solutions is as follows:

	Simplified Design Wind Pressure Simplified Method (Method 1) p_s			
	Exposure B		Exposure C	
	Zone A	Zone C	Zone A	Zone C
Low	12.8 psf	8.5 psf	12.8 psf	8.5 psf
Average	12.8 psf	8.5 psf	14.9 psf	9.9 psf
High	12.8 psf	8.5 psf	15.5 psf	10.3 psf
Standard Deviation	0.00 psf (0 %)	0.00 psf (0%)	1.05 psf (7%)	0.71 psf (7%)

	Design Wind Pressure Analytical Method (Method 2) p			
	Exposure B		Exposure C	
	Zone A	Zone C	Zone A	Zone C
Low	7.2 psf	7.2 psf	14.8 psf	10.3 psf
Average	10.4 psf	9.6 psf	17.5 psf	15.4 psf
High	13.6 psf	13.6 psf	32.1 psf	27.8 psf
Standard Deviation	2.74 psf (26%)	2.47 psf (26%)	6.43 psf (37%)	5.86 psf (38%)

The data clearly demonstrates:

a. There is good understanding and consistent application of the Simplified Method (Method 1) for determination of design wind pressures.

b. The Analytical Method (Method 2) is not clearly understood or consistently applied as demonstrated by the large variation in the design wind pressure.

3.3.7 Minimum Design Wind Loading

The minimum design wind loading per ASCE 7-05 is “10 psf multiplied by the area of the building”. Only ½ of the respondents checked the minimum 10 psf loading and only 1/3 performed the check correctly. Many solutions incorrectly increased the Zone C pressure to 10 psf instead of multiplying 10 psf times the area of the building.

	% of Total Solutions	
Minimum Design Wind Loading	49% Checked 10 psf Minimum	35% Properly Checked 10 psf Minimum

3.3.8 Wall Area

A large number of the respondents utilized ½ the wall height in determining the wall area for the wind base shear. The published solution used the full wall height for a wall area of 840 square feet. Given that the trial design problem did not specify the intended use of the wind force, the variation using either ½ or the full wall height is certainly understandable.

	% of Total Solutions	
Wall Area used for Wind Shear	22% ½ Height 420 sf	78% Full Height 840 sf

3.3.9 Wind Base Shear

The process used by respondents to calculate the wind base shear is of interest. Many of the respondents did not utilize the lower Zone C pressure areas when calculating the wind base shear. In fact, almost half of respondents utilized the higher Zone A pressure for the entire width of the building rather than using both the Zone A and Zone C pressures as permitted by ASCE 7-05.

	% of Total Solutions	
Wall Area used for Wind Shear	54% Zone A & C Pressures	46% Zone A Pressures Only

While 54% of the respondents considered both the Zone A and C pressures in the solution, only 35% of the respondents properly applied the provision.

Given all of the variations discussed in the prior sections of this report, a wide variation in the results of the Wind Base Shear should not be surprising. From the published solution, V_{WIND} = 9.5 kips. A summary of the results from the Trial Design Solutions is as follows:

	Wind Base Shear V_{WIND}
Low	3.9 kips
Average	8.8 kips
High	24.2 kips
Standard Deviation	3.72 kips (42%)

It is instructive (and concerning) to observe the extremely wide scatter in the wind results, much worse than the results from the seismic portion of the problem. It should also be noted that the average solution underestimates (not conservative) the wind load as compared to the published solution. This is primarily due to the selection of Exposure B by many of the respondents in lieu of Exposure C as used in the published solution.

4.0 Recommendations

4.1 Increase Minimum Work Experience for Licensure

The results from this problem would indicate that a minimum of 3 to 4 years of work experience, beyond a bachelor's degree, should be required for licensure. While there has been much discussion recently regarding the importance of minimum education requirements for licensure, there has been virtually no discussion regarding minimum work experience requirements. With the ever increasing complexity of the codes, it would seem a review of the experience requirements is in order.

4.2 Seismic Loading

4.2.1 Increase Awareness of Simplified Seismic Design Procedures

The results of this problem indicate that efforts should be made to increase engineer's awareness of the Simplified Seismic Design Procedures. These efforts could include: (a) increased referencing to Section 12.14 in ASCE 7-05 code requirements, (b) increased exposure in ASCE 7-05 professional development seminars.

4.2.2 Increased Training in Determining S_S and S_1

The results of the problem indicate that increased training is warranted in determining S_S and S_1, especially among experienced senior engineers (20+ years experience). The training should include the various options for obtaining S_S and S_1 including maps and software.

4.3 Wind Loading

4.3.1 Reduce Restrictions on Simplified Wind Method

Dramatic reduction of the numerous restrictions to the use of Method 1 in Section 6.4.1.1 of ASCE 7-05 should be undertaken to allow expanded use of the Simplified Method. The Simplified Wind Method (Method 1) is applied much more consistently and safely as demonstrated by the results of this problem. The Analytical Wind Method (Method 2) is not being safely understood or consistently applied by practicing engineers due to it's complexity.

4.3.2 Elimination of Pressure Zones for MWFRS

The Pressure Zones A, B, C, D should be eliminated from the Simplified Procedure for MWFRS. Only ½ of the engineers considered the zones in the base shear calculation and only 1/3 of the engineers applied the zones properly.

4.3.3 Clarification of Default Exposure

The default Exposure should be clarified in ASCE 7-05. Many engineers automatically assume Exposure B if the building is located in or near a city. Perhaps less technical qualitative language could be added to the Exposure definitions to provide additional guidance.

4.3.4 Increase Awareness / Simplification of Minimum Wind Loading

The results of the problem indicate that efforts should be made to increase engineer's awareness of the Minimum Design Wind Loading provisions. These efforts could include: (a) increased referencing to the minimum provisions in the code, (b) increased exposure in ASCE 7-05 professional development seminars, and (c) simplification of the provisions to a 10 psf minimum pressure rather than 10 psf minimum pressure multiplied by the area of the building.