6 RETROFITTING ALTERNATIVES

6.1 SEPARATION

The easiest way to cut vibration problems on the building is to disconnect it from the adjacent ramp. In this case the building members keep the low Eigenfrequencies, but the excitation does no longer exist. This solution would make necessary a series of new columns for the ramp, especially on the upper part of the ramp.

A rough cost estimate was realised with these data:

- total length 6 m
- material steel S235 or 275
- profile HEB 240
- 4 € per kg, including material, joints and protection layers [15]

Steel works, excluding all other costs, would be about 2000 €.

During adaption works the ramp would have to be closed, while in the building the activities could go on without restrictions.

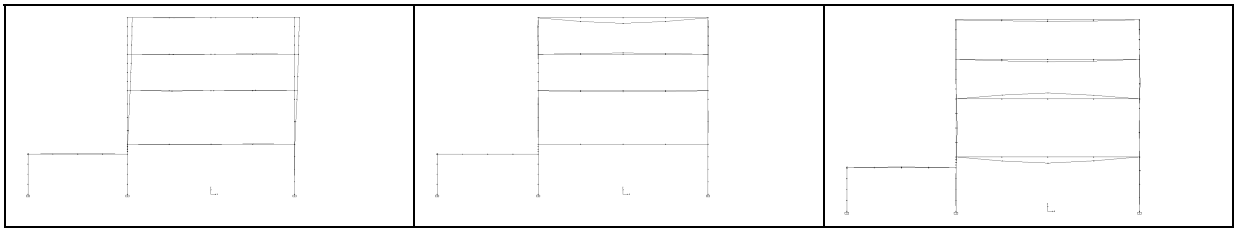
6.2 CHANGE LINK PROPERTIES

Another possible retrofitting would be to make the link ramp – frame a pinned joint. This would mean to separate the transversal ramp flanges from the frame column. As a result the ramp frame would loose stiffness, but on the other hand the excitation on the building would change from a moment to an axial force in the column.

In order to maintain the relation of solicitation and resistance, some other restraint (column) would be necessary, which leads to the anterior alternative. If a reduction of this relation is allowed, it would be about 1/4, Eigenfrequencies would still be near to excitation frequency. Thus, there is more to lose than to gain.

6.3 BRACES

Diaphragms or truss-diagonals in frame direction would reduce the susceptibility, augmenting the frames´ stiffness and with it the Eigenfrequencies. A short comparison is documented below:



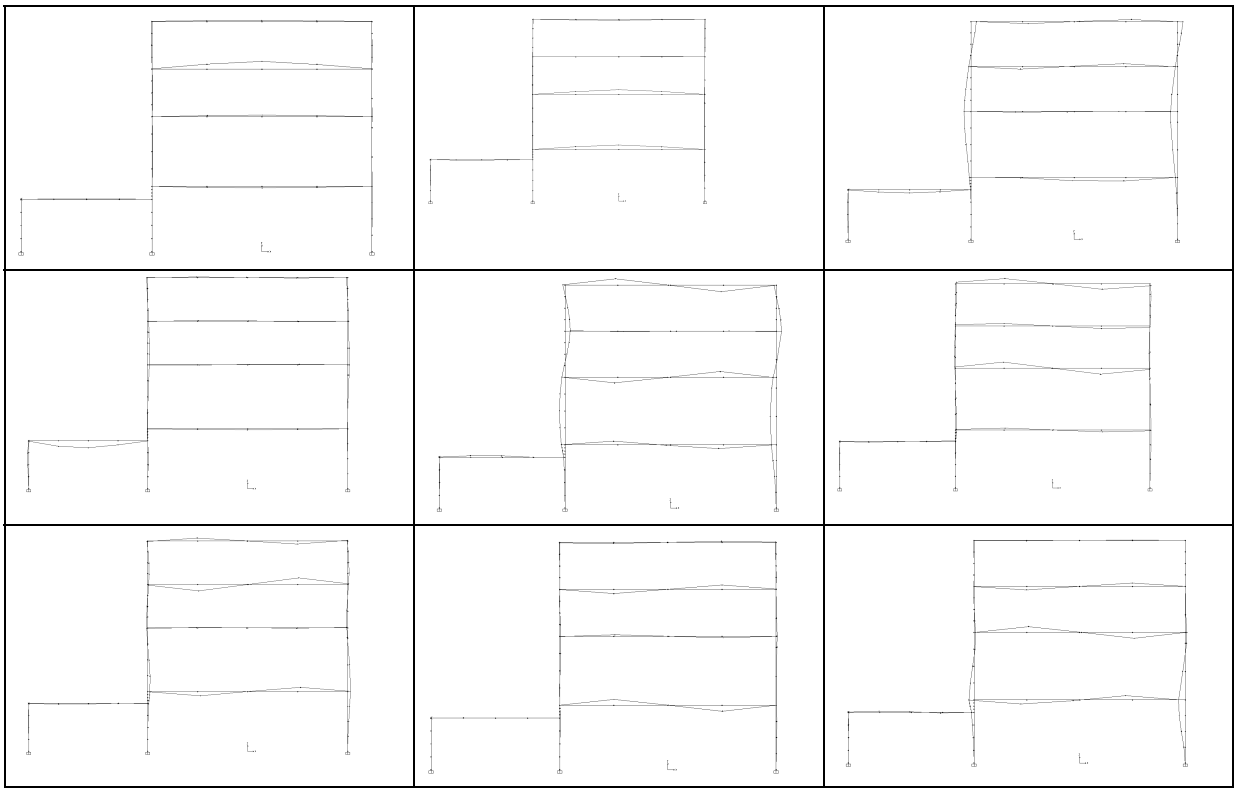


Figure 6–1: Modal shapes frame 1 with ramp

Of all calculated vibration modes, mode number 8 is the nearest to measured and calculated deformation and frequency range. As the ramp´s Eigenfrequency is about 11,1 Hz, this frame in the 8th mode enters in a stadium near to resonance vibration.

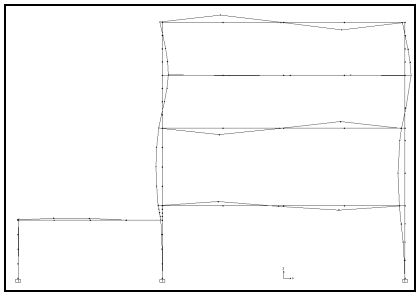


Figure 6–2: 8th mode, frequency 11,44 Hz

Now when stiffening this frame, modal shapes and frequencies change:

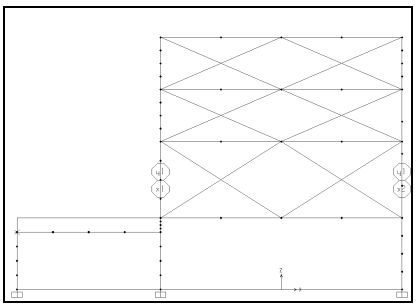


Figure 6–3: Retrofitting alternative 3 - braced frame 1

On the ground floor it is impossible to locate braces due to vehicle traffic in this zone. Now the first modal shapes take this deformation:

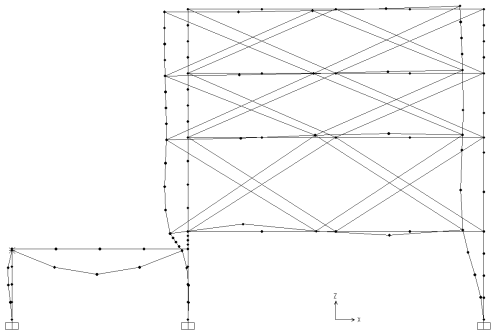


Figure 6–4: First mode braced frame 1 - 5,61 Hz

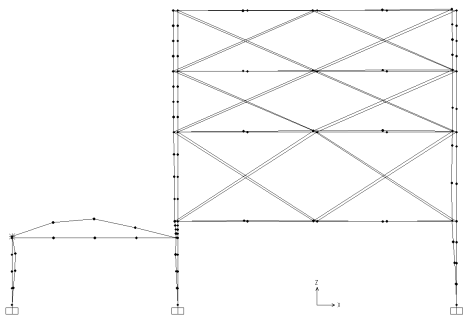


Figure 6–5: Second mode braced frame 1 - 7,63 Hz

Again this first mode could enter in resonance with the excitation frequency, 2 * 5,61 = 11,22 Hz ~ 11,1 Hz. The third mode is based on floor vibrations in gravity direction, see below:

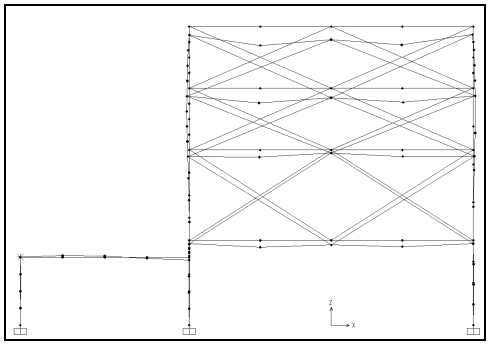


Figure 6–6: 3rd mode braced frame 1 - 11,81 Hz

From there on higher modes are less sensitive to excitation frequency. Thus, the use of braces changes modal shapes, increases stiffness and frequencies, but it would not exclude the existence of some Eigenfrequency near to the excitation frequency.

A rough cost estimate was realised with these data:

- total length 116 m
- material steel S235 or S275
- diameter 4 cm
- 4 € per kg, including material, joints and protection layers [15]

Steel works, excluding all other costs, would be about 4600 €.