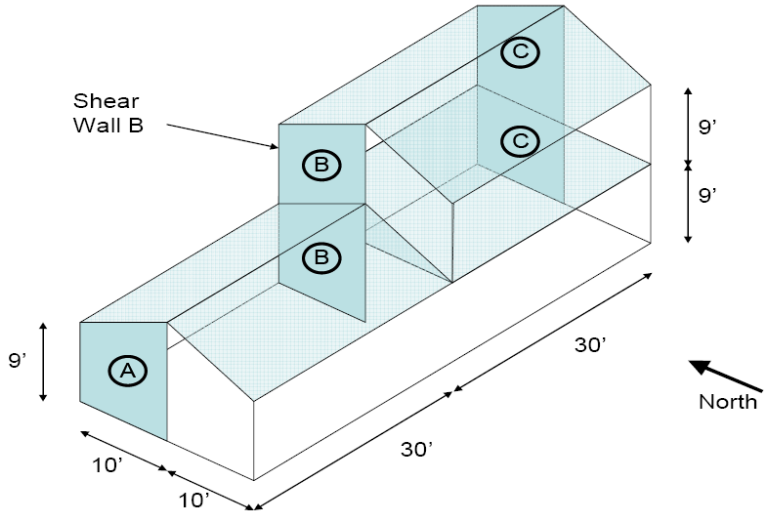
White Paper
Trial Design Problem 01-07

August 8, 2008

1.0 Introduction

During the past several years there has been much discussion and debate (complaining and frustration may be more accurate) regarding the current wind loading requirements of ASCE 7-05. As a result, a new set of Simplified Wind Provisions was recently developed by engineers on the West coast and carried forward by NCSEA. In February, the International Code Council voted to incorporate these Simplified Wind Provisions into the 2009 IBC.



In response to the code activity regarding wind loading requirements, the Design Practices Committee developed trial design problem 01-07. The problem consists of determining wind loads for a small, simple two story structure using both ASCE 7-05 and the new Simplified Wind Provisions.

The goals of this problem were to:

a. Determine if the new Simplified Wind Provisions will improve the accuracy, consistency and efficiency of determining design wind loads. (Note: the trial design problem utilized a draft version of the new Simplified Wind Provisions that have now been adopted into the 2009 IBC).
b. Identify and promote needed revisions and simplifications to the wind loading provision of ASCE 7.
c. Promote dialog and continuing education among practicing engineers related to wind loading provisions.

2.0 Demographics of Participants

There were a total of 35 participants submitting solutions for this trial design problem. We would like to sincerely thank those engineers who took the time to submit a solution. A break down of the demographics of the participants is as follows:

Highest Educational Degree	51% Bachelors	38% Masters	11% Unknown	
Years Experience	31% 0-4 Years	40% 5-10 Years	12% 11-20 Years	17% 21+ Years
Professional License	37% EIT Only	40% PE	23% SE	
States	23% Virginia	17% Pennsylvania	14% Oregon	46% Others

3.0 Evaluation of Responses

3.1 Experience Level

Experience matters! Although the results of this Trial Design Problem are less dramatic than prior problems, the results consistently demonstrate that engineers with 5 or more years of experience produce more accurate results. For example, the published solution developed by the committee calculated a 4.5 kip shear force in wall B due to ASCE 7-05 wind provisions. The results of the submitted solutions are as follows:

	Wall B Wind Shear Force	
	0 to 4 Years Experience	**5+ Years Experience**
Average Submitted Solutions	6.4 kips	5.6 kips
% Error Average Submitted vs. Published Solution	42% Error	24% Error
Standard Deviation Submitted Solutions	42%	35%

3.2 ASCE 7-05 vs. New Simplified Wind Provisions

3.2.1 General

This section of the report is limited to a comparison of the results between the two methods for overall accuracy, consistency and efficiency. For a detailed review of the results from each method, see the subsequent sections of the report.

3.2.2 Accuracy

Based on analysis of the submitted solutions, the new Simplified Wind Provisions are very successful in improving the accuracy of the wind design loads.

	Wall B Shear Force	
	ASCE 7-05	**New Simplified**
Published Solution from Committee	4.52 k	4.83 k
Average of Submitted Solutions (5+ Years Experience)	5.66 k	5.48 k
% Error	**25%**	**13%**

It is interesting to note that the average solution per ASCE 7-05 actually resulted in a higher wind force being applied to the shear wall than the new Simplified Wind Provisions. The increased errors in the submitted solutions per the ASCE 7-05 provisions counteracted any potential savings from the more complex code language.

3.2.3 Consistency

Based on analysis of the submitted solutions, the new Simplified Wind Provisions are very successful in improving the consistency of engineers applying the code wind design provisions.

	Design Wind Pressures	
	ASCE 7-05	**New Simplified**
Standard Deviation of Submitted Solutions (5+ Years Experience)	19%	8%

3.2.4 Time to Complete

Each participant recorded the time necessary to complete the wind loading calculations for both the ASCE 7-05 provisions and the new Simplified Wind Provisions.

	ASCE 7-05	New Simplified
Average Time to Complete	113 minutes	48 minutes

The results are dramatic. The ASCE 7-05 method took more than twice as long to complete. The numeric results clearly indicate that the ASCE 7-05 wind loading provisions are much more complex and time consuming than the new Simplified Wind Provisions.

3.3 ASCE 7-05 Results

3.3.1 General

Several areas of the ASCE 7-05 provisions were implemented properly with almost 100% consistency including the basic wind speed (V), the wind directionality factor (K_d), the importance factor (I), the exposure category, the topographic factor (K_{zt}), and the gust effect factor (G).

However, there were several areas where a majority of the solutions did not properly implement the ASCE 7-05 code provisions including torsion / end zone pressures, internal pressures and rigid vs. low rise buildings. These topics are discussed in more detail below.

3.3.2 Torsion / End Zone Pressures

The ASCE 7-05 requirements includes increased design wind pressures at the end zones of low rise building or the consideration of torsion for other buildings. Analysis of the submitted solutions indicates that only 45% of the solutions considered the effect of torsion or end zone pressures in the calculations.

Since more than $\frac{1}{2}$ of the solutions did not even consider torsion or end zone pressures, this is an area of the code that needs serious attention. Possible reasons for the lack of consideration by practicing engineers include:

- For Low Rise Buildings the code refers the designer to Figure 6-10. In our opinion, Figure 6-10 is much too complex and confusing to be consistently implemented by practicing engineers. There are 8 basic load cases shown on

the figure. In addition, the notes indicate that the 2 torsion load cases should be applied "to all eight basic load patterns", creating a total of 16 wind load cases that must be analyzed. Add this to the multiple load combinations that must be considered and the level of analysis is certainly not warranted for a simple low-rise building.

- For Rigid Buildings the code refers the designer to Figure 6-9. Figure 6-9 is also requires an extensive number of load cases that must then be combined with the load combinations, creating a relatively complex and time consuming analysis. The application of the torsional moment to flexible diaphragm structures (like the current trial design problem) is also not clear. In short, the level of analysis that must be performed for relatively small, simple buildings does not seem warranted.

3.3.3 Internal Pressures

Only ½ of the submitted solutions properly accounted for the internal pressure effect on the MWFRS. The code equations for the design wind pressure on the MWFRS are as follows:

$p = qGC_p - q_i(GC_{pi})$ Eq. 6-19, Rigid Buildings
$p = q_h[(GC_{pf}) - (GC_{pi})]$ Eq. 6-18, Low Rise Buildings

These wind pressure equations explicitly include the effects from both external and internal pressures. For typical buildings, the external pressures on the windward and leeward walls are additive for design of the MWFRS. However, the internal pressures on windward are leeward walls are typically opposite and do not impose a net pressure on the MWFRS.

With ½ of the engineers not understanding the code language for internal pressures, significant revisions of these code sections are clearly necessary to simplify and clarify the intent.

3.3.4 Rigid vs. Low Rise Buildings

The published solution developed by the committee classified the building as "Low Rise" per ASCE 7-05 definitions. Analysis of the submitted solutions indicates that 58% of the solutions classified the building as "Low-Rise" and followed the provisions outlined in section 6.5.12.2.2 of the code. The remaining 42% of the solutions classified the building as "Rigid Building of All Heights" and used the more general procedures outlined in section 6.5.12.2.1 of the code.

Since almost ½ of the solutions did not classify the building as Low Rise, it seems this is an area of the code that should be edited to help clarify the intent.

Sections 6.5.12.2.1 states that forces "shall" be determined per that section for Rigid Buildings of all Heights. Section 6.5.12.2.2 states that forces "shall" be determined per that section for Low Rise Buildings. The language seems contradictory for Low Rise Rigid Buildings.

3.3.5 Wind Force Distribution to Walls

The published solution developed by the committee used tributary area to determine the wind forces acting on the wall. There was some discussion among the committee on this topic since tributary area will not give 100% accurate results for non-symmetric loading (note that the loading is not symmetric for ASCE 7-05 since wind pressures are larger and the end zones of the building). However, based on the size of the building and the minimal level of error, it was felt that tributary area was appropriate.

Of the submitted solutions, 94% of the practicing engineers also used tributary area to determine the forces on the wall. One solution used free body diagrams of the diaphragm (a more accurate approach than tributary area) to determine the wall forces. One solution used a rigid diaphragm analysis.

3.3.6 Minimum 10 psf Wind Pressure

A number of the submitted solutions improperly applied the 10 psf wind pressure. Instead of projecting the 10 psf minimum to a vertical plane normal to the assumed wind direction, the engineers compared the calculated design wind pressure for both the windward and leeward walls to the 10 psf minimum. Perhaps this could be further clarified in the code.

3.4 Results from New Simplified Wind Provisions

3.4.1 General

Several areas of the new Simplified Wind Provisions were implemented properly with almost 100% consistency including the basic wind speed (V), the wind velocity pressure (q_s), the importance factor (I), the exposure category and the topographic factor (K_{zt}).

Overall, the new Simplified Wind Provisions significantly improved the accuracy, consistency and efficiency of the wind load calculations as compared to ASCE 7-05 provisions.

3.4.2 Design Wind Pressures

Based on analysis of the submitted solutions, the new Simplified Wind Provisions are very successful in improving the accuracy and consistency of engineers applying the code wind design provisions. In general, determination of the design wind pressures was very accurate and consistent. The most frequent error in determining the design wind pressures was in the K_z factor. The new Simplified Wind Provisions refer back to ASCE 7-05 for this factor.

3.4.3 Wind Force Distribution to Walls

See Section 3.3.5

3.4.4 Minimum 10 psf Wind Pressure

See Section 3.3.6

4.0 Recommendations

Based on the results of the trial design problem, we recommend the following:

- **Adoption of new Simplified Wind Provisions into ASCE 7.** The results of the trial design problem clearly demonstrate the superiority of these simplified wind provisions in accuracy, consistency and efficiency. If the goal of the code is to produce safe, efficient designs, these simplified provisions should be included in ASCE 7.

- **Elimination of the ASCE 7 torsion / end zone wind pressure requirements for design of the MWFRS for all buildings less than 100' in height.** Over ½ of the practicing engineers in the trial design solutions did not even attempt to consider the torsion / end zone pressure requirements for the trial design problem. For smaller buildings, the analysis complexity created by the numerous load cases (16 load cases on Figure 6-10) is not commensurate with the size and scale of the structures. For smaller buildings, a slight increase in the basic design wind pressure applied to the entire structure, to accommodate the increased forces from any potential torsional effects, would be much more effective and consistently applied by practicing engineers.

- **Dramatic reduction in the number of restrictions on the ASCE 7 Method 1 – Simplified Procedure.** The trial design problem, a simple 2 story house, did not meet the conditions required for the Method 1 – Simplified Procedure since the building did not have a "symmetrical cross-section in each direction" (Section 6.4.4.1.7). We strongly recommend that the building configuration restrictions imposed on the Method 1 – Simplified Procedure be dramatically reduced to allow most buildings under 100' tall to used the simplified procedure.

- **Clarify the code language in ASCE 7 to improve consistency in (a) application of internal pressure for MWFRS design, (b) determination of rigid vs. low rise buildings, and (c) the application of the 10 psf minimum pressure requirement.** The results of the trial design solutions clearly indicate that these sections of the code are not being properly understood and consistently applied by practicing engineers.