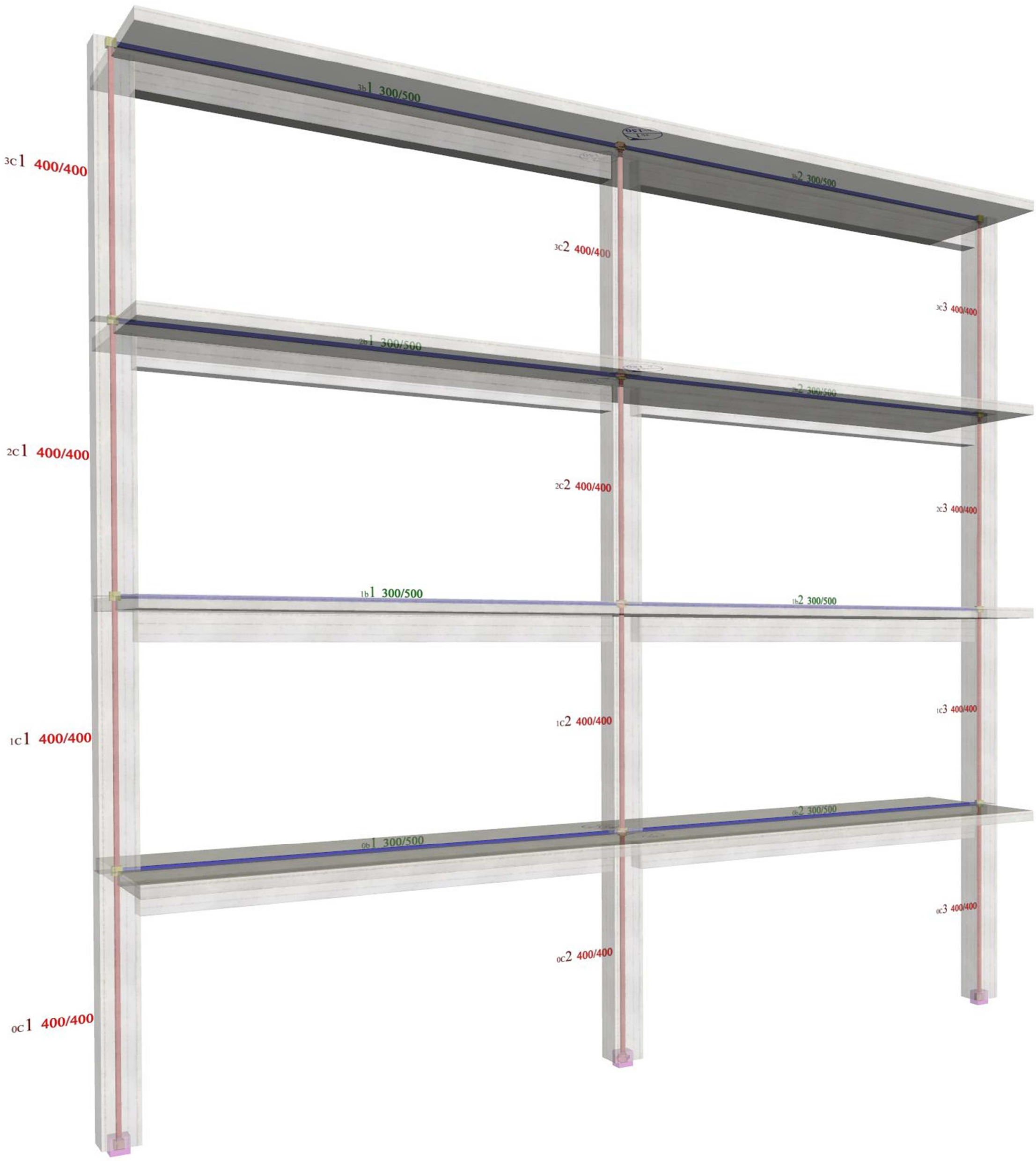


Figure 5.3.1-1: Four-storey frame type structure comprising three columns

In case of a basement, seismic forces developed at its roof level have a zero value. However, fixed end condition applies only to the base of the columns along the basement perimeter walls.

If the frame also comprises walls, as presented in the following paragraph, the stiffnesses and the moment distribution of the walls differ between them. This difference becomes more distinctive as the number of stories increase.

The total joint displacements and column stress resultants (shear forces and bending moments) are obtained from the frame analysis. Quantities K, k and a derive from the previous results. The apparent stiffness K_i of storey i derives from the expression $K_i=V_i/\delta_i$, while the apparent stiffness of column j of storey i from the expression $K_{i,j}=V_{i,j}/\delta_i$.

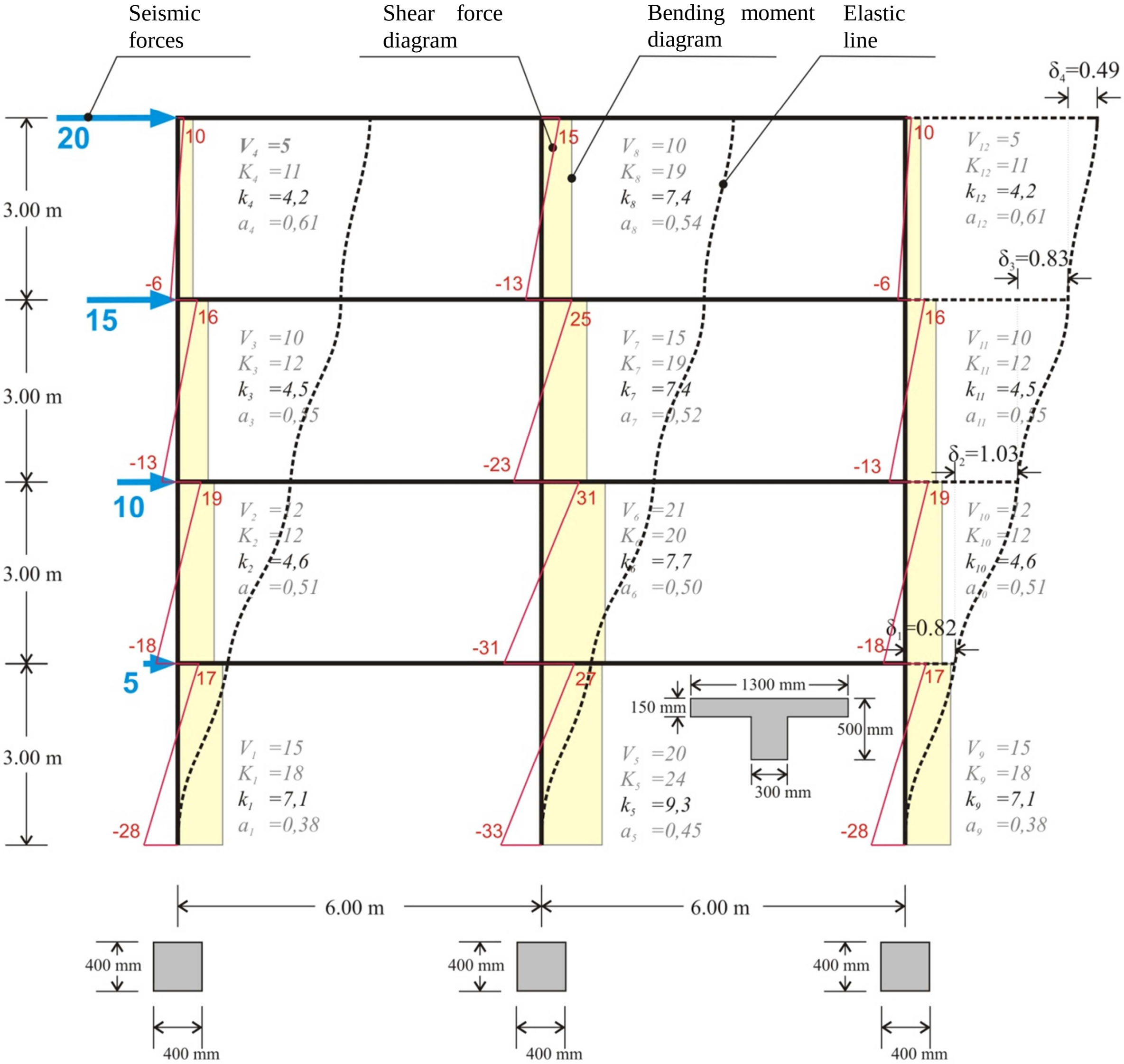


Figure 5.3.1-2: Column frame type structure with triangular distribution of seismic forces (practical graphical representation)

Example 5.3.1 (3rd storey):

Column stiffnesses: $K_{3,1}=9.6/0.823=12, K_{3,2}=15.8/0.823=19, K_{3,3}=9.6/0.823=12$.

Storey stiffness: $K_3=(20+15)/0.823=43$. *The same value is obtained if calculated as the summation of the column stiffnesses of the storey, i.e.* $K_3=K_{3,1}+K_{3,2}+K_{3,3}=43$.

If shear effect is taken into account (Shear effect=ON), the displacements are $\delta_1=0.85$, $\delta_2=1.05$, $\delta_3=0.84$, $\delta_4=0.50$ *mm, i.e. the difference is insignificant.*

If rigid bodies effect is taken into account (Rigid body=ON), the displacements are $\delta_1=0.80$, $\delta_2=0.97$, $\delta_3=0.77$, $\delta_4=0.45$ *mm, i.e. both decrease of displacements and increase of stiffnesses are small but measurable.*

Eight-storey frame type structure under triangular seismic loading

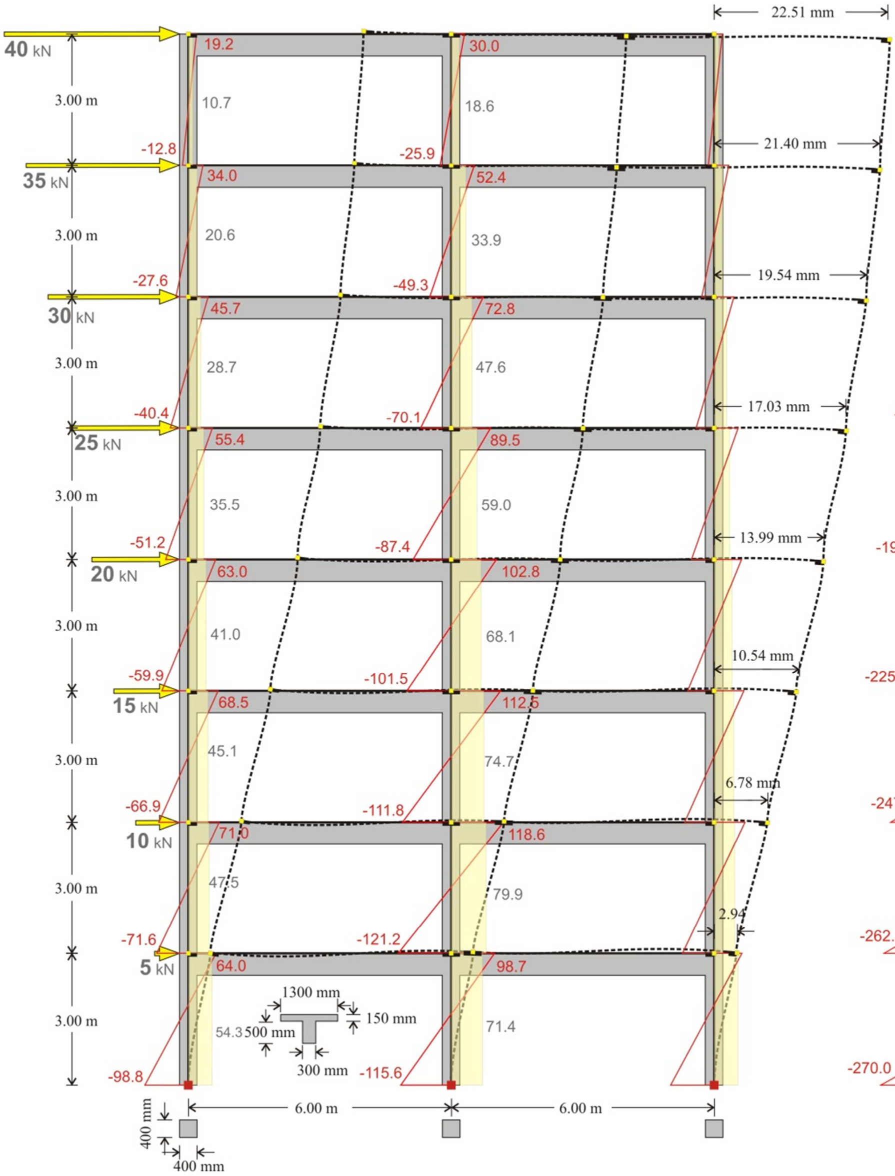


Figure 5.3.3-7: FRAME type structure comprising three column with cross-section 400/400

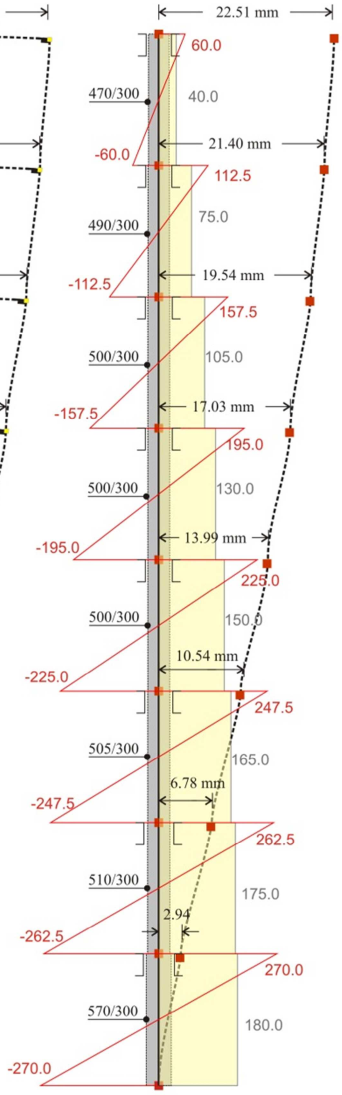


Figure 5.3.3-8: Equivalent structure of one fixed-ended column per storey

Notes:

- *In all types of structures, frame or dual, the sum of column shear forces of a storey is equal to the sum of the seismic forces of all the above storeys. Indicatively, for the first storey the sum is $54.3+71.4+54.3=180$, while for the last $10.7+18.6+10.7=40$. The middle column of the first storey carries the $71.4/180=40\%$ of the total shear force, while each of the end columns carries 30%. In the last storey the middle column carries the $18.6/40=46\%$, while each of the end columns carries 27%.*
- *In both frame and dual systems, for each column M_o-M_u=$V{\cdot}h$, where M_o is the moment at the top, M_u is the moment at the base, V is the shear force and h is the height of the column. For instance, for the middle column of the previous structure 98.7-$(-115.6)=71.4\times3.0$ $(214.3\approx214.2)$.*

Eight-storey dual type structure under triangular seismic loading

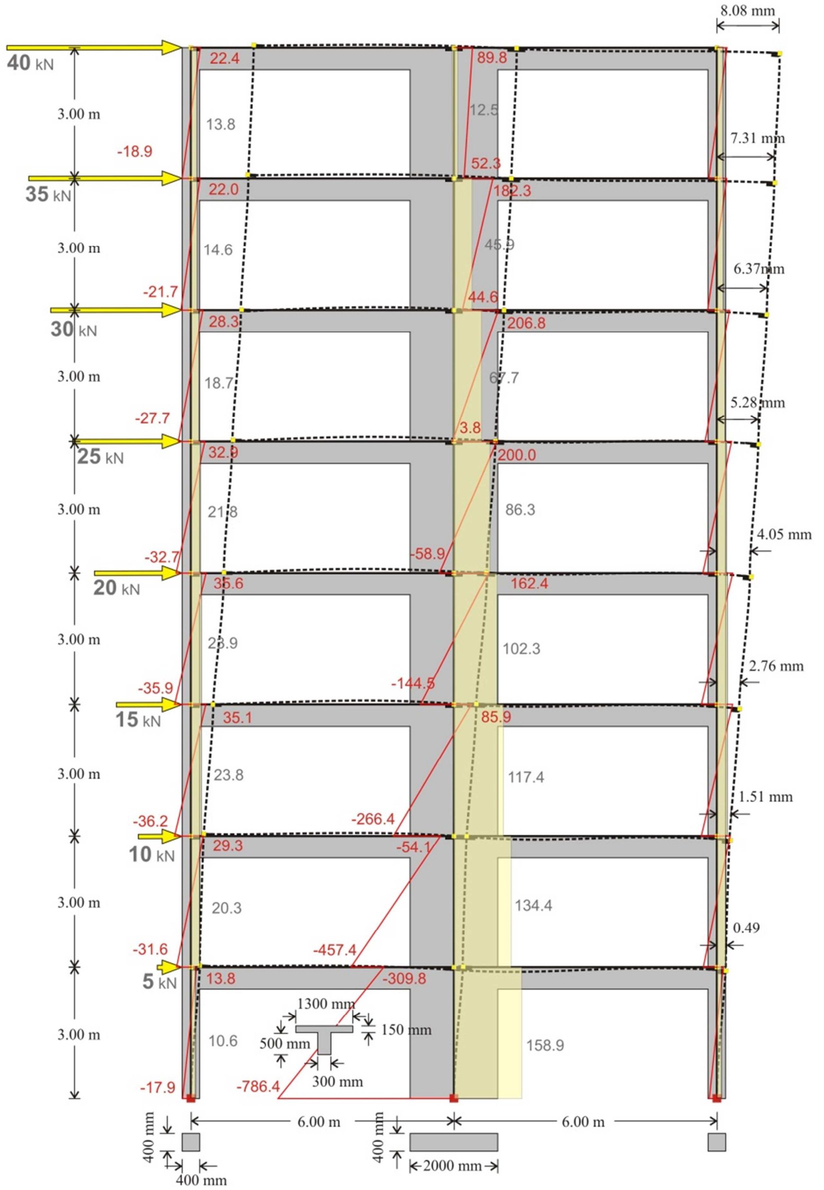


Figure 5.3.3-9: DUAL type structure comprising two columns and one wall with cross-sections 400/400 and 2000/300 respectively.

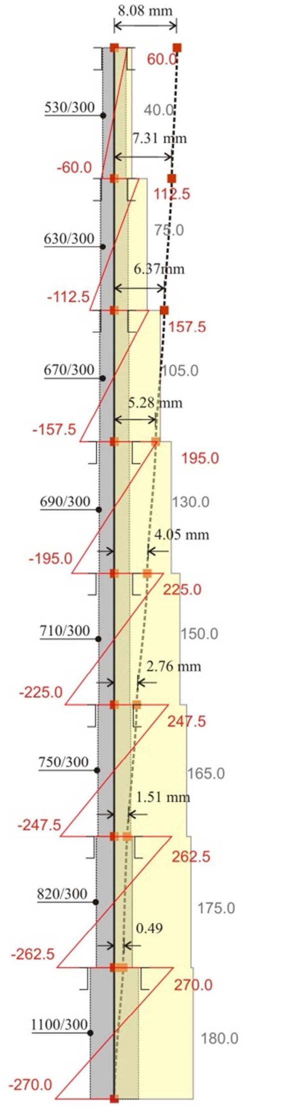


Figure 5.3.3-10: Equivalent structure of one fixed-ended column per storey

Notes:

- *In the first storey, the sum is* $10.6+158.9+10.6=180$*. The wall carries* $158.9/180=88\%$ *of the total shear force, while each column carries* 11%*. In the last storey, the sum is* $13.8+12.5+13.8=40$*. The wall carries* $12.5/40=32\%$ *of the total shear force, while each column* 34%*. It is concluded that the wall has a favourable effect on the first storey columns, in contrast to that corresponding to the last storey.*
- *The expression* M_o-$M_u=V{\cdot}h$*, applies for both columns and wall. Indicatively, for the first storey wall* $-309.9–(-786.4)=158.9\times3.0$ $(476.5\approx476.7)$*, while for that of the last storey* $89.8-52.3=12.5\times3.0$ $(37.5=37.5)$*.*
- *The maximum displacement of the dual type structure is equal to* 8.08 mm*, i.e. almost three times smaller than the one corresponding to the frame type structure (*22.51 mm*).*

Fifteen-storey frame type structure under triangular seismic loading

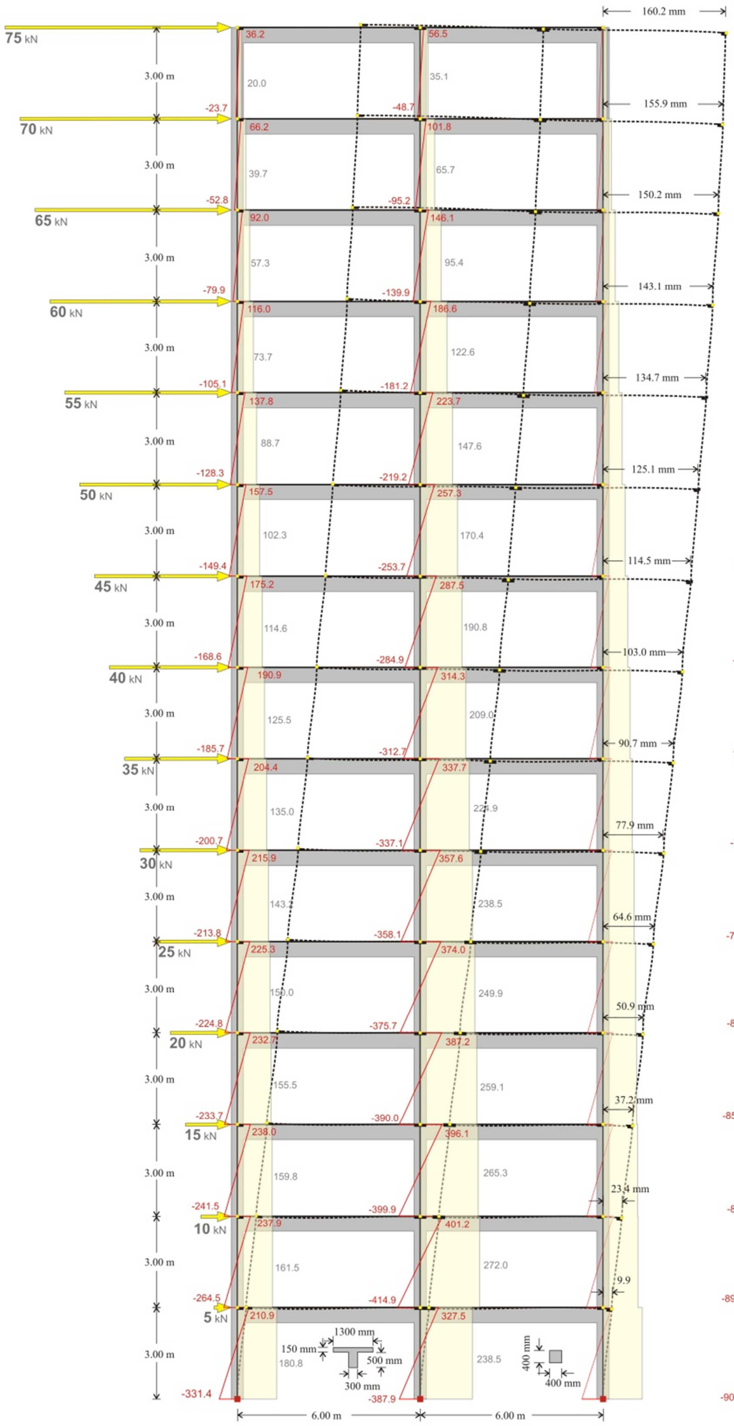


Figure 5.3.3-11: FRAME type structure comprising three columns with cross-section 400/400

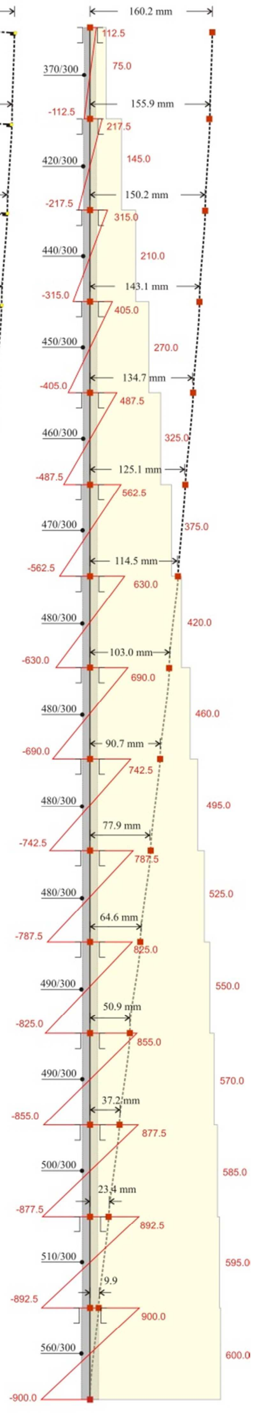
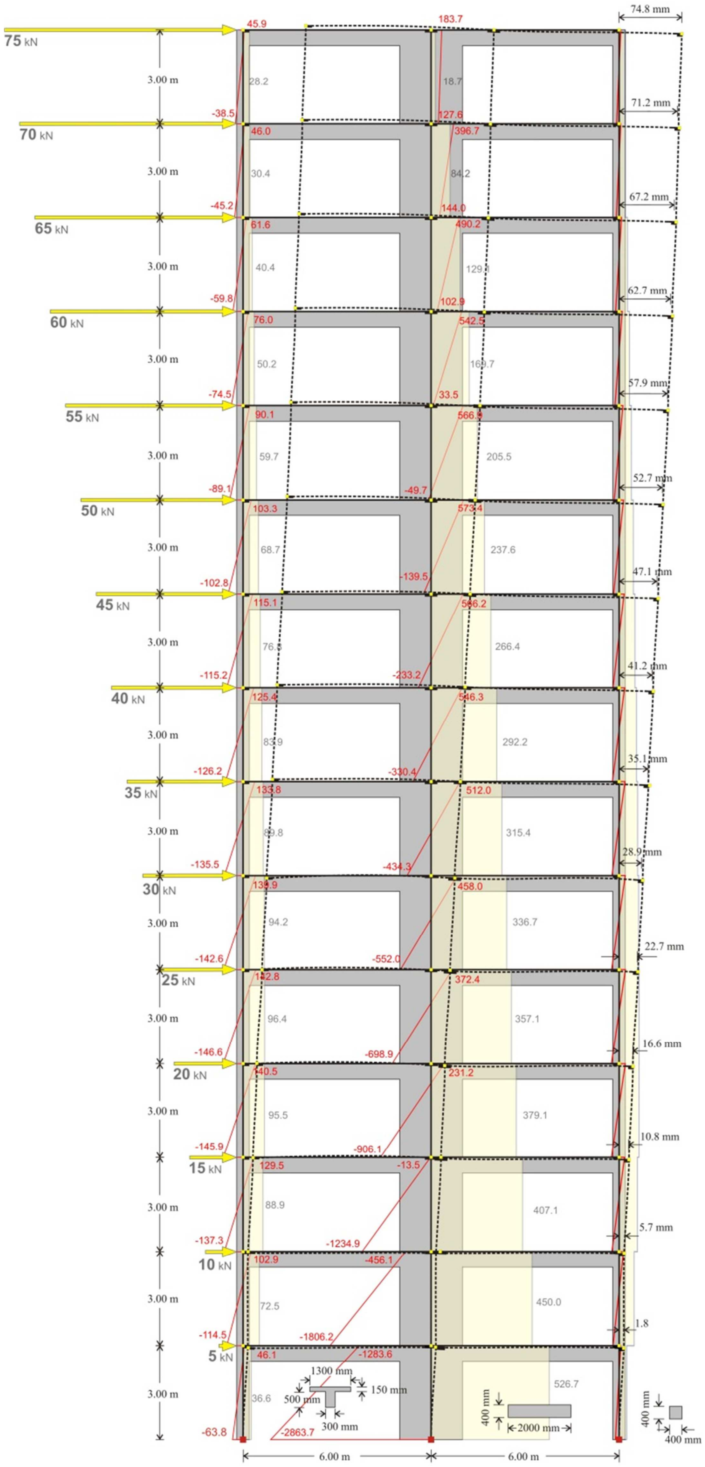


Figure 5.3.3-12: Equivalent structure of one fixed-ended column per storey

Note:

It should be emphasised that in all previous examples, the comparison of the two structural systems is important rather than the absolute quantities, which after all derive from specific values of the seismic forces. These values have been selected arbitrarily, yet satisfying the triangular distribution rule.

Fifteen-storey dual type structure under triangular seismic loading



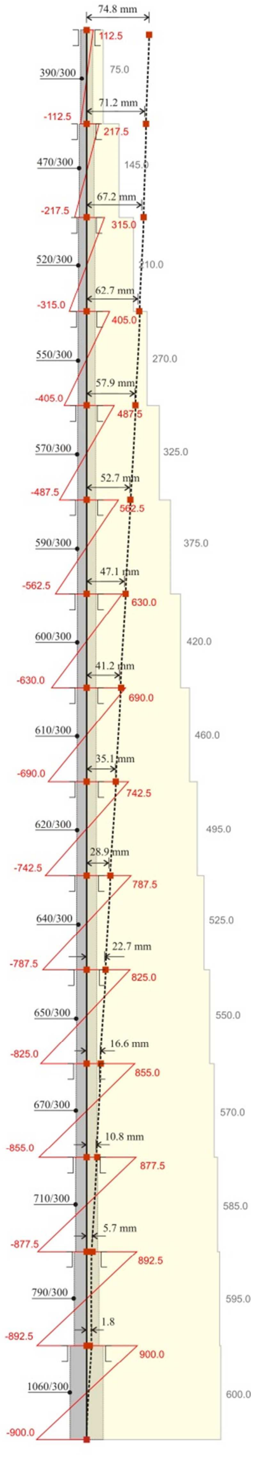


Figure 5.3.3-13: DUAL type structure comprising one wall with a cross section of 2000/300 and two columns with a cross section of 400/400 with cross-sections 400/400 and 2000/300 respectively

Figure 5.3.3-14: Equivalent structure of one fixed-ended column per storey

Note:

The maximum displacement of the frame type structure is equal to 160 mm, i.e. almost twice of that corresponding to the dual type structure (75 mm).