Subject: Building Constructions - Skeleton Frame Structures	**Year:** 2019/2020	**Semester:** Fall	**Classroom /Dates:** Tuesdays at 8:15 – K352
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Workshop Exercise no. 1. - Structural requirements – Load bearing system selection

A summary for foreign students

Through a typical 4 story residential building we aim to show the system of requirements and the methods and options for structure selection.

<u>1. Effects on, and requirements for the building:</u>

Conditions that influence the structure are to be collected by the designer. The following list is a brief summary for the building in this workshop exercise.

<u>1.1</u> <u>External Conditions</u>: the effects of the external environment are to be examined based on the specific location of the building and its planned functions

- landscape: the building plot ha a great incline, we may have to use by-levels and graded foundations
- soil mechanics: the soil is clay based and sufficiently loadbearing 1m below the surface, the use of special foundations is not required
- hydrogeology: because of the inclined surface we must count with water seepage, aquiferic water and blocked water problems
- exposure to wind: parts of the building will be exposed to strong northern winds, this must be taken into consideration when designing the façade cladding, the flat roof and the various seals and joint on the façade
- exposure to the sun: the incline is oriented towards the northeast direction and there are 5-8 m high trees in the vicinity that provide sufficient shading on the lower and unfavourably oriented parts of the façade, but the rest must be provided with proper shading
- noise: the building is located next to a busy main road and a big traffic crossing. The external constructions will have to be properly sized according to the relevant standards (MSZ 15601-1,2). The daytime noise level can reach 70 dB, while the night-time level is around 55 dB. For typical residential buildings the allowed noise levels in the interior is L_{2A}=40 dB for day- and L_{2A}=40 dB for night-time. According to this the façade constructions will have to provide more than 40dB sound resistance. (The exact calculations are not part of this semester)

<u>1.2</u> <u>Requirements resulting from the function:</u>

- a cellular organization for the interior is required do to the nature of the building (apartments)
- the layout of the floorplan must be at least partially variable
- the necessary headroom is specified in the relevant building regulations, in Hungary it is minimum 2,50 m (optimally at least 2,70 m)
- number of levels: the building has 4 stories, this will basically define the applicable structural materials and systems
- handicapped access: determined according to the relevant building regulations. In Hungary residential buildings only have to have to be partially accessible (staircases, landings, corridors, main entrances, etc.). The layouts of the individual flats don't have to comply to such requirements (unless otherwise specified).
- fire protection: the building has to comply with the relevant fire protection regulations. In Hungary this is the "Országos Tűzvédelmi Szabályzat" or National Fire Safety Regulation. A few relevant excerpts from this regulations: the topmost floor level of the building is <13,65 m form the adjoin ground level, therefore it is classified as a *middle height building*. According to the total floor area of the building can be designed in one fire compartment. The shafts of the HVAC equipment and pipes must be properly sectioned between the different floors. The requirements of fire protection must be described on a risk analysis.
- building physics requirements:
  - building energy (energy consumption): the necessary values for the thermal insulation (heat transfer coefficients or U values) for the individual external envelope constructions, as well as the specific heat loss coefficient and overall energy usage of the building are all regulated in the law 7/2006 TNM (V.24.) in Hungary, in accordance to the EU's Energy Performance of Buildings Directive (EPBD). As an example from this regulation: U_{wall}≤0.24 [W/m2K], $U_{flatroof}$≤0.17 [W/m^{2}K] and U_{window}≤1.15 [W/m^{2}K].

- moisture transfer and hygienic requirements: the building must comply with the MSZ 04-140 standard. Damaging interstitial condensation and overly low internal surface temperatures are not allowed (e.g. danger of mould growth).
- acoustics: the Hungarian acoustics requirements are specified in the standards MSZ 15601-1,2. For an example: partition walls between flats - $R'_w+C \geq$ 51 or 54 dB, slabs between two flats - $R'_w+C \geq$ 51 or 54 dB, impact sound resistance individual flats (both vertically and horizontally) $L_{nw}' \leq 55$ or 52 dB. You can guess the necessary structures and required dimension based on the knowledge gained during BC-4. (The exact calculations are not part of this semester)

- HVAC equipment: in residential buildings both individual and common heating systems are possible. For higher levels an air-conditioning system may also be required.

1.3 Requirements resulting from statical issues:

- The stability, earthquake resistance, adequate rigidity… etc. of the building must always be provided. It is recommended to choose a bracing system that exerts the least amount of torque on the building (proper layout). The span of the slabs is most economical if kept under 6-7 m, with cantilever structures under 2-2.5 m… etc.

2. The selection of the structural system

After analysing the information collected above, we will demonstrate a careful selection from three logically available options below.

2.1 Monolithic reinforced concrete wall system:

The use of a masonry structures is not feasible due to the height of the building (maximum 2 stories, or 3 in extreme cases with at least partial reinforcement). But on the basis of the floorplan, it seems that a perpendicularly oriented RC walled system could be suitable. Rigidity will be given by parallel r.c. walls. It would be beneficiary to place the shear walls around the staircase. But the placement of the entrance hall at the ground floor may pose problems. The use of the elevator shaft is not possible, because of acoustical reasons it must be structurally separate from the rest of the construction. Possible locations are shown on the floorplan.
The easiest solution for the balconies is to continue the main walls to the exterior and using them to support the balcony slab. In this case a thermal bridge free solution is only possible by enveloping the whole external construction with thermal insulations (walls and balcony).
The flights of the staircase must be acoustically separated as well. They can be ‘hanged’ on the reinforced edges of the landing slabs. The choice of prefabrication for the staircases is a possibility.

The various aspects of this solution must be properly weighted.

Pros:
- clear and simple structure
- the acoustic requirements are easily met
- the solution of the by-levels is easy

Cons:
- a thermal bridge free construction is only possible by completely enveloping the balconies
- the floorplan is completely rigid, only some partition walls are movable

2.2 Monolithic Reinforced Concrete frame system:

2.2.1. Perpendicular beamed frame system with multiple support RC slabs

A prefabricated system would also be possible, but much more complicated due to the by-levels.
The floorplan suggests a perpendicularly oriented beam system with multiple support RC slabs as the preferred solution. Pillars are located at the most favourable position based on the floorplan. The perpendicular beams hung partially under the slab. The bracing of smaller monolithic RC skeleton frames (max 4 stories) can be solved without shear walls relying solely on the rigid connections between the pillars and the columns, but this requires beams in both directions. This is a more favourable solution regarding its earthquake resistance, but for simplicity’s sake we’ll use a simpler solution with RC shear walls placed in a similar fashion as in the last example.

The most important rules for the placement of shear walls are:
- every slab has to be individually supported

- every slab needs support in both (all) direction, this would require at least 2 shear walls per slab
- every slab has to be supported against torque as well, this requires at least 3 shear walls per slab with more than one intersection points on their axis at sufficiently large distances
- shear walls need to be as solid as possible
- the 'center if gravity' of the shear walls has to be as close to the centre of the slab as possible
- the support should be approximatively the same strength in all (both) directions

The balcony slabs can be supported by cantilever beams (solution A). The solution for the thermal bridge problem is once again to envelope the whole balcony slab in thermal insulation. The separating walls between the balconies can be masonry constructions. Since these walls are present another solution for the balconies is to push the pillars to the outer edge of the balcony (solution B). This eliminates the need for cantilever beams, but also deprives the wall between the balcony and the rooms behind of their direct support, therefore they could only be constructed with lightweight materials or be mostly glazed.
The stairs can be supported by longitudinal beams or solely by the reinforced edge of the landing slab. The same acoustic considerations apply to both the flights and the elevator shaft as in the last example.

Pros:
- clear and simple structural plan
- the floorplan is more 'free'
- the design of the façade is more 'free'
- more than one possible solution for the balconies

Cons:
- partition walls between neighbouring flats require extra care if they are not shear walls as well

2.2.2. Longitudinal beamed frame system with multiple support RC slabs

In this case, the horizontal beams are preferably integrated into the slabs (flat slab), as the hung beams would interfere with the interior. In this case the rigidity can only be assured through structural walls, these walls may be internal or external, although internal walls are more effective (closer to the centre of gravity). Pillars are located on the basis of the floorplan.
The balconies are most easily solved by cantilever slabs. This allows for the use of thermal brakes to solve the thermal bridge problem.
Most other considerations are the same as with the previous example.

Pros:
- the floorplan is more 'free'
- the design of the façade is more 'free'
- there are more possible solutions for the balconies

Cons:
- only a flat slab is favourable architecturally
- the partition walls between flats require extra attention
- the solution of the by-levels is more complicated

Only for general reference! This guide will not replace class attendance. Complete and comprehensive explanation – that will be required for passing both midterm and final examinations – is given only in lecture and practical classes.