Discussion

Seismic Design Practice for Steel Buildings

Paper presented by EDWARD J. TEAL
(4th Quarter, 1975 issue)

Discussion by **SEAOC Seismology Committee**

The paper was also presented as part of several seminars on the west coast and has, therefore, had wide dissemination to the practicing engineers interested in seismic design. There are a number of precautions that the designer should be aware of when using the approach given in the paper.

When drift considerations, rather than strength, govern design, a procedure which uses a reasonable deformed shape to establish the deflections for use in Formula (1-3) is valid. The drift limits where the above condition would prevail are not the maximum story drift limits given in the Recommendations. There are also other considerations to be noted, as follows:

1. The maximum interstory drift will inevitably be greater than the average interstory drift. The straight line mode shape assumption, although reasonable for period calculations, is not necessarily valid for drift. Most structures, even those with a first mode shape that approximates a straight line, as assumed in the SEAOC Recommendations, will usually have some curvature (e.g., slightly concave, convex, or S-shaped). The maximum story drift (as limited in the Recommendations) may be as much as 50 percent, or more, greater than the average and, therefore, the use of the maximum permitted drift as the average drift could lead to unrealistically long periods.

2. Effects of elements, nonstructural and structural, that are not part of the primary lateral force resisting system may also have an influence on the period of the structure. There are differing opinions on how much of the stiffness properties of these elements should be considered. Total participation of these elements is probably valid for low intensity shaking of short duration, but for high intensity, long duration shaking something less than the total stiffness of these elements should be considered. For structural steel frame structures the effects on the period of such items as concrete fireproofing, concrete slabs, metal decking, steel frames not considered part of the main lateral force resisting system, precast panels, concrete block walls, and partitions should be considered. Although some of these elements may be of relatively low strength, they will tend to stiffen the structure and may induce larger amplitudes of response in the structure or parts of the structure. Because of these "non-participating" elements, the difficulties of establishing a single value that accurately represents the fundamental period of a structure makes it advisable to consider a range of values. The use of the stiffer configuration, representing the shortest period, would produce a conservative value of $C \times S$. The use of the more flexible configuration, representing the longest period, would be conservative for limiting drift. A less conservative approach would be to use an average value of period for both forces and displacements. It is not possible, because of variations between different buildings, to establish an exact factor relating the realistic period to the period determined on the basis of the bare structural steel frame, but some fraction of the latter period should be considered for use in design.

3. Starting with an estimated period longer than the actual period can result in an unconservative design when the final period of the designed structure is found to be shorter than the assumed period. Under this circumstance it would be necessary to increase the base shear. This increase of force will require larger elements and result in a stiffer structure with a still shorter period. This procedure will have to be repeated several times until the estimated period is not longer than the calculated period. If the design iteration procedure is stopped too soon, the resulting structure will not satisfy the seismic code criteria. The sample problem shown in Section 3 of *Seismic Design Practice for Steel Buildings* is an example where this occurs.

4. Wind criterion for drift is usually more restrictive than seismic. For example, while seismic drift is governed by $0.005H$, wind drift is frequently limited to $0.0025H$. Although seismic forces may be greater than wind forces, if drift governs the design it is possible that the wind criteria will be more restrictive than the seismic criteria.

A check of the sample problem illustrates the points listed above. The moment frame structure is assumed to have a uniform drift of $0.005H$, which leads to a calculated period of T = 2.8 sec. Based on beam and column sizes selected, the structure was analyzed by members of the Seismology Committee for its fundamental period and mode shape. Calculated fundamental periods ranged from 2.0 to 2.3 sec, depending on modeling assumptions. A recalculation of the CS coefficients using T = 2.0 sec gives a value of 0.057, which is 43 percent higher than the design value of 0.04. A check of member stresses for the new value of CS indicated that the recalculated stresses were close to the allowable limit. The calculated mode shape of the structure indicated that the maximum interstory drift (between the second and third stories) is almost 50 percent greater than the average lateral drift. A check of interstory drifts for the recalculated shears (taking into account the calculated stiffness) give a maximum value 10 to 20 percent greater than the $0.005H$ limit. Therefore, the structure should be slightly stiffened. This will result in a period shorter than calculated above. If structural and nonstructural elements other than the two exterior moment resistant frames were included, the period would be shortened further. As the period T shortens, both C and S increase. For example, if T = 1.5 sec, then C = 0.054, S = 1.42, and CS = 0.076. This is almost twice the base shear shown in the sample problem. (See Fig. 1.)

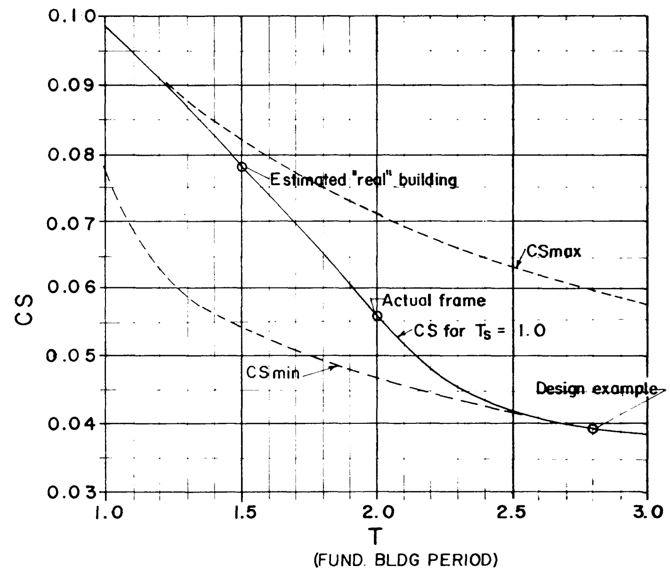

Figure 1

In addition to checking the seismic design, a check of drift due to wind forces should be made. Assuming the minimum UBC Wind-Pressure-Map area criterion of 20 psf (Table No. 23-F), the design wind force at the base will be about 120 kips in the east-west direction. By coincidence, this is one-half of the seismic base shear used for drift calculations in Table 3-1. Therefore, drift due to wind is approximately one-half the assumed seismic drift. If wind drift limits were one-half seismic drift limits and the seismic drift limits were satisfied, then the wind drift limits would be satisfied. However, as illustrated above, the maximum interstory drift is roughly 50 percent greater than the average lateral drift. Therefore, a wind interstory drift limit of $0.0025H$ would not be satisfied by the sample design.

One other comment may be worth mentioning. On pg. 118, a comparison between two methods of estimating the period is made. It shows that 2.6 sec is in good agreement with 2.8 sec, therefore, "2.8 seconds is a reasonably accurate period for this building in the east-west direction and there is no need to revise the calculations." However, no building elements had yet been sized, so this is not a check of the building period. It is a check between two short cut period approximation methods based on limited drift. The slight difference between the two values can be attributed to the use of F_t in Eq. (14-3) but not in the other method.

This discussion points out some of the considerations that should be given when basing seismic design on maximum permitted drift limits. For the type of structure shown, the formula $T = 0.1N$ may indeed be too conservative; however, the proposed procedure could result in an under-designed structure unless proper precautions are observed.

It is suggested that in using the period calculated by the drift criteria, a check be made after the design to assure that the calculated base shear is equal to or greater than the base shear used in the preliminary design phase. To minimize the number of iterations needed to achieve this, it may be prudent to make a reduction in the period determined on the assumption that the average story drift is equal to the maximun drift criterion. Alternatively, one may use a story drift lower than the maximum permitted story drift limit to calculate the period.

The SEAOC Seismology Committee has prepared this discussion in the hopes of avoiding misinterpretation of the intent of the Recommendations. A new Commentary prepared by the SEAOC Seismology Committee will soon be available and will comment further on period estimation as well on other features of the Recommendations.

Discussion by **Edward J. Teal**

The SEAOC Committee discussion concerns general dynamic response, and opinions about good practice, rather than fixed substitution for dynamic response given in the Code minimum study criteria for earthquake design. As is noted in the text of the paper, the design example illustrates the application of these Code fixed minimum static design criteria. For this purpose, only the shear distribution, drift limit, and period formulas given in the Code are applicable, and these were used to obtain trial sizes for a *single representative story* of the building. As noted in the text, the final design frame must, of course, be checked for Code compliance and good practice. However, a final design which adheres directly to Code minimums will produce a flexible building, one whose fundamental period at critical response is close to that calculated for the example, and as determined by the Code drift limit. Period calculations developed by the SEAOC Committee cannot apply to the final design, since only a *preliminary design for one story* was given in the example.

In the article, the author has avoided giving design recommendations and commenting on the adequacy of the Code provisions as written. As a matter of fact, he believes that a building designed strictly to the Code drift limits will be considerably too flexible, 2 to 4 times too flexible, depending on the level of earthquake damage risk desired. But that is his opinion, not Code interpretation. Reference 2 of the article provides a detailed discussion of drift control criteria, with examples of actual design practice. The recorded strong motion period of those buildings which were instrumented during the 1971 San Fernando earthquake closely confirmed calculated drifts and periods which were based on the bare frames.

The author believes that the SEAOC Committee discussion provides needed emphasis on the important subject of building drift control.