# Code feature section

# A NOTE ABOUT BASE SHEAR

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Californian and Japanese seismic analysis rules have in common with New Zealand seismic rules a relation between the base shear coefficient and the prime mode vibration period. The prime mode period may be assessed by a rational method or it may be approximated.

For the great majority of building designs approximation will be the method used, and it is here that the New Zealand rules differ from others.

New Zealand designers assess the period of a structure from consideration of its flexibility, defined (for this purpose) as the lateral deflection, D, in inches, of the topmost mass under inertia generated by lateral accelerations which vary linearly from zero at ground level to gravitational at the topmost mass. The familiar simple harmonic result $T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}$ which defines the fundamental vibration period of the system, becomes $T = 0.32\sqrt{D}$ when the dimensions are adjusted, and this is the approximation of the New Zealand Code. It is strictly accurate when the characteristic shape of the prime mode is a straight line.

Californian and Japanese designers have available to them empirical rules relating prime mode period to the dimensions of the building, principly to its height. In comparison with the New Zealand rules, they are crude; but we must remember that the object of the exercise is the design of a structure, that the prime mode period appears only in a parametric role and thus is only of passing interest. The Californian and Japanese rules are much easier to apply and may be adequate for design in cases where full dynamic treatment is not needed.

This difference between the New Zealand rules on the one hand and the Californian and Japanese on the other makes direct detail comparison impossible; but it is useful and instructive to reason the relation between limits of base shear coefficient and building height that apply to shear type (i.e. stiff girder open framed)

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+ Comment upon the introduction of this section is given on the Editor's page. Further contributions from readers will be welcome to make this feature a continuing success.

buildings in New Zealand, that is, to attempt to cast the rules in terms of the fundamental properties that are used to define seismic loading elsewhere in the world. Not only does this permit broad comparison but it produces useful information for designers. It is the second aspect that is the principal purpose of this note, though a brief comparison with Californian provisions, more revealing than the comparison given in the Commentary on the New Zealand Code, is made in passing.

A series of trilinear diagrams is used in our Code to define the dependence of base shear coefficient for the three seismic zones on prime mode period. All have a 'plateau' of coefficient maximum extending from T = 0 sec. to T = 0.44 sec. and a 'valley' of minimum coefficient for all T greater than 1.2 sec. The uniformly sloped connection between them can be described as

$$C = \alpha - \beta T , \qquad 0.44 \leq T \leq 1.2 \qquad \text{(a)}$$

in which $T = 0.32\sqrt{D}$ , $\alpha$ and $\beta$ are constants. (b)

Now it will be shown that D in equation (b) has a maximum value, controlled indirectly by the Code limit upon interstorey deflection, which is 0.0025 of the storey height ($\phi_m = \frac{1}{400}$) normally, or 0.005 of that height ($\phi_m = \frac{1}{200}$) when adequate clearance is allowed for relative movement of partitions and non-structural parts. Maximum flexibility is achieved when structural components are so proportioned and arranged that, under the action of earthquake simulating load, the slope is $_m$ everywhere. Then the deflection of the topmost mass, at height $h_n$, is $\phi_m h_n$ and that at the height of the centre of mass, $\bar{h}$, is $\phi_m \bar{h}$.

The design base shear is CW. The base shear corresponding to the presumed-elastic deflection D is $W\bar{h}/h_n$. Consequently the limit upon D is

$$\frac{D}{W\bar{h}/h_n} = \frac{h_n \phi_m}{CW} , \quad \text{or} \quad D = \frac{\bar{h}\phi_m}{C} \qquad \text{(c)}$$

Substitution in turn in (b) and (a) gives

$$\bar{h} = \frac{C(\alpha - C)^2}{(0.32\beta)^2 \phi_m} \qquad \text{(d)}$$

This equation defines $\bar{h}$ in terms of C and $\phi_m$ subject to limits at the plateau and valley values of C.

Zone A $\alpha$ and $\beta$, respectively 0.155 and 0.079, were used with $\phi_m = \frac{1}{200}$ to construct the curve BC, Fig. 1, and with $\phi_m = \frac{1}{400}$ to construct B'C'. The limits B, B' are the valley C, 0.06 for the zone, and CC' are the plateau C, 0.12 for the zone. Broken lines, plotted within the area ABCDE, are for $\phi$ valves of stiffer buildings.

The boundary A B C D E encloses all base shear coefficients that can satisfy the Code, for stiff girder framed buildings with separated partitions. A B' C' D E is for buildings with no special partition movement provisions.

The value of such a plot as Fig. 1 to designers in the early stages of design work is clear. It is feasible and practical to proportion, at least approximately, in such a way that a preselected Ø value results. This means that the first analysis for seismic load can be made confidently with an earthquake simulating load that varies insignificantly, if it varies at all from the one prescribed by the Code. But a greater value of the plot is what it reveals of the real effect of the provisions made in our Code.

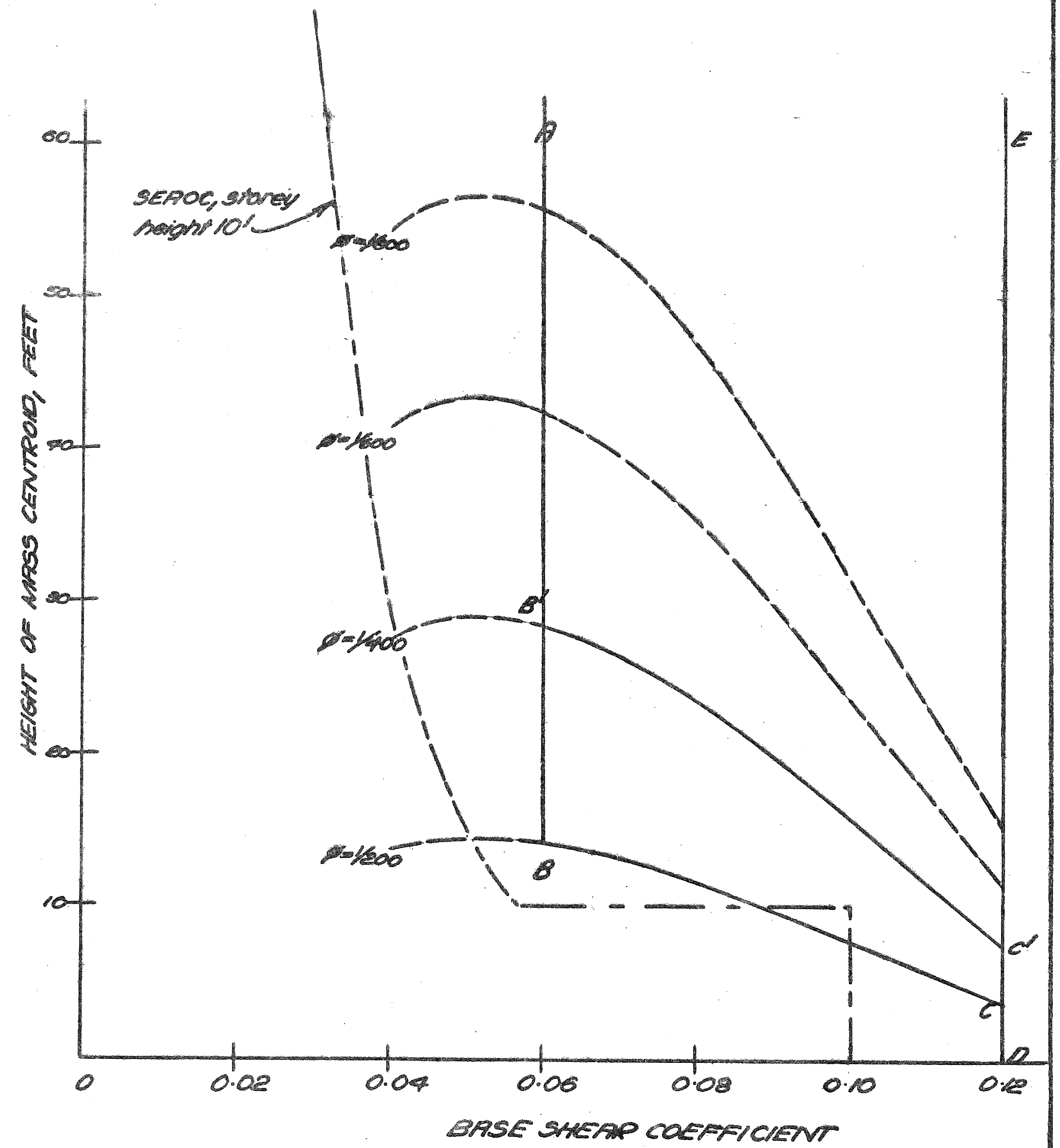
(i) It is possible and practical to design a structure with a base shear coefficient off the 'plateau' provided the height to the mass centroid exceeds 3'-10" (Zone A. The heights for Zones B and C are respectively 3'-4" and 2'-7"). This may surprise designers.

(ii) When the mass centroid height exceeds 14'-2" the seismic coefficient can be the minimum (valley value) of the Code.

(iii) If the mass centroid height is much greater than 28'-3" (point B') it may be futile to separate partitions. Separation of partitions, required only when the calculated drift angle exceeds $\frac{1}{400}$, is very expensive, and drift angles somewhat smaller than $\frac{1}{400}$ will be sufficient to ensure that the smallest earthquake simulating load is appropriate.

Plots corresponding to that of Fig. 1, but for Zones B and C and for Public Buildings in Zone A are shown in Fig. 2. The limit curves only are shown. Further Ø curves can be constructed easily with Equation (d) and appropriate values of and .

Finally, for comparison with the Californian rules, a curve of base shear coefficient, KC, against mass centroid height, constructed from SEAOC equations 13-1, 13-2, 13-3A and Table 23C, is shown on Fig. 1. In California the seismicity is on much the same scale as it is in New Zealand, so the comparison has some point. In the construction of the curve it has been assumed that the vertical distribution of mass is uniform and that the storey height is 10 ft. This single curve compares with the area A B C D E (or with A B' C' D E when partitions are not separated). It shows that Californian rules demand much less lateral strength throughout the range, except for flexible single or double storey buildings, than do New Zealand rules. The SEAOC rules do not recognise the zoning concept.




FRAMED BUILDINGS - ZONE A.

FIG 1.