Structural Design of Palazzo dell'Edilizia of Alessandria

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Abstract. The case study concerns the structural project of the "Palazzo dell'Edilizia of Alessandria", a multi-functional building that will host the activities of a public company managing building industry and construction workers issues. The early architectural concept design has been carried out by the well-known Architect Daniel Libeskind. LGA Engineering team by means of BIM approach developed the structural design in a Level Of Detail corresponding to a Definitive Project.

The building is organized into four above ground stories that house classrooms, offices, conference halls and multi-purpose spaces. Under structural point of view the main body is made of a central rigid concrete core and surrounding steel frames. The most iconic component of whole complex is the 50 meters high tower made of steel frames interconnected each other and with the other main elements of the building.

During project development, the main structural challenges to deal with has been the design of long span beams, cantilever slabs and beams, out of plane structural elements and their mutual connection, and above all the managing of the complex geometry and the height of the tower steel frame.

Keywords: Steel, structure, BIM, tower, lattice girder, FEM analysis

1 Introduction

The building is organized into four above ground stories and one underground level. In addition to the main body, the structure has a 50 meters high steel tower interconnected with the other main structural elements of the building (Fig. 1).

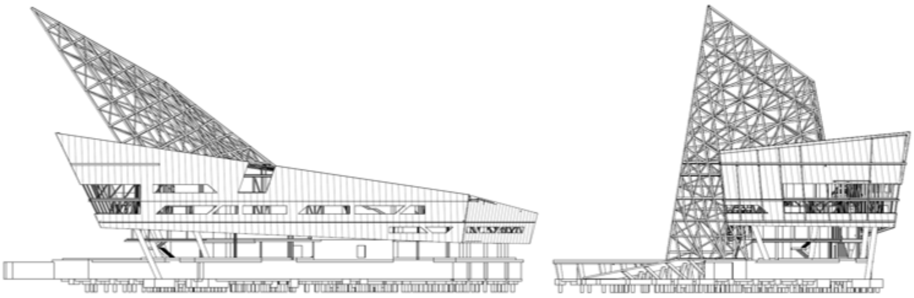

Fig. 1. Side and front view of the BIM model of Palazzo dell'Edilizia of Alessandria.

Due to the complex geometry of the building and to respect the architectural layout several structural configuration has been analyzed and the definitive solution adopted concerns a composite steel and concrete structure.

2 Description of building components

Foundation structural elements are made of isolated concrete pads and concrete beams with underlying foundation piles. Most of the foundation elements were developed in a previous project phase and at the moment of the conception of the definitive structural design were already be realized (Fig. 2) therefore they have been considered as existing structures.

Fig. 2. Existing foundation elements and underground concrete structures.

The underground level hosts the car parking and has a main structure made of vertical concrete columns and concrete walls, horizontal elements of the floor composed by prestressed precast concrete beams and precast concrete slabs (Fig 3a).
The ground floor is characterized by two large spaces designated to didactic laboratories, some accessory spaces and a coffee bar zone in the front side of the building. Vertical main structural elements are both concrete walls and columns and steel columns, while the horizontal elements of the floor have a composite structure made of main steel beams and precast concrete slabs (Fig.3b).

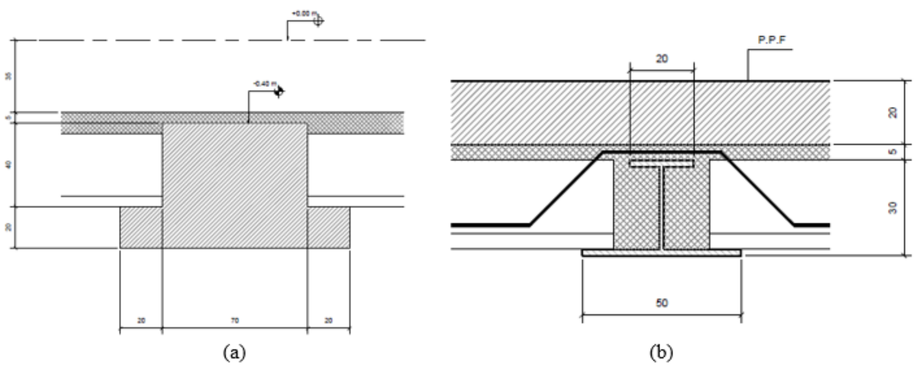

Fig. 3. Schematic detail of connection between prestressed precast concrete beams and precast concrete slabs of underground level (a) and schematic detail of connection between steel beams and precast concrete slabs of upper floors (b).

Between the ground floor and the first floor there is an intermediate floor that takes up a reduced amount of the whole surface of the building and that house a dining hall and some accessory spaces. This floor is partially supported by vertical elements such as concrete walls and steel columns and in the forward part of the building is hung to the upper floor by means of steel tie-rods.
The first floor hosts classrooms and offices and is characterized by main structural elements made of steel lattice girders of height equal to the whole space between the two floors (Fig. 4a,b). The secondary structural elements are steel beams and precast concrete slabs.
The main space that is located in the second floor is the conference hall, placed in the front side of the building. The needs of ensure a large space without structural elements inside made the structural designers develop steel lattice girders connected with the ones of the floor below and supported by the four sloped concrete columns of the ground floor. Secondary structural elements, as for the first level, are made of steel beams and precast concrete slabs.
The roof structure is made of steel elements such as columns and beams and has been designed in order to be as light as possible. It is developed on a sloped plane with the upper edge corresponding to the forward part of the building and the lower one corresponding to the back part where the roof is partially open and are located some terraces accessible from the second floor.

Fig. 4. Location of lattice girders in first floor (a) and axonometric view of components of the steel frame (b).

Structural elements of the external walls are made of precast concrete panels with stiffener components strictly connected to the main structure at the level of the different floor by means of composite concrete and steel edge beams (Fig. 5). This layout let the whole structure be connected on the different levels and these wall elements works as windbrace system giving stability respect to wind and seisic horizontal actions.

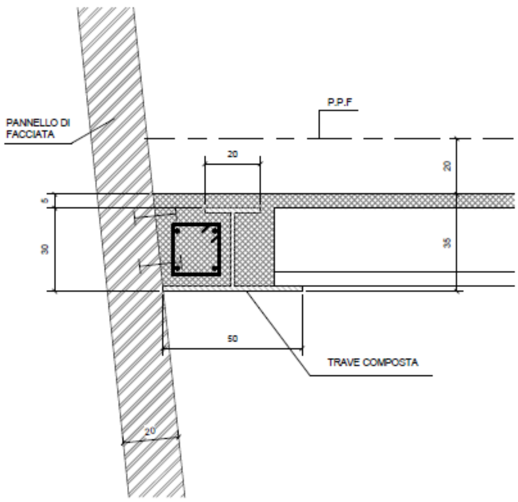

Fig. 5. Detail of the connection between concrete precast wall panels and edge composite beams of floor structure.

The central part of the main body of the building that hosts stairs and elevators is a concrete core made of concrete walls connected each other that provide vertical support to the tower steel structure and horizontal stiffness.

3 Description of steel tower components

In addition to the main body of the building, the structure includes a steel tower with an overall height of 50 meters which crosses the shape of the building and it is structurally connected to it. In particular the structure of the tower consist of steel frames that on the back part of the building provide supports to the floors and are supported by the concrete walls of the underground level, while on the front side are supported by the concrete core at the level of the last floor (Fig. 6).

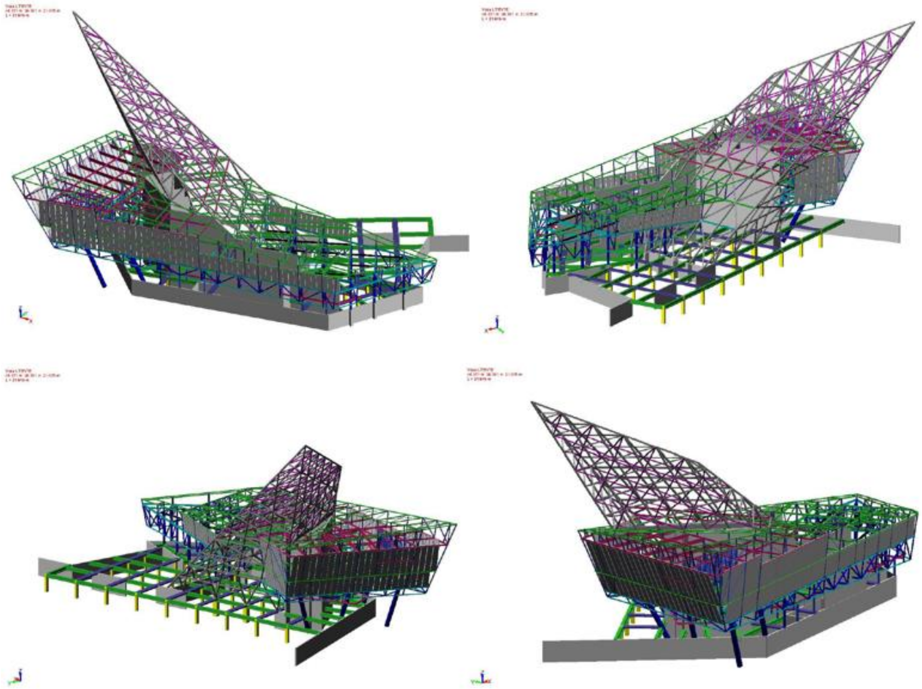

Fig. 6. Different views of FEM model.

Tower steel structure is subdivided into 4 plane frames realized with square hollow section steel elements coupled each other along the lateral side of the four faces (Fig. 7). The back side of the tower hosts a photovoltaic plant with panels arranged on the steel structure up to the height of about 32 meters, while the other three faces are open lattice structures without any cladding.

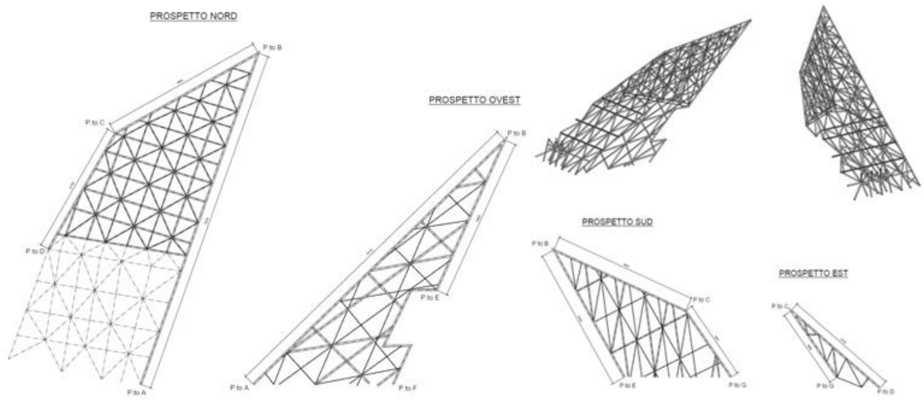

Fig. 7. Composition of steel tower frames.

4 Structural design development and BIM approach

Due to the complex configuration of the building, as described above, structural design was carried out by different steps starting from simple hand calculation until reaching advanced FEM analysis. Large use of BIM approach lets the project team manage the complex geometry of the building and simplify the developing of the structural conception of the components by means of software interoperability in exchanging information between Revit, Advance Design and Dolmen (Fig. 8).

Fig. 8. Conceptual scheme of BIM interoperability between different project scenarios.

The most challenging task of the designers was to evaluate the behavior of the building in both static and dynamic configuration with specific regard to the tower steel

structure response to wind and seismic action. In order to develop a complete structural design the early numerical evaluation has been the realization of two different FEM model of the main body of the building alone and the tower alone as well. This way to proceed let the designers perform simplified splitted analysis of the two main component of the complex in which the sizing of the main structural elements was carried out. After that the structural models merged in a unique FEM model and the detailed structural analysis was performed to develop all the detail of the structural configuration described above.
Complexity and importance of the project made the designers develop analogous FEM model of same components by means of different structural software such as Advance Design and Dolmen in order to compare and validate the results of the structural analysis performed (Fig. 9).

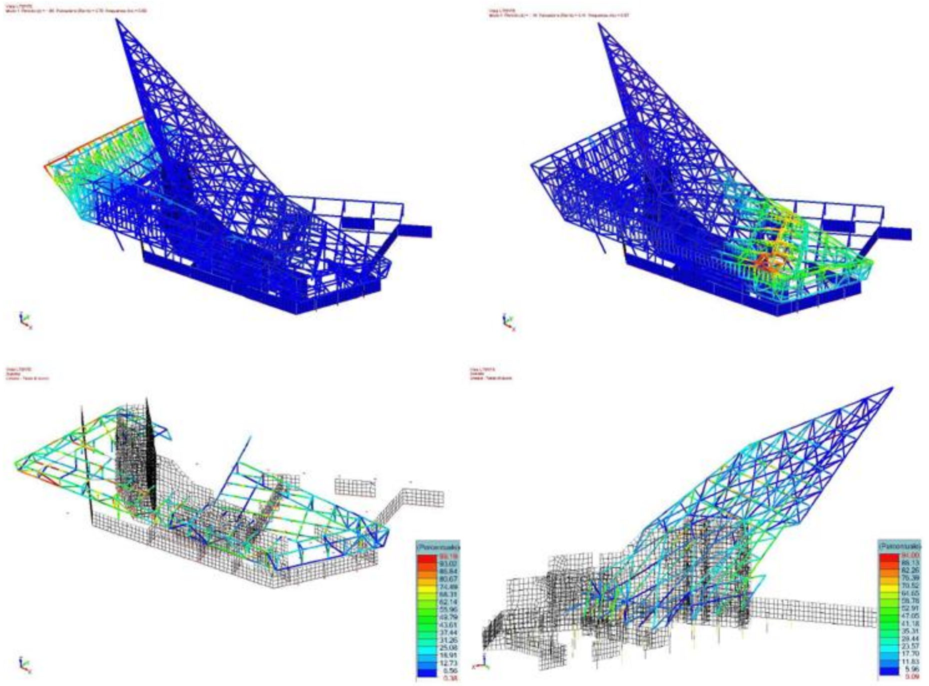

Fig. 9. Some results of FEM analysis regarding mode of vibrations and steel elements work ratio.

An in-depth numerical analysis has been carried out regarding the wind action on the steel lattice structure of the tower. In detail, evaluation of vortex shedding phenomena and occurrence of aeroelastic instabilities was performed according to EN 1991-1-4 [1] by means of determination of physical and dynamic characteristic of the structure, such as natural frequency of the flexural mode of cross-wind vibration, Strouhal number and critical wind velocity for bending vibration (Fig. 10).

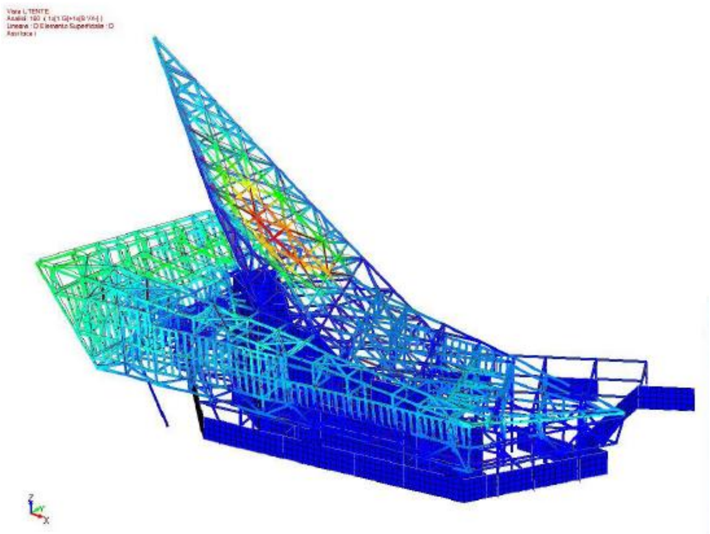

Fig. 10. Maximum displacements under wind action.

More detailed analysis about interaction between wind and tower steel structure (e.g., CFD computation, wind tunnel test) shall be performed during next phase of executive structural design development.

References

1. EN 1991-1-4 “Action on structures – Part 1-4: General actions - Wind actions”.