

AD 097: Nominal base stiffness



It seems that it may be useful to explain the use of the simple approximate method for nominally pinned and nominally rigid bases given in Clause 5.1.2.4 of BS 5950: Part 1. It applies directly to four types of calculation at the ultimate limit state, all concerned with design of rigid-jointed frames.

As noted in AD 090, we consider that it is appropriate to use the method in a modified form for calculating the deflexions of rigid-jointed frames at the serviceability limit state. For rigid-jointed frames, 5.1.2.4 applies directly to:

- (a) effective lengths of columns
- (b) elastic frame analysis
- (c) elastic critical load factor calculations
- (d) classification as sway or non-sway.

It should be noted that although 5.1.2.4 allows the user to assume a pinned base, it does not allow the base to be taken as fully rigid. It seems that this point is sometimes overlooked, possibly due to combining this restriction with a simple approximate method in the same clause.

This simple approximate method is intended for use where the actual foundation stiffness is not known, which is frequently the case when the steel frame is being designed. If the foundations have already been designed, and the ground conditions are sufficiently known, it may be possible to obtain a reliable value for the foundation stiffness. Allowance should then also be made for the flexibility of the steel baseplate connecting the column to the base. It is likely that a significantly larger stiffness would result (depending on the ground conditions and the baseplate details), but in the majority of cases it is unlikely that an accurate value will be available for the steelwork design.

Effective lengths of columns

Allowing for the stiffness of the base when determining in-plane effective lengths of columns using Appendix E, it is important to realize that the base stiffness has to be treated as a beam stiffness, not a column stiffness. Here, the stiffness used for the steel members is I/L , the stiffness coefficient or nominal stiffness (as also used for continuous columns in simple construction, see 4.7.7).

At the base, K_c is the value of I/L for the column, K_L is zero and K_b is the base stiffness, taken as equal to K_c for a nominally rigid base, or $0.1K_c$ for a nominally pinned base. The joint restraint coefficient k_2 is then $K_c/(K_c + K_c) = 0.5$ for a nominally fixed base. If the base stiffness is treated as a column stiffness, then $k_2 = (K_c + K_c)/(K_c + K_c) = 1.0$ for a nominally fixed base, which is clearly incorrect because Figure 23 shows that $k_2 = 1.0$ represents a fully pinned base. It is unfortunate that Appendix E does not make this clear. Anyway, $k_2 = 0.5$ as calculated above should be adopted for a nominally fixed base or $K_c/(K_c + 0.1K_c) = 0.91$ for a nominally pinned base. If then k_1 is (say) 0.6 and the frame is braced against sidesway, figure 23 leads to effective length ratios L_E/L of 0.71 for the case

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of the nominally fixed base and 0.83 for the case of the nominally pinned base. For a frame not braced against sidesway, figure 24 leads to values of 1.55 and 2.3 respectively.

Whereas these values are typical, it must be realized they depend heavily on the actual value of k_1 , which must always be determined in practice.

Elastic frame analysis

For frame analysis, it is necessary to use the actual member stiffness of $4EI/L$ when calculating the spring stiffness of a base, for use in an analysis program that accepts spring supports. For a nominally pinned base, the base stiffness at the ultimate limit state can be allowed for by introducing 10% of $4EI/L$; similarly for a nominally rigid base, a spring stiffness of 100% of $4EI/L$ should be included.

However, some programs do not accept spring supports. In this case a dummy member with the necessary stiffness should be included. Any appropriate member will do, but it is usually better to make it horizontal as shown in Fig. 1. This is then consistent with the use of a beam to represent the foundation stiffness when determining the effective length (see above). At first sight, the simplest approach is to fix the far end as shown in Fig. 1(a), but the end moments may then confuse a checker verifying that the net reactions equal the applied load. Instead, the far end should be pinned, as shown in Fig. 1(b), and the length L_f should be reduced to $0.75L_c$, while retaining the same value of E , where L_c is the length of the column. The same value of I should be used for a nominally fixed base, or 10% of I for a nominally pinned base. The stiffness of the foundation is then $3EI/L_f$, which is equal to $3EI/(0.75L_c)$ or $4EI/L_c$ for a fixed base, or 10% of this for a nominally pinned base.

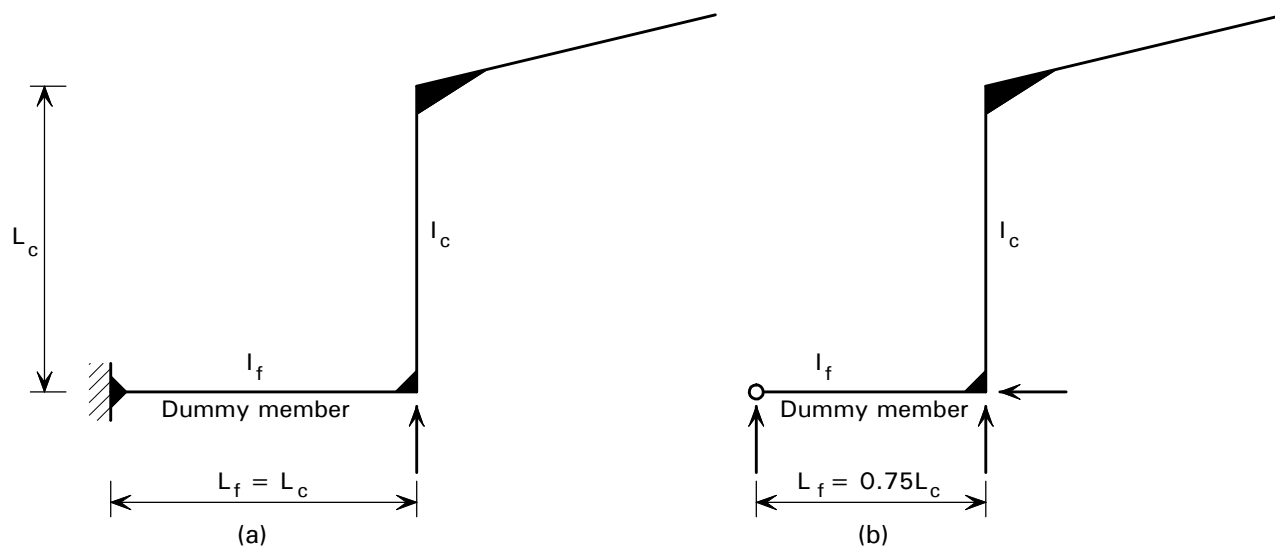


Fig. 1. Dummy members representing nominal base stiffness: (a) dummy member with fixed end, (b) dummy member with pinned end. E is constant, $I_f = I_c$ if nominally rigid, $I_f = 0.1I_c$ if nominally pinned

Elastic critical load factor calculations

When determining the horizontal deflexions of the frame due to horizontal forces equal to 0.5% of the factored vertical loads, in order to calculate the sway index needed to determine I_{cr} according to Appendix F, the frame analysed should have either spring supports or dummy members at the bases, as described above for elastic frame analysis.

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It should be noted that this also applies to the determination of I_{cr} (but not of course to the calculation of I_p) when using the method given in 5.7.3.3 for plastic design of a sway frame. The phrase “except as in 5.7.3.1” in 5.1.2.4(a) refers to the statement in the second paragraph of 5.7.3.1 that the in-plane effective lengths of the columns should be taken as $1.0L$. This precludes the use of Appendix E to derive smaller values (as explained above) in this particular case. It is not intended to over-ride the need to allow for foundation stiffness when determining I_{cr} . This clause would probably be clearer if this phrase were omitted.

Classification as sway or non-sway

Classification of multi-storey frames is covered in 5.1.3, and 5.5.3.2 contains a comparable provision for portal frames. Both require the calculation of horizontal deflections under horizontal forces equal to 0.5% of the factored vertical loads, as for elastic critical factor calculation in accordance with Appendix E. Again, the frame analysed should have either spring supports or dummy members at the bases, as for elastic frame analysis.

Concluding remarks

It should now be clear what 5.1.2.4 means about using the same base stiffness for all calculations; the calculations concerned are the four ultimate limit state calculations discussed above. It is also important to note that nominally rigid bases must be assigned a spring stiffness and not taken as fully rigid, in any relevant calculation at the ultimate limit state.

Note: See also AD090 and AD114