

1. The frame of the building

1.1. General information

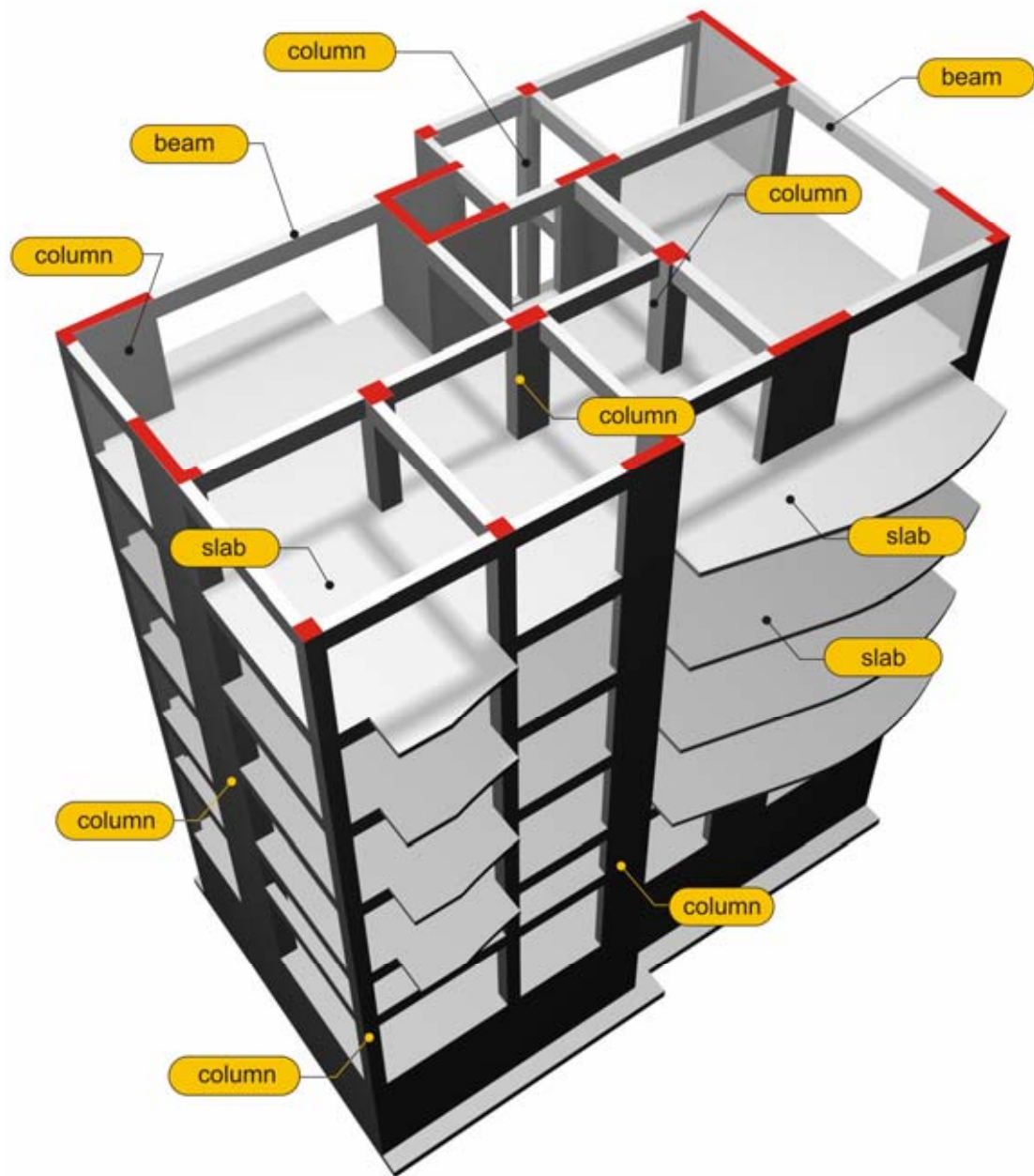
Every building consists of a load bearing frame, usually created by reinforced concrete, or by steel, or by the combination of both.



In this book we will examine the buildings' frames made out of reinforced concrete in areas with usual earthquake activity. Although the load bearing frame is not visible after the completion of the construction phase, it is always present, supporting the structure

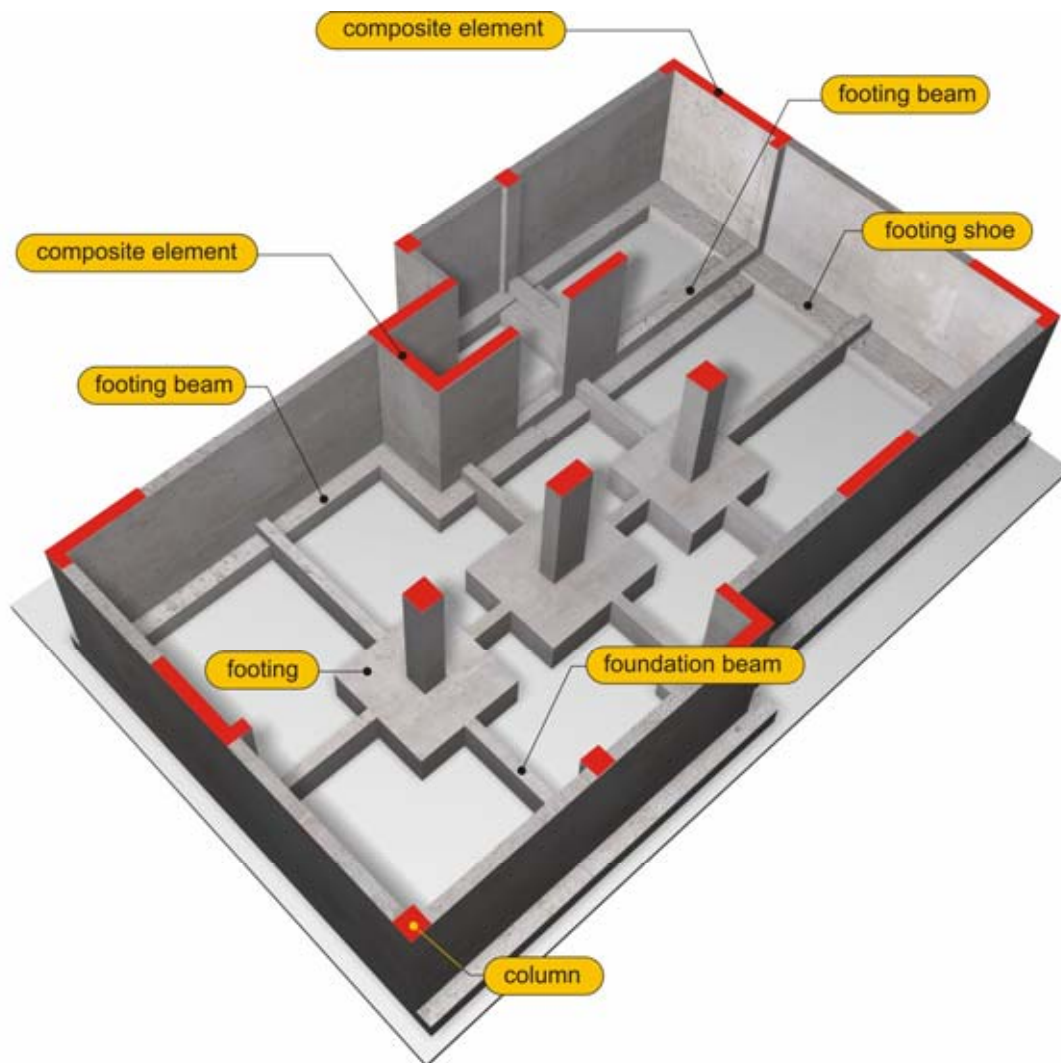
The load bearing frame consists of horizontal and vertical load bearing structural elements as well as foundation elements.

The following picture presents the load bearing frame of a building in photorealistic view (the slabs of the last floor have been excluded in order to allow for a more descriptive presentation).



*The slabs and beams are the horizontal load bearing structural elements
The columns are the vertical load bearing structural elements
The antiseismic bearing frame consists of columns and beams.*

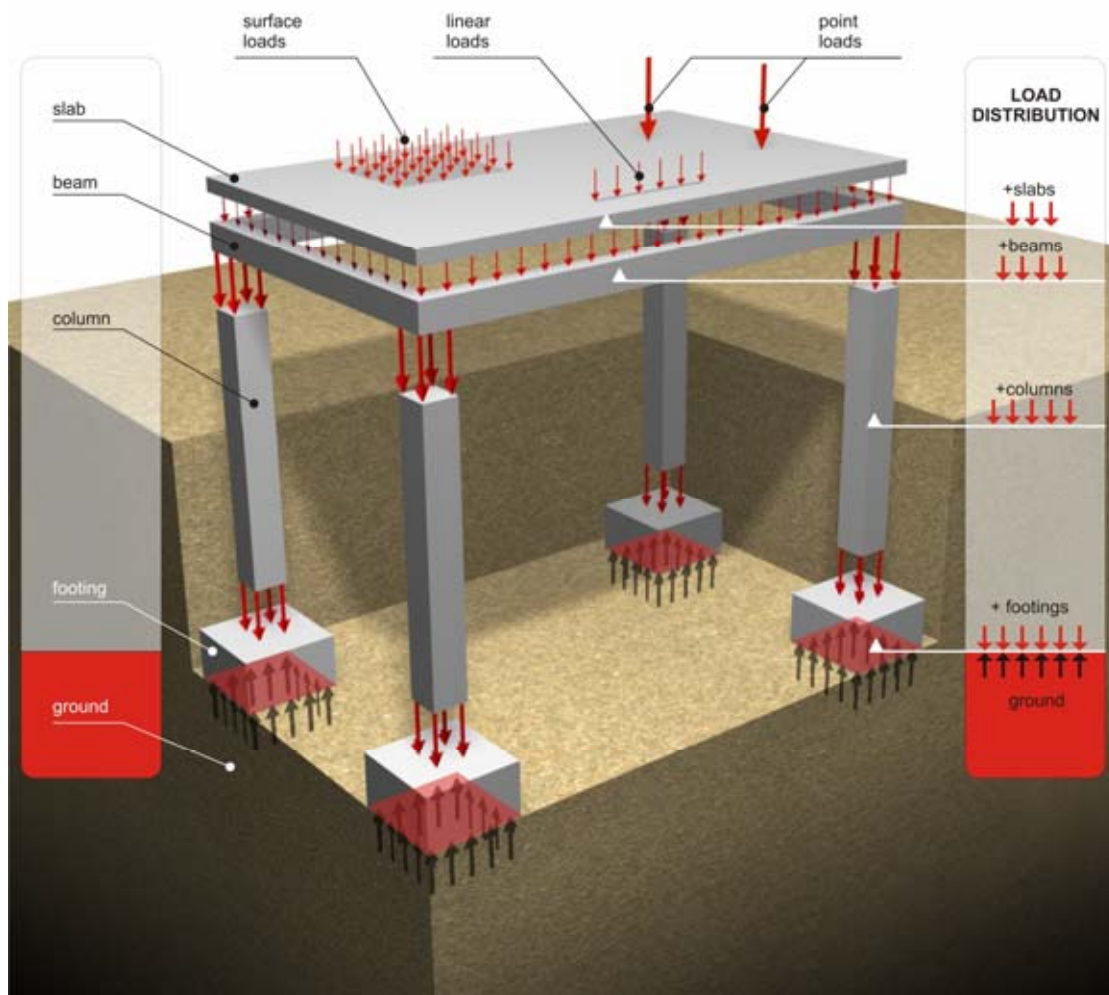
The following picture presents the foundation of the building in photorealistic view.



The foundation elements are the footings, the foundation beams and the footings beams. Additional elements may be, the foundation slabs and the piles.

The frame of a building should always have the necessary capacity in order to safely bear all gravitational loads during the life span of the building.

The bearing mechanism of the frame is based upon the theory of gradual stressing. The gravitational loads are initially imposed on the slabs which then transfer it to the beams. The beams transfer the loads to the columns and finally the columns transfer it to the footings. All loads are then transferred to the ground through the foundation elements



The gradual distribution of loads starting from the slabs and resulting to the ground.

The slabs receive the loads of the floors for every storey. These loads can be dead loads (e.g. floor covering from marble) and live loads (e.g. the weight of people)

The beams receive the loads transferred by slabs as well as the loads imposed by walls supported on beams.

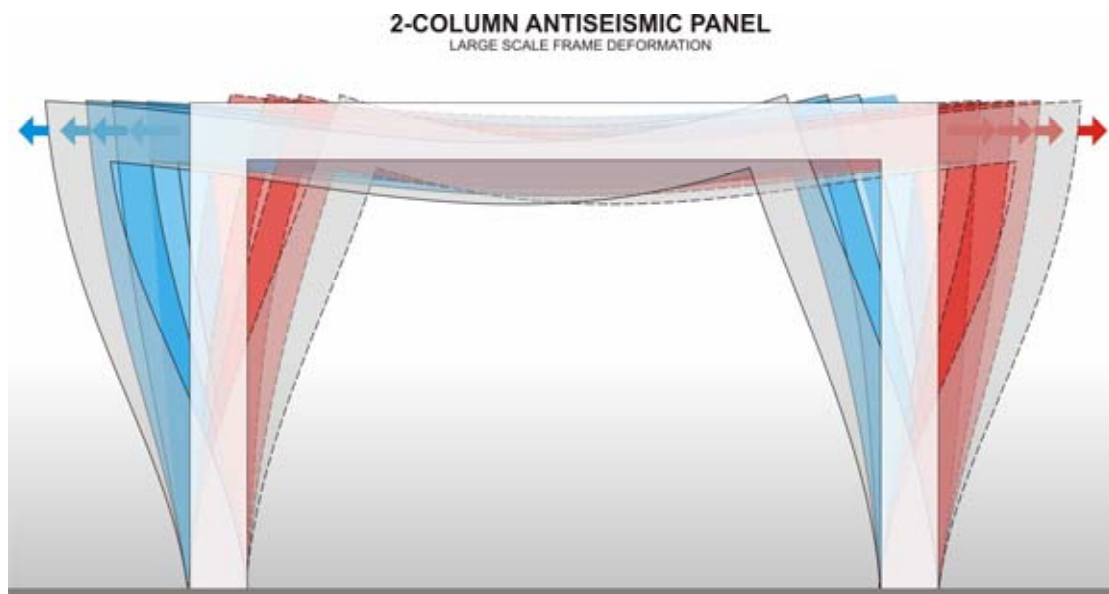
The columns receive all loads transferred by beams and then distributed it to the footings.

The footings receive the loads transferred by columns and then distribute it to the ground.

The foundation beams are constructed in order to ensure that all footings are maintained in their original positions in case of excessive stress conditions (e.g. in case of an earthquake or a ground settlement)

In the following chapters, we will identify several types of every structural element except the ones already explained. However the structural behavior of all types is identical.

In countries with frequent earthquake activity, like Greece, the bearing frame of the building is also designed to cope with intense stresses developed in rare, but critical cases (during an earthquake), during the life span of the building.



An earthquake creates deformations and stresses in the building, towards all directions. The frame of a building is designed to cope with these stresses.

The slabs are structural elements that do not receive any of the stresses imposed during an earthquake. However their existence is vital (they ensure the cooperation of all structural elements by connecting them) for the proper distribution of seismic forces during the earthquake.

The antiseismic importance is not the same for the various structural elements of the frame. For example, during an earthquake, the bearing capacity of a column is much more important than the bearing capacity of a beam. The failure of a column may result in the failure of all adjacent structural elements like beams and slabs. These elements might then create a chain reaction leading to several columns failing, which may finally result to extensive damages in the frame or may even lead to the collapse of the building. On the contrary, the failure of a beam usually results in local minor damages which, in case of an intense earthquake, may benefit the overall stability of the building. This is the reason that columns in countries with frequent earthquake activity are generally larger and better reinforced from columns in countries with no earthquake activity.

For improved earthquake capacity of a building it is suggested to use columns with large dimensions, which generally might create problems to the architectural customization of internal spaces. This is the reason that it is preferred to use shear walls in both directions. Apart from contributing greatly in the compressive strength of the building, the shear walls also significantly enhance the stiffness of the building, which means that all displacements are decreased and as a result we have less deformations of the frame during an earthquake.

In earthquake resistant buildings it is necessary to use beams which will support the slabs. Whenever due to architectural or other reasons, it is not possible to use beams with their height expanding under the slab, it is suggested that the slabs should be designed with adequate height in order to ensure the simulation of the beam's behavior by creating reinforced beam zones inside the body of the slab (hidden beams)

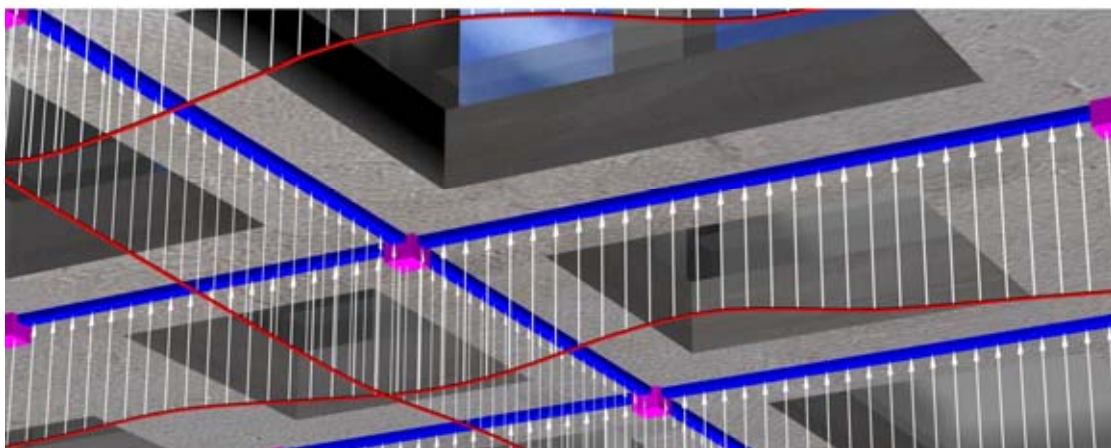
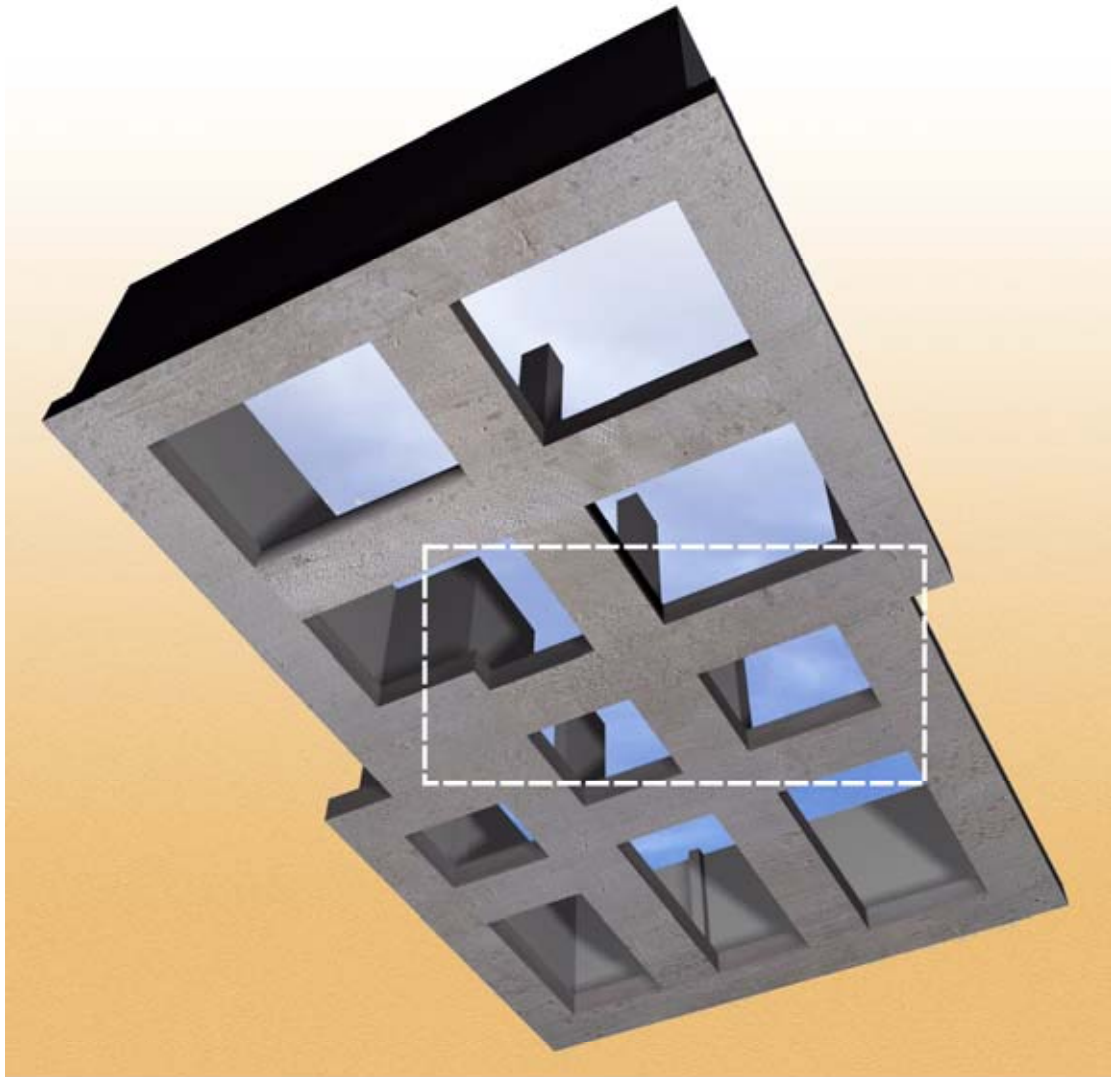
It is suggested that all columns in a multi storey building are not interrupted in any floor, starting from the ground (foundation) and continuing until the highest floor. A column that stops in an intermediate floor and does not continue until the foundation level is called a fitted column.

Usually this kind of column is supported by a beam since it is not permitted by Greek regulations to support such a column in slabs. However, it is advisable to avoid using these types of columns in order to ensure the proper earthquake resistance of the building.

As far as the foundation beams and the footings are concerned, it is obvious that a possible failure will directly affect the supported columns which will then result in the adjacent beams failing. The slabs will then follow since there will be no beams to support them. The above mechanism will take place in every floor of the building and will eventually result in the entire frame failing.

The construction of a basement and the usage of appropriate shear walls around the basement can significantly improve the behavior of the building during an earthquake.

Finally, the construction of continuous footings and/or the use of foundation beams will also improve the stability of the building and will ensure that partial settlements of the ground, which would create fractures in the frame, are avoided.



After the construction, the foundation is covered with soil and by the basement slabs. Because it is not visible, we wrongly assume that it does not participate in the buildings' antiseismic behavior. In reality, the foundation is constantly working to ensure stability of the building and its behavior is crucial, especially during an earthquake