TN338_temperature_multi_story_070709

TEMPERATURE EFFECTS IN MULTISTORY BUILDINGS[1]

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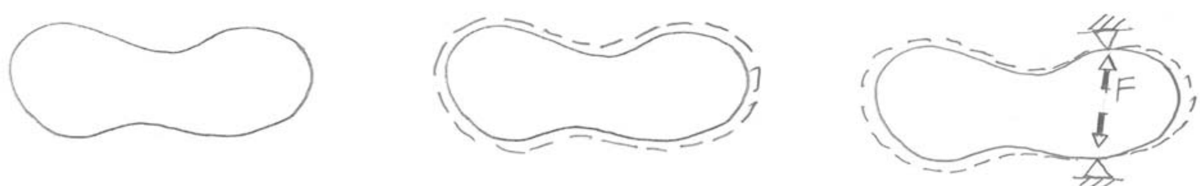
This narrative explains the response of a multistory building to a uniform rise or fall in ambient temperature.

Consider an object such as shown in Fig. 1-a. A uniform change in temperature through the entire object is accompanied by a uniform expansion, or contraction of all its parts. If the object is free, it will expand or shrink uniformly (Fig. 1-b). No internal forces will be generated in the object. However, if the free expansion or contraction of the object is restrained at connections external to it, such as supports (Fig. 1-c), it results in the generation of internal forces in it.



(a) Free floating object   (b) Floating object rise in temperature   (c) Restrained object rise in temperature

FIGURE 1 FREE FLOATING AND RESTRAINED OBJECTS WITH TEMPERATURE RISE

Figure 2 illustrates the elevation of a multi-story frame. If the connections of the frame to the foundation are such that they would not allow free displacement of the structure, restraining forces will be generated at the connection of the frame to the foundation. The connection shown in Figure 3-a will result in restraining forces in the frame, whereas those shown in Fig. 3-b do not result in internal forces from a uniform change in temperature, since the pin and roller support do not restrain the free moment of the frame.

In summary, uniform rise or fall in temperature results in forces at the constraints. For building frames, since the global constraints are limited to attachments at the foundations, the external forces generated are concentrated around connections of the frame at these locations. The forces rapidly diminish with number of upper levels from the foundation.

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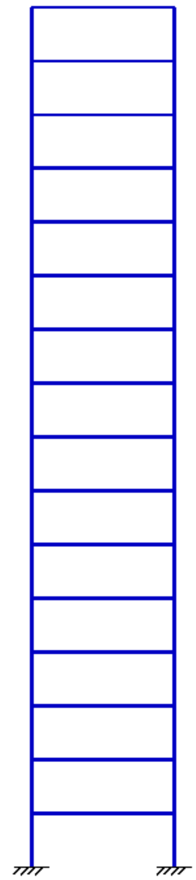


FIGURE 2 VIEW OF A MULTI-STORY FRAME

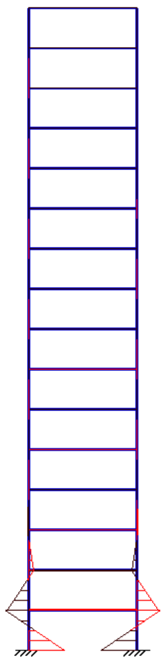
(a) Frame fixed at bottom
statically indeterminate

(b) Frame on roller supports
statically determinate

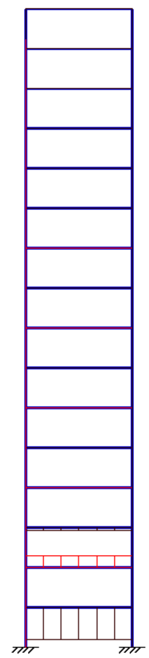
FIGURE 3 STATICALLY DETERMINATE AND INDETERMINATE CONNECTIONS

Figure 4 shows the distribution of moment and axial force in the multistory frame from a uniform rise or fall in temperature. Note that both actions drop rapidly at the second and third levels from the foundation. At the third level and beyond, the values are typically not of design-significance.

The distribution shown in Fig. 4 is based on the elastic response of the frame on the assumption of “no cracking.” In practical structures, there is always some degree of cracking, in particular in the columns and walls supporting the first elevated floor. Unlike cracks from applied loads, cracks due to temperature effects relieve the associated stresses. As a result, real concrete structures are rarely subjected to the stresses determined from elastic analysis of their frames.



(a) Moments



(b) Axial forces

FIGURE 4 ACTIONS IN MULTISTORY FRAME DUE TO UNIFORM CHANGE IN TEMPERATURE

For clarity the distribution of actions for the lower levels of the frame shown in Fig. 4 are reproduced in larger size in Fig. 5. Note that alternate levels are under tension or compression. Although not apparent from the current example, it is important to note that the rapid drop in actions with distance from the supports is not influenced by the shape and changes in the geometry of the superstructure. The conclusion equally applies to frames that are surrounded by podium levels at the lower levels.

(a) Moments (b) Axial forces

FIGURE 5 ACTIONS IN LOWER LEVELS OF A MULTI-STORY FRAME UNDER UNIFORM CHANGE IN TEMPEARTRE