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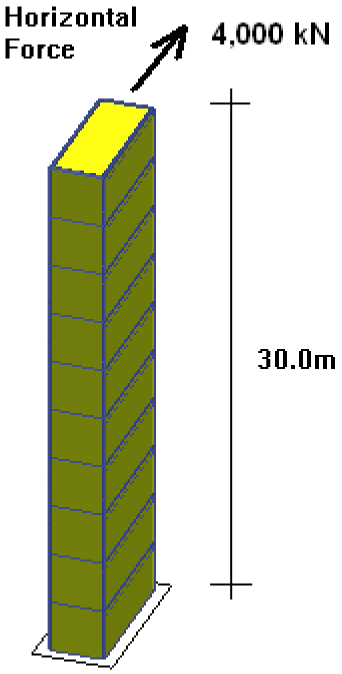
Notes on Lateral Load Resistance of Multi-Storey Buildings

When considering the lateral load on a multi-storey building it is a general practice to apply the entire lateral load on the centrally located lift-core, ignoring the rest of the building, as it is a more convenient and more conservative approach.

Let us examine an isolated lift-core of a multi-storey building, 30m in height (10 floors x 3m), experiencing a horizontal force in Y-Y direction of 4,000 kN. This force will generate a bending moment at the base of M = 120,000 kNm (4,000 x 30 = 120,000).



Lateral Load on Isolated Lift-Core

The lift-core is made of four walls measuring 3.0m by 8.0m long and are 200mm thick. The walls of the lift-core can be considered as an "I" section, where the two 8.0m walls make the "Web" of an "I" section, and the 3.0m walls are the "Flanges".

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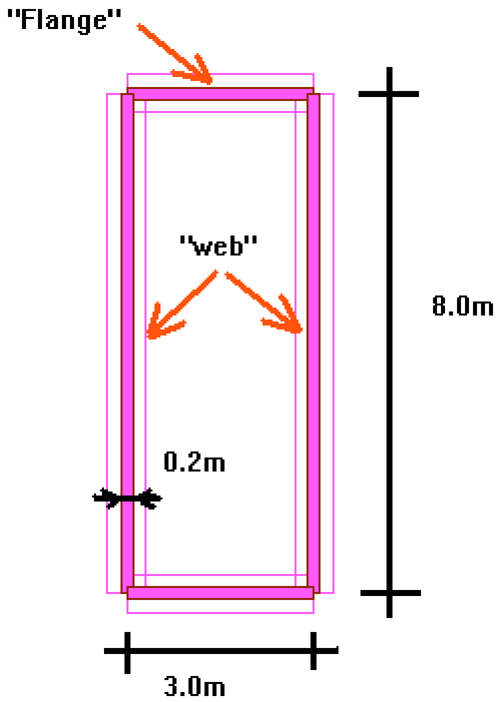

Lift-Core Cross-Section

The second moment of area of the "Web" is:

I web = 2 x (0.2 x 8^3)/12
I web = 17.07 m^4

The second moment of area of both "Flanges" is:

I flng = 2 x (3 x 0.2^3)/12 + 2 x 0.2 x 3 x 4^2
I flng = 19.2 m^4

Total moment of inertia (web + flanges) is:

I = 17.07 + 19.20
I = 36.27 m^4

So, for the ideal "I" section the "Web" will take 47% of the total moment and the "Flanges" will take 53%. For the ideal "I" section the "Web" will take a moment of 56,400 kNm, and the "Flanges" will take a moment of 63,600 kNm.

Ideal "I" section:

M web = 56,400 kNm
M flng = 63,600 kNm

R/C BUILDING software will produce similar values for the moment distribution between the "Web" and in the "Flanges", with slight increases of the moment taken by the "Web". (See figure below)

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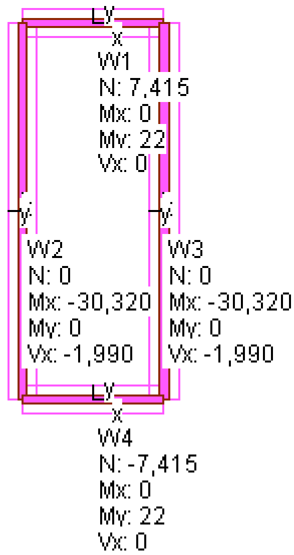

R/C BUILDING, Lift-Core Internal Forces

R/C BUILDING software:

M web = 30,320 x 2
M web = 60,640 kNm

M flng = 7,415 x 4 x 2 + 22 x 2
M flng = 59,364 kNm

Total Moment M = 120,000 kNm

The moment taken by the "Flanges" in R/C BUILDING software is slightly lower than the ideal "I" section since the "Web", the longer walls, can not fully engage the "Flanges" in bending, and therefore the lift core does not act exactly as an ideal "I" section. This is because the "Web", the longer wall, exhibits some shear deformation which can not fully connect the "Flanges" as in an ideal "I" section. However the difference between the distribution of the moment between the "Web" and the "Flanges" in the ideal "I" section and in R/C BUILDING software is very small.

Note that almost the entire Global Shear force is taken by the "Web", the long walls, as expected in an ideal "I" section (See figure above: 2 x Vx = 2 x 1,990 = 3,890 kN). That is 99.5% of the total Global Shear force.

R/C BUILDING software will treat the lift core as a partially connected "box" section, with a slightly different distribution of the internal forces between the "Flange" and the "Web", when comparing with an ideal "I" section. Generally this is a more conservative approach and it is more appropriate since a vertical crack along the wall ends can easily develop, which will dismantle the "box" section. Also if an ideal box section is assumed for the design some special measures must be introduced to ensure the integrity of the "box" at ultimate level of the lateral load.

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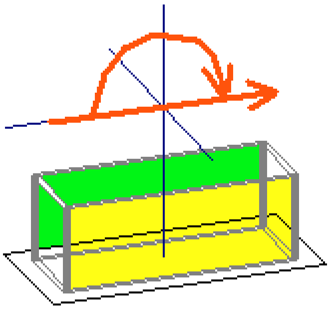
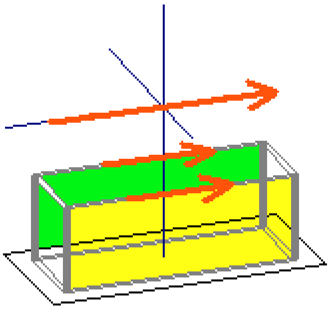
The lateral load on a multi-storey building can be transferred to the base into a Global Bending Moment and a Global Shear Force.



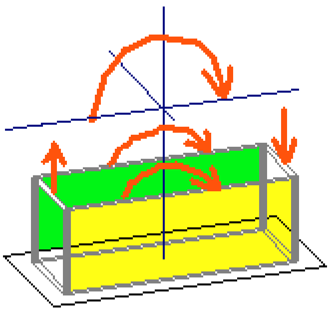
Later Load Transformed to the Base:
Global Moment and Global Shear

Normally the Global Shear Force is a major action and it is taken by several shear walls in the direction of the force. The lateral resistance of a building on a lateral load is provided by shear walls in the direction of the force. In our case they are the longer walls. (See figure below)



Global Shear Force Taken by Walls in the Same Direction

If the lift-core is considered by itself then the Global Bending Moment at the base is taken partially by the longer walls in bending, about 50%, and the rest is taken by the shorter wall in compression-tension action. (See figure below)



Global Moment Taken by Wall Moments and Axial Loads

However in a building structure the lift core is never isolated. Normally there are a number of columns around the lift-core. When we consider the Global Shear we can treat the lift-core to be

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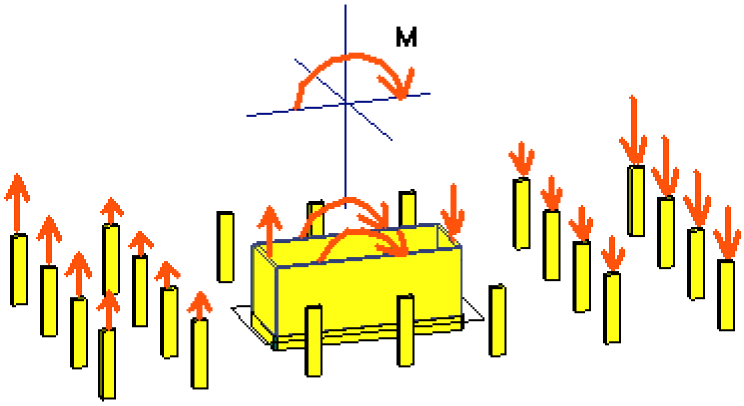
isolated from the structure, since the columns are not able to take significant portion of the Global Shear. This is a common practice when the frame action of the column and beams is ignored and the entire lateral shear force is applied on the isolated lift core. This is a more conservative approach. The only potential risk in this approach is that when there are some short columns, which will attract larger shear, they will be ignored when considering the lift core is isolated.

However if we apply the Global Moment onto an isolated lift-core we will get tension in the walls and in order to prevent overturning we have to anchor the walls to the ground. Generally this does not represent the structural behaviour of a building properly. The columns, even if they are considered to be pinned, will take a significant portion of the Global Moment in compression-tension and this will provide a much larger footing area and hence the overturning of the lift-core will be prevented. Therefore there will be no need to anchor of the lift-core. (See figure below)



Global Moment Taken By Lift-Core Walls and Columns

The columns with a greater distance from the lift-core, the centre of rotation, will take a larger axial load since the lever arm is larger. This effect on the columns can not be ignored, even if we assume pinned columns. The pinned columns' connections will not prevent the increase of the axial load caused by the Global Moment. This increase of the axial load, especially in the columns on the perimeter, may cause brittle behaviour of the columns. This is illustrated by the column M-N interaction diagram shown below.

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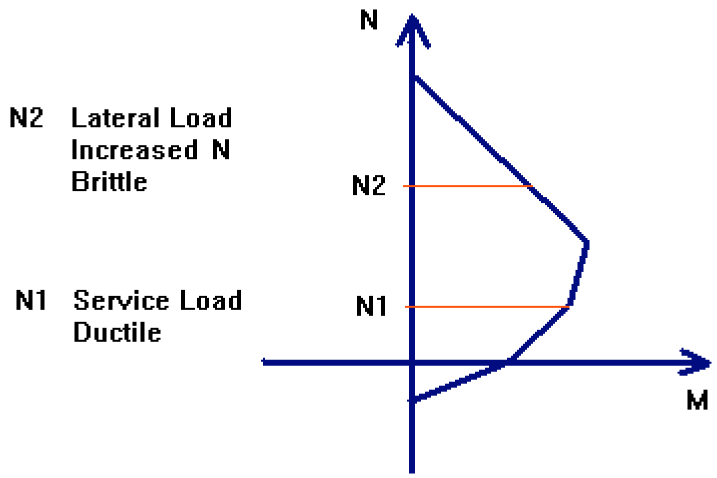

Increased Axial Load by Global Moment Causes Brittle Column Failure

Treating the lift core as isolated and ignoring the increase of the axial load in the columns reduces the safety and might compromise the stability of the entire building structure.

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