Project | Assessment of Structures under Wind, Fire, and earthquake

The fact that earthquakes, as well as winds, exert lateral forces on buildings invites a comparison between the two. Suffice it to say that although earthquakes and winds produce dynamic forces with distinctly different characteristics, approximated by static loadings in the simplified approaches usually adopted in building design codes. It is generally recognized that the two forces need not be considered simultaneously; ascertaining the necessity of determining the governing lateral load provisions in any given design problem where both apply. A comparison of this sort, however, is valid only for one particular set of conditions and may fail to reveal the effects of certain important variables (e.g. geographic location) on the relative importance of earthquake and wind on a country wise basis.

The aim of this project is to introduce the participants to the field of earthquake and wind engineering, starting with the study of code requirements and their application to different structural systems. The structural performance for different levels of seismicity and wind-speed will be evaluated using modern software. During the project, various modelling techniques and analysis methods will be demonstrated. Different modeling assumptions (e.g., material parameters) and modifications of the structural layout (e.g., irregularity in elevation) should be considered while evaluating its influence on the dynamic behavior. After the project, the participants should be able to model and analyze structures using standard procedures.

In addition to the evaluation of the structural performance for wind and seismic loads, students are asked to elaborate on a comparative fire safety concept with regards to the occupant's evacuation time.

At the end, a small presentation should be prepared by the participants in order to discuss the results.

Task I - Building codes, parameters, and analysis methods

1.1. Overview of the code requirements for earthquake and wind resistant design as well as for fire resistance of the construction elements and products.

1.2. Comparison of the code requirements on the different national fire safety in buildings regulations.

1.3. Elaboration of the relevant code provisions and coefficients for the determination of earthquake and wind lateral forces.

1.4. Description of the basic equations for estimating the design lateral forces and overturning moments.

1.5. Discussion upon the code restrictions/limitations on the application of linear analysis methods.

Task II – Structural analysis and damage prognosis

2.1. Case Study

Appendix-A illustrates the plan and elevation of the multi-storey 3D reinforced concrete frame, as well as the typical reinforcement of columns and beams. The ground storey has a height of 3.5m while the upper stories has a height of 3m each. All beams have a double reinforced rectangular cross section of 50cm x 25cm.

For the regular and irregular variations of the RC frame (*Table 2.1 & 2.2*), load conditions and action parameters, equivalent horizontal forces and overturning moments have to be determined. Therefore, the structural system has to be modelled and analysed according to **sec. 2.2**.

Table 2.1: Schematic of the system variation.

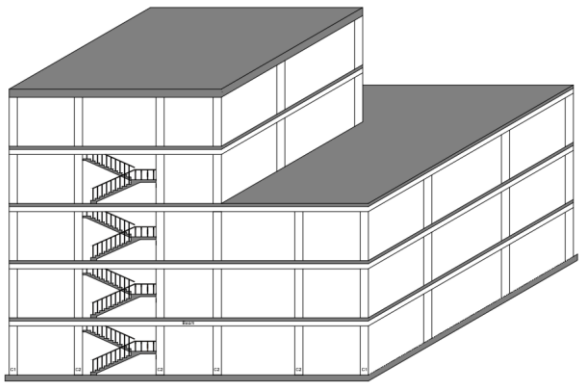
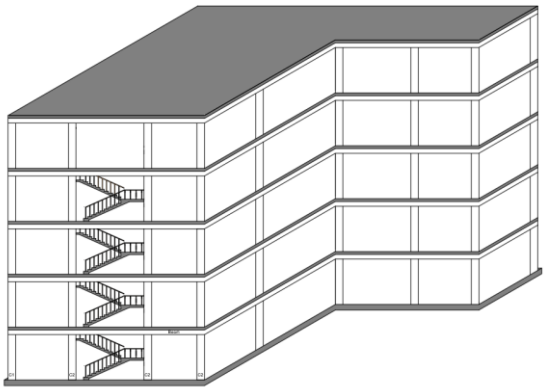
Irregular in Elevation (IE)	Irregular in Plan (IP)
	

Table 2.2: Applicable variations to the original RC frame structure.

No. [X]	**Variation I:** No. of stories	**No.** [Y]	**Variation II:** Type of systems	**No.** [Z]	**Variation III:** Column Reinforcement
1	20	1	Regular & IE	1	A
2	20	2	Regular & IP	2	B
3	25	3	Regular & IE	3	C
4	25	4	Regular & IP	4	D

Each group has at least to investigate two variants: one regular and one irregular frame system. A groups number (XYZ) will be assigned to each participating group to determine the type of variation: **x for number of stories, y for type of structural systems (configuration), and z for the reinforcement properties!**

EXAMPLE: Models to be investigated in case of register number **123**:

- **X = 1:** 20-story frame system
- **Y = 2:** Regular frame and frame with irregularity in plan
- **Z = 3:** Reinforcement properties (*see **Figure A2***).

2.1.1. Structural Layout

All structural details are given in Appendix A. The slab is 15cm thick. All stirrups have a diameter of 12mm.

2.1.2. Input Parameters

The general input data are provided in Appendix A. The material properties are given in Table 3.

2.1.3. Load cases

In addition to the self-weight, the following loads should be considered:

- Additional dead load slab: 5 kN/m
- Live load: 3 kN/m

Table 3: Material properties for concrete and steel.

Material property	Unit	Concrete	Steel
Young modulus [E]:	GPa	28.5	210
Poisson ratio	-	0.2	-
Strength (compression or yield/ultimate)	MPa	32.0	545.5/618.8
Weight [γ]	kN/m³	25.0	77
Mass density	t/m³	2.55	7.77

2.2. Analysis

2.2.1. Methods

The following analysis methods should be applied:

- Lateral Force Approach (LFA);
- Response Spectrum Analysis (RSA);
- Static Wind Forces.

whereas the Lateral Force Approach and Static Wind Forces should be applied in a simplified way (hand calculation = approach I) as well as assisted by analysis software (approach II). In addition, the results of the LFA and RSA have to be compared.

2.2.2. Approach I

- The masses of each floor have to be determined.
- Horizontal seismic forces and its distribution over the height have to be calculated according to the National Seismic Code for highest seismic zone and two subsoil conditions (soft and rock).
- Horizontal wind forces and its distribution over the height have to be calculated according to the National Building Code for highest wind zone and two exposure classes (open and urban terrain).

2.2.3. Approach II

- Transfer of the system into a 3D numerical model;
- Consideration of system variation;
- Evaluation of the dynamic behaviour;
- Comparison of the results from the LFA with the outcome of the simplified approach I and the response spectrum analysis;
- Comparison of the results from the earthquake and wind lateral force analysis.

Task III – Fire Safety Concept

- Evaluation of the code requirements for the building fire resistance;
- Analysis of the construction elements and products needed for assuring integrity to flames and hot gases and thermal insulation;
- Comparison of the results regarding safe evacuation of the building.

Task IV – Deliverables

The participants are requested to prepare **<u>One</u> short scientific report** of the results regarding the carried out studies. The report should include:

- Comparative study of the national code requirements (consideration of Eurocode national annexes as well as further national regulations) from the partner countries for wind, fire and earthquake;
- Modell description;
- Comparison of the earthquake and wind results. Discussion upon the dominant loading type;
- Fire safety concept with regards to the occupant’s evacuation time.

APPENDIX A

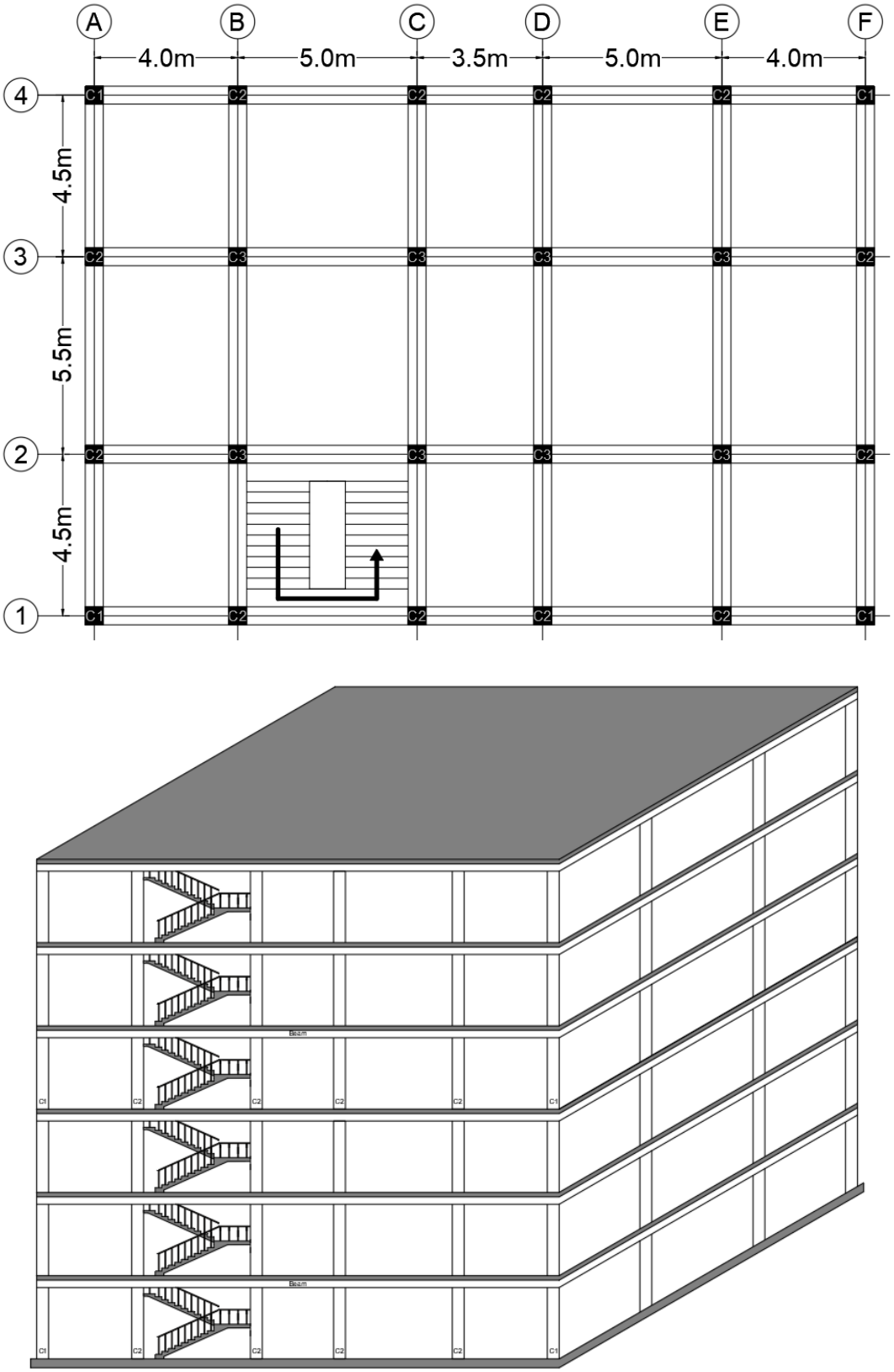


Figure A1: System description of the exemplary multi-story RC frame.

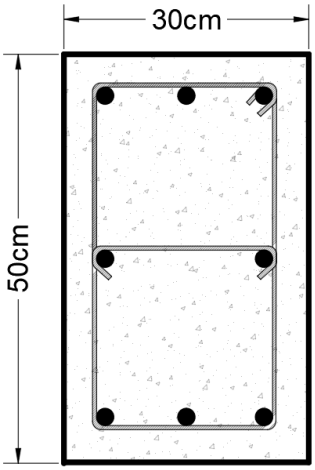
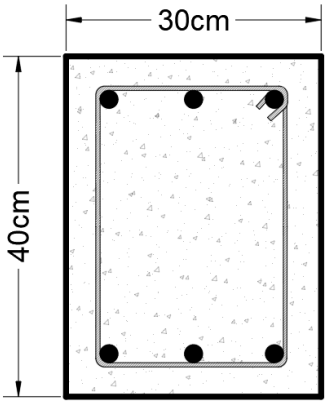
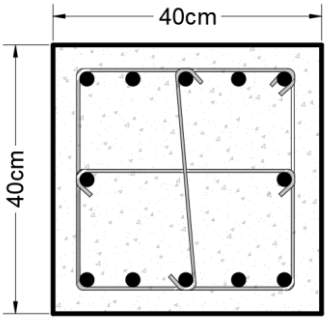
Var.	Column 1	Column 2	Column 3
			
A	8ϕ16	6 ϕ16	12 ϕ16
B	8 ϕ14	6 ϕ14	12 ϕ14
C	8 ϕ12	6 ϕ12	12 ϕ12
D	8 ϕ10	6 ϕ10	12 ϕ10

Figure A2: Variation in column cross section

* Continuous longitudinal reinforcement over the height. Stirrups: ϕ12@15cm c/c

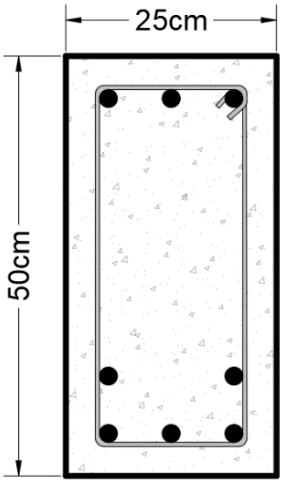


Figure A3: Beam cross section with 8 ϕ14 reinforcement continous over the length. Stirrups: ϕ12@10cm c/c