Addamiano Engineering S.r.l.

Polo Eccellenza Desio

Structural Design Brief

REVISION 1

Addamiano Engineering S.r.l.

Polo Eccellenza Desio

Structural Design Brief

In collaboration with ArcelorMittal

May 2010

This report takes into account the particular instructions and requirements of our client.
It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party

Arup Italia srl
Corso Italia 13, 20122 Milano, Italia
Tel +39 02 8597 9301 Fax +39 02 8053 984
www.arup.com

Job number 37103

Contents

Figures

Introduction

Client	Polo Tecnologico Brianza SPA
Project management	Addamaniano Engineering, Nova Milanese (MI)
Architect	Massimo Roj - Progetto CMR in collaboration with Vigano' & Vigano Architects and Addamiano Engineering
Arup scope of work	Structural engineering – Design of foundations and vertical structures
Project details	Office building 24 storeys high, 92.5 m (height measured from the level of the pedestrian entrance to the architectural top of the building) located in Desio (MI). 3 basement levels to be used for plant rooms and storage with a connection to the adjacent car park. Total tower surface 26 000 m² (excluding the nearby underground car park and the pedestrian square, both part of the same development) North-side entrance through a commercial arcade and covered by a transparent waved canopy.
Structures	Reinforced concrete flat slabs supported on ArcelorMittal HD steel S460+M columns, steel constructor Cometal S.p.a. Three reinforced concrete cores. Architectural steel frame on the roof level.
Construction	Structures completed in 2009. Construction lasted 11 months. Fit-out under completion as at June 2010 (delays incurred due to the 2008 international financial crisis).

Figure 1 *Architectural Rendering, © Progetto CMR*

The structural concept of the Desio tower is quite simple, with clearly identified load paths. This simplicity is the main feature of the structural system which provides several advantages, among which structural regularity and high constructability minimizing time of construction. The structural scheme is apparent by looking at the assembly of the structural elements widely documented and still clearly visible as the façade and the internal fit-out is yet to take place.

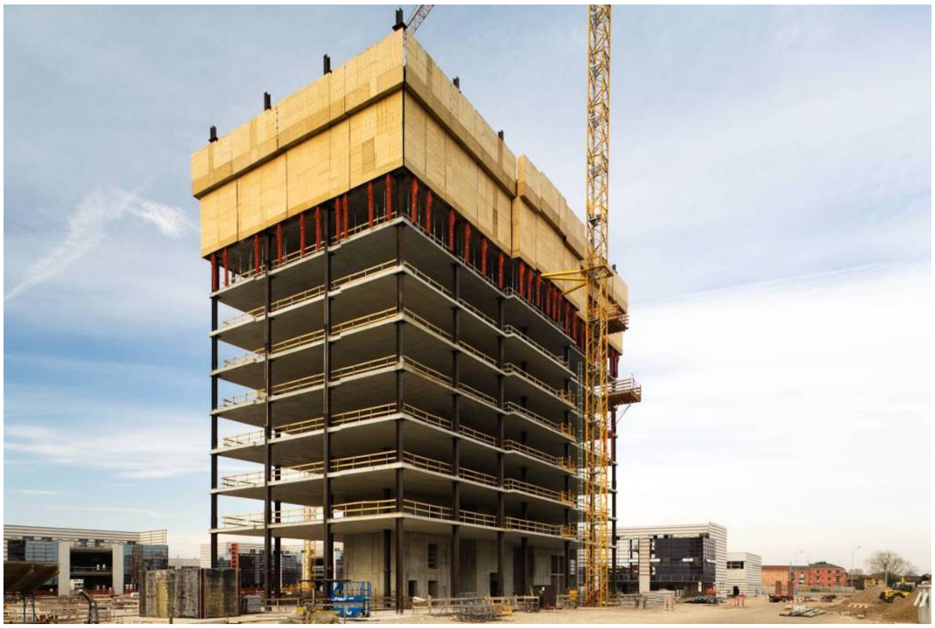


Figure 2 *Lower levels under construction, © Arup*

Figure 3 *Intermediate levels under construction, © Addamiano Engineering*

Layout

The regular structural layout of the tower fits the simple and clean overall geometry demanded by Progetto CMR architects which consists of a rectangle with a short side plan dimension of 24 m throughout the height of the building and the other side stepping from 46 m (lower levels) to 32 m (intermediate levels) and to 24 m (upper levels) from base to the top of the building (see plans below).

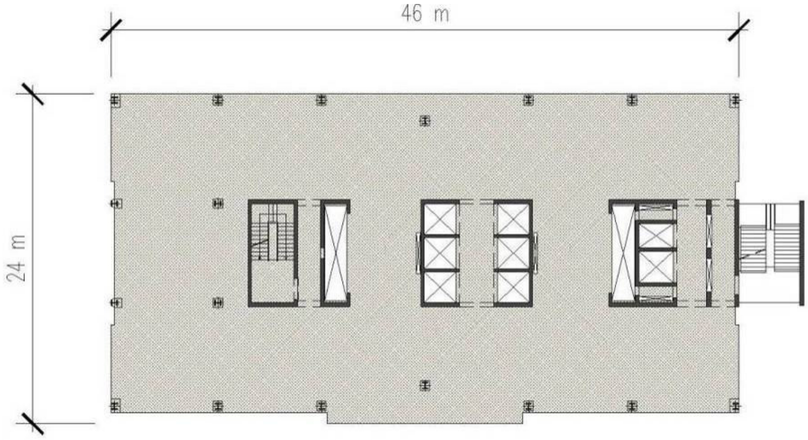


Figure 4 *Plan of the lower levels, © Arup*

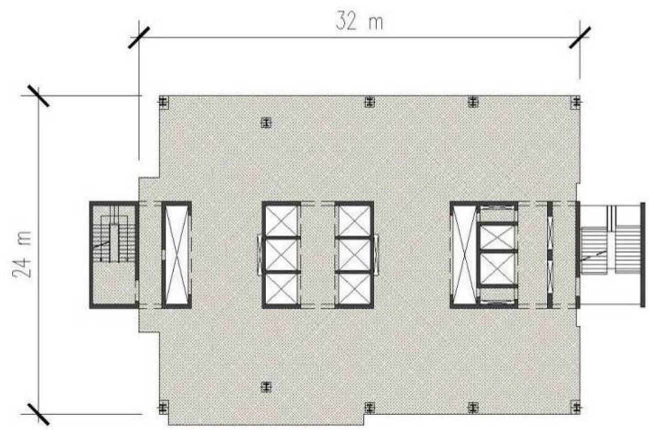


Figure 5 *Plan of the intermediate levels, © Arup*

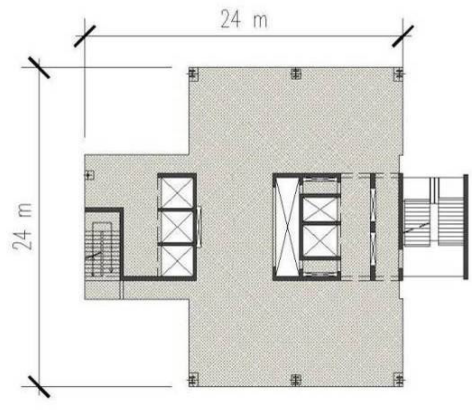


Figure 6 *Plano of the upper levels, © Arup*

The building is 88m high, height measured from the pedestrian entrance to the highest occupied floor within the building (according to the measurement criteria set by the Council on Tall Buildings and Urban Habitat). Hence 'Polo Eccellenza Desio' can be considered as tall building as higher than 50m, limit commonly accepted.

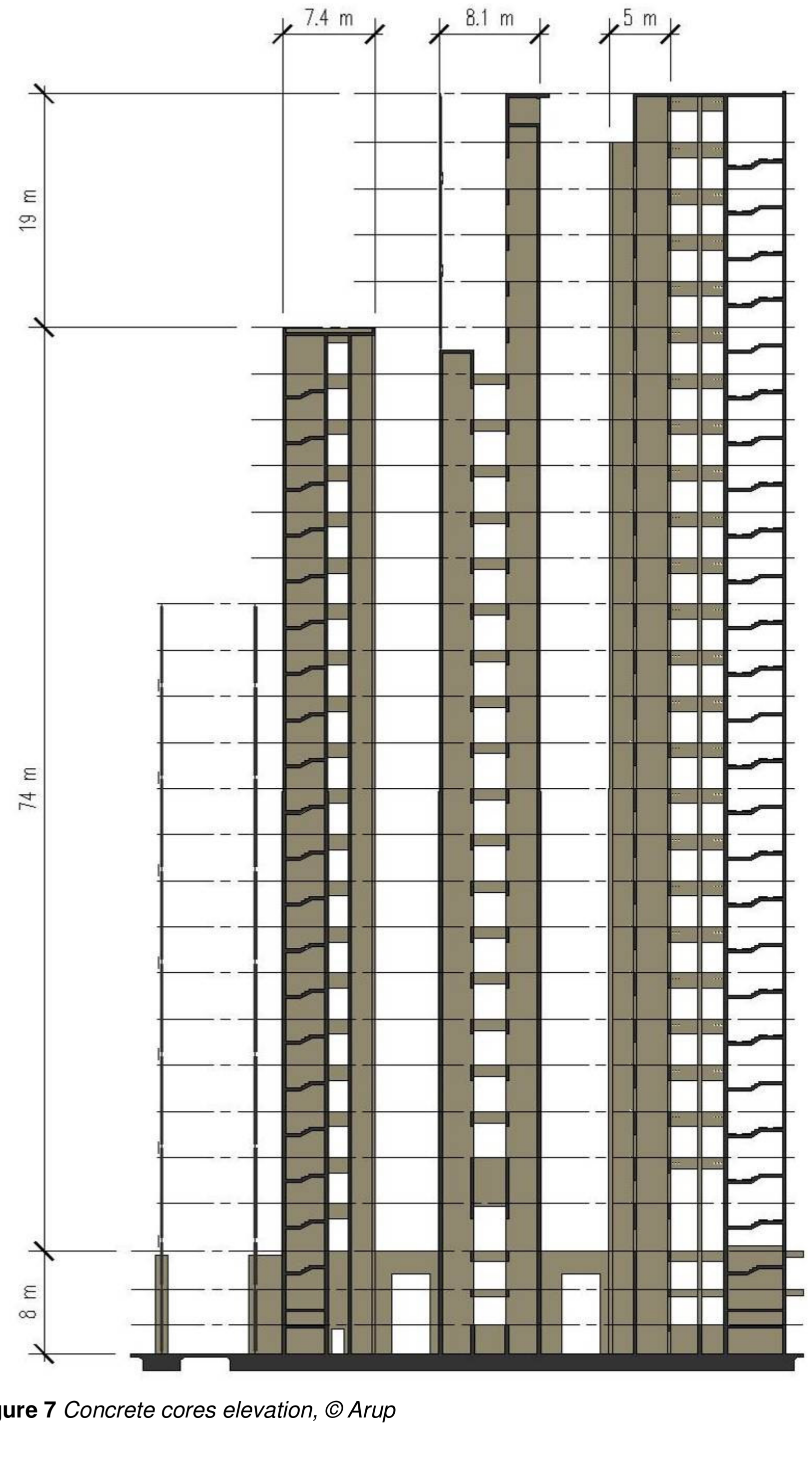


Figure 7 *Concrete cores elevation, © Arup*

Based on the dimensions herein illustrated the core slenderness is 4.5:1, which corresponds to the maximum ratio height to total width. This value is lower than the slenderness of many tall buildings all over the world today. This slenderness ensures that the tower is not prone to excessive dynamic structural amplifications under wind loads.

The slab thickness is typically 250mm with an upstand edge beam aligned with the short side to limit slab edge deflections due to structural end span discontinuity and to the weight of the facade, which is heavier along these sides. The interstorey height is 3.68 m and the net height, raising floor to ceiling, is 2.70 m as shown in the following section. The typical span between core and perimeter column grid is 7.5 m

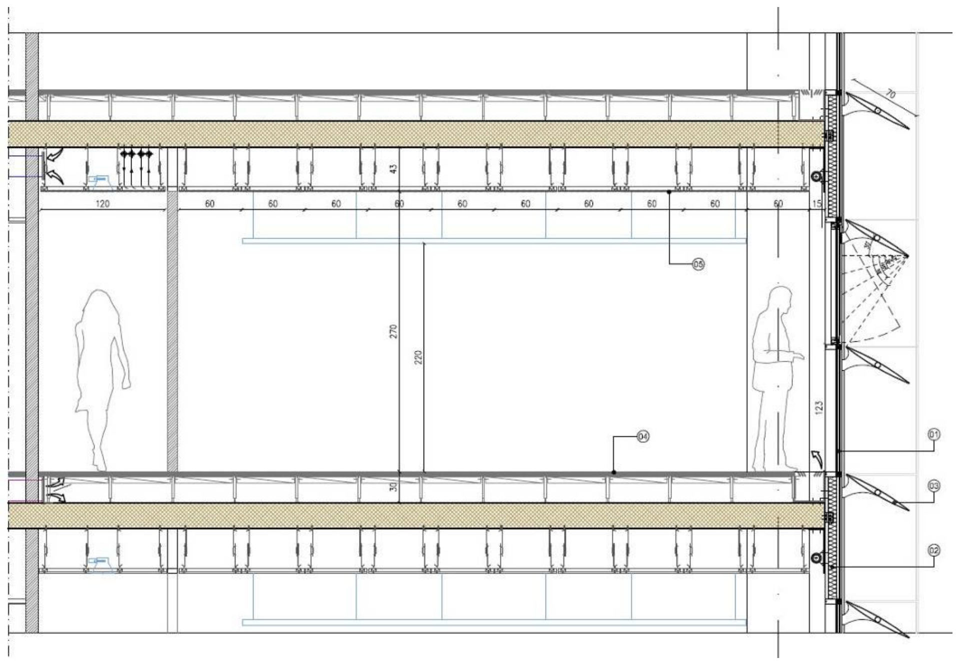


Figure 8 *Architectural section showing the typical storey (dimension in cm), © Progetto CMR*

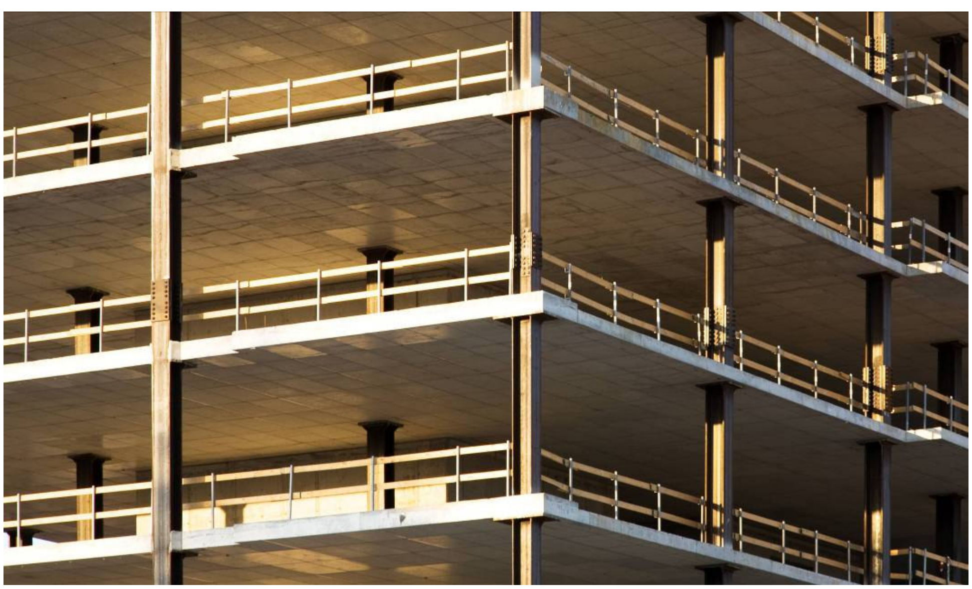


Figure 9 *Upstand beams along the short sides of the building, © Arup*

Stability system

The lateral stability is provided by an assembly of reinforced concrete walls, which form three independent cores used as staircases, lifts and service shafts.

The central cores system is one of the most commonly used lateral systems for buildings not higher than 200m. There are also other structural alternative systems. The literature assigns to each system an approximated number of stories within which that system is economically viable as far as the material quantities are concern, as shown in the graph below.

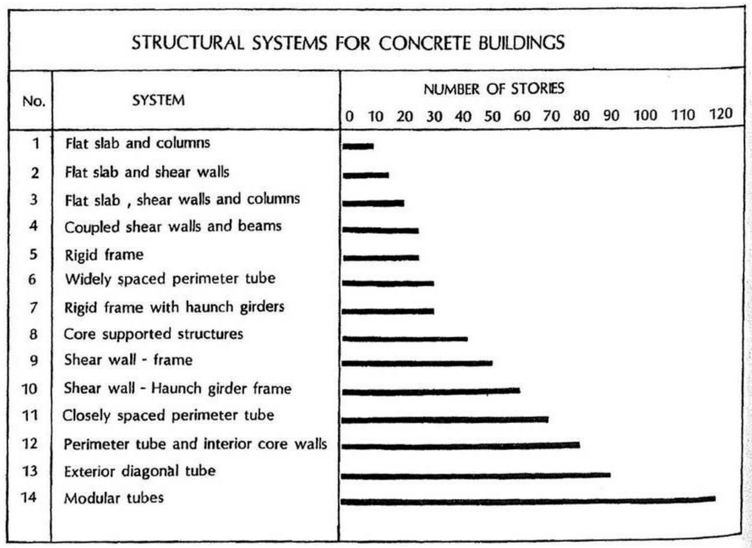


Figure 10 *Conventional structural systems for concrete buildings*

One of the most suitable systems for Desio tower (24 stories) is the shear walls and flat slabs system. The concrete cores work as cantilever beams from the foundations level. Each cantilever is represented by an assembly of walls composing the cores (see the following figures).

Figure 11 *Architectural layout – lower levels, © Progetto CMR*

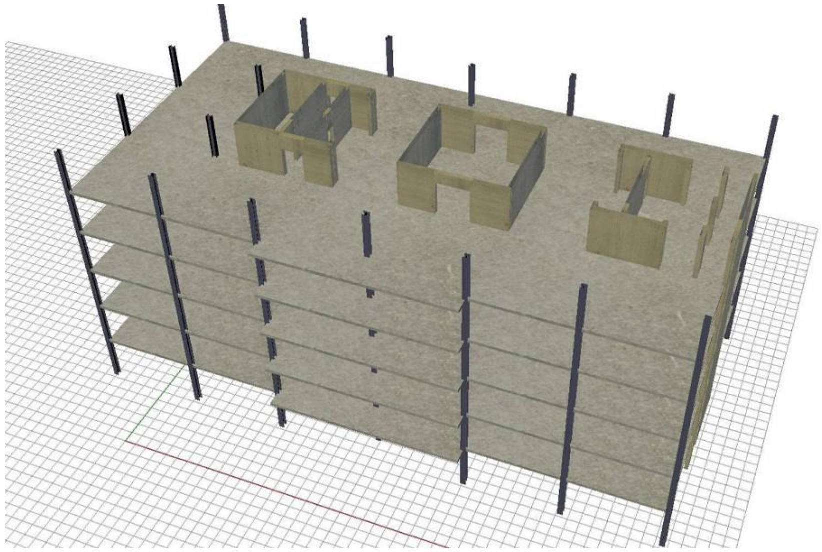


Figure 12 *Perspective view of the structural elements (staircase and floor openings omitted), © Arup*

Wind pressures acting on the facades are transferred to the cores through floor plates and then down to the foundations.

The choice of the core walls system is the outcome of the comparison with the concrete frame system. According to the spacing of the grid lines set by the architects the central cores system results in less material quantities as per the same stiffness. Cores also guarantee acoustic insulation from the services inside and work as fire insulator between offices and staircases.

The tower structure has been designed by the Arup Milan office in order to resist the horizontal forces calculated in accordance with the current Italian code DM 14 January 2008.

Multiple analyses have been carried out including simple models used for the preliminary phases and more complex and specific models for the final design stages. The structural analysis models have been made by using the finite elements software Oasys GSA (General Structural Analysis), Arup's in-house software. The dynamic structural characteristics have been extrapolated from a linear dynamic modal analysis. These results have been double checked against the numeric results calculated by using approximated formula from literature and international codes. The output from the modal analysis has been used to quantify, through a response spectrum analysis, the code seismic effects on the structure. As the periods associated to the first modes of the structure are not greater than 4 seconds the code response spectrum can be used. For periods greater than 4 seconds the Italian code recommends using acceleration records in order to calculate the seismic load.

Figure 13 *Lateral system modelling, © Arup*

The wind loads have been calculated by using the Italian code and the Eurocode where certain parameters required in order to carry out the calculations are not specifically covered in the former. In order to estimate the overall effects of the wind on the building it has been considered unnecessary to carry out a wind-tunnel test, which is generally recommended for buildings prone to significant dynamic effects, complex geometries, etc. Prismatic shapes, as a rule of thumb, can be considered as candidates for wind-tunnel test when the height exceeds the range of 40 to 50 stories. The cores layout is approximately double symmetric on plan with respect to the facade centroids such that there is no excessive torsional effect due to the wind pressure uniformly distributed on the facade.

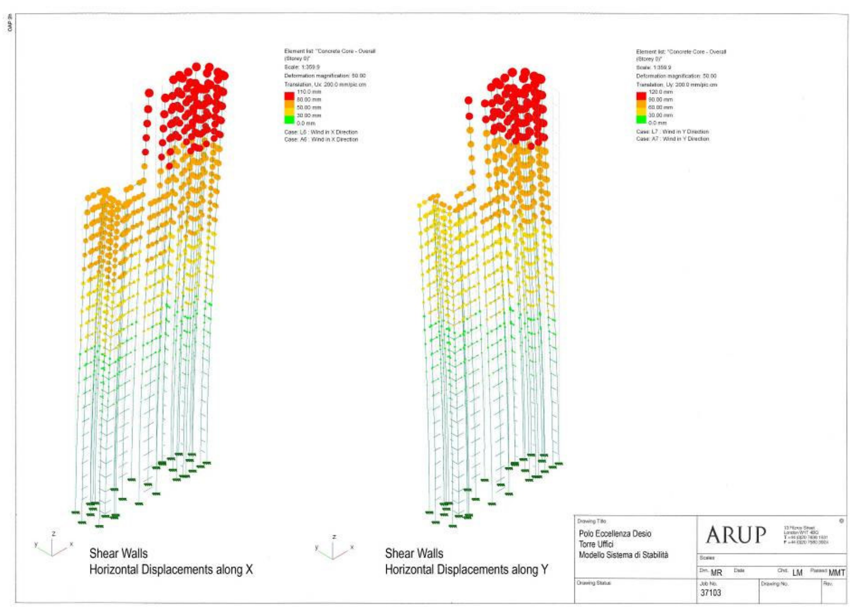
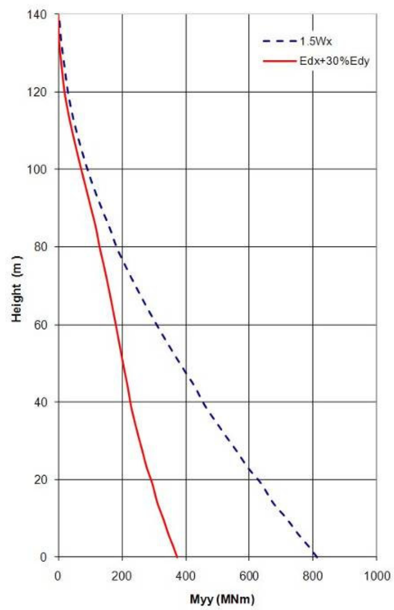
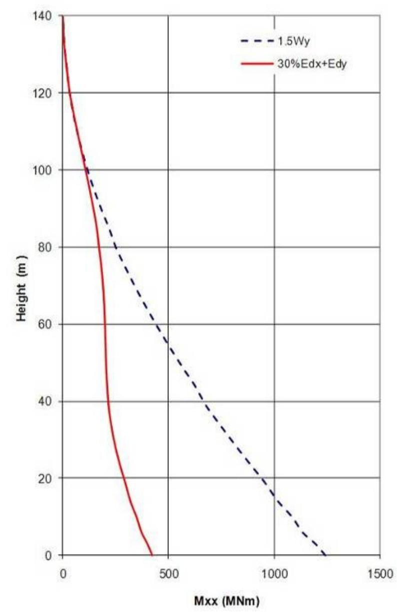


Figure 14 *Horizontal displacements under wind load, © Arup*

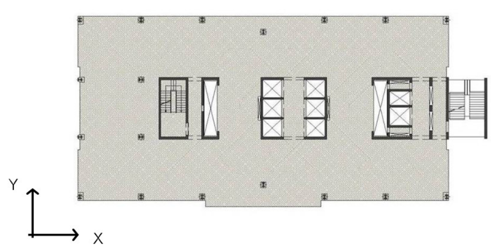
As Desio is classified as low seismic area and the dynamic masses are relatively small, the wind loads govern on seismic loads for both directions as shown in the following figure. This is common for most of tall buildings located in regions of low seismic hazard. In general, as buildings grow taller and more slender, wind loading effects become more significant in comparison to earthquake effects: wind overturning moments typically increase with height cubed whereas the elastic seismic overturning moment is unlikely to increase at no more than height to the power 1.25.



M_{yy} – Wind versus Seismic load (ULS)



M_{xx} – Wind versus Seismic load (ULS)



In the graphs above:

Wx, Wy	Wind load along X, Y directions
Edx, Edy	Design seismic load along X, Y directions

Gravity system

Arup has worked from the preliminary phases of the project conceiving a structure which could fulfil the client's need for reducing sizes of the vertical structural elements as much as possible in order to get more office space to lease. At the same time the structure should be easy to build according to the local technology and expertise available and designed to speed up the construction. However for a tall building gravity loads, to be transferred to foundations through columns and cores, are significant. Moreover the cores have to resist the horizontal forces as well. A way to deal with these conditions is using high strength materials.

For the above reasons, the steel grade selected for columns is the high strength S460+M by ArcelorMittal produced in the Luxembourg mills of Belval and Differdange. Use of this grade makes Desio Tower one of the first Italian examples of tall buildings which have adopted such a high certified steel grade. This choice has resulted in several benefits: minimised floor cycle times (average 18 days time per storey), high level of (off site) quality control, minor architectural impact, and therefore more leasing space available. This has been made possible as the main property of the steel grade S460+M is a high yield strength (fy=460MPa), as opposed to standard S275 & S355 grades. As the columns are not part of the wind load resisting system, they are designed for strength only with no axial stiffness requirement.

Figure 15 *Slab under construction, © Arup*

A high concrete strength has also been used in order to reduce the core walls thickness at the lower levels. The concrete grade C45/55 (cylinder/cube strength in MPa) has been adopted from foundation level to level 9. This grade allows reasonable wall thicknesses to be achieved, based on the actual gravity loads on the cores combined with the wind loads. Its properties are also such that no special precautions are required at the interfaces between cores and slabs (of grade C28/35), and between cores and foundations (of grade C32/40).

In order to maximize construction speed Bamtec technology has been used for reinforcing the flat slabs. This option has been selected during the preliminary phases of design by the client (Addamiano Engineering) and developed locally by CSE. Slabs reinforcement have been placed more efficiently in terms of time and quality assurance compared to the traditional technologies.

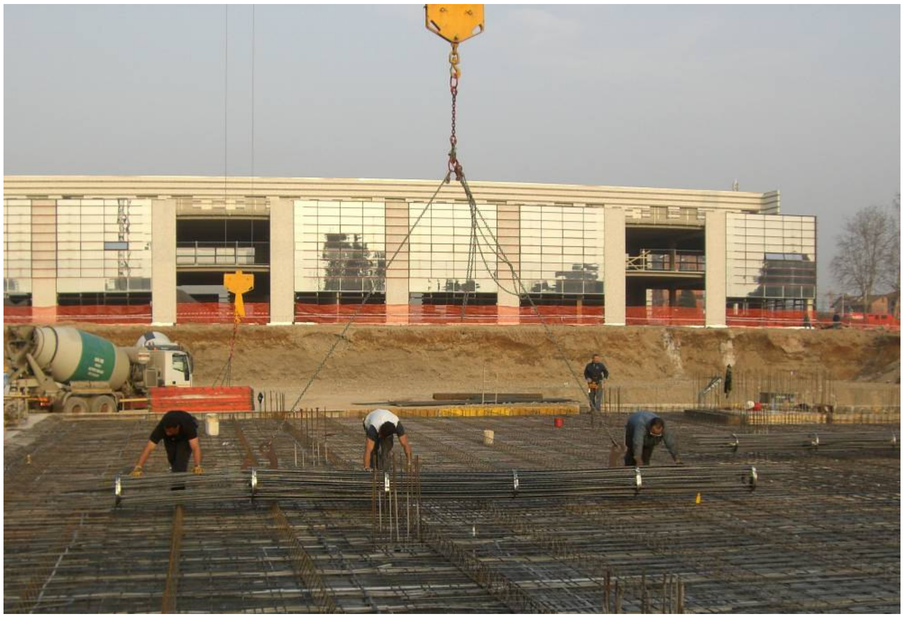


Figure 16 *Flat slabs – Bamtec technology, © Arup*

The Desio tower is one of the first examples in the Milan area using the technology for pumping concrete at heights. This has been achieved through a careful concrete mix design that the Client has commissioned to the Farina Calcestruzzi contractor. The main contractors, Addamiano Costruzioni e Minerva Costruzioni, have been monitoring all the pouring phases to ensure the final quality.

The tower construction has also been optimised by using the rail climbing system (RCS) by PERI. With the RCS climbing protection panel, the slab edges on the upper floors have been completely enclosed. Site personnel have been secure against falling at all times and protected against strong winds at the upper levels. The adoption of this system has also guaranteed an appearance of site visual cleanness during construction.

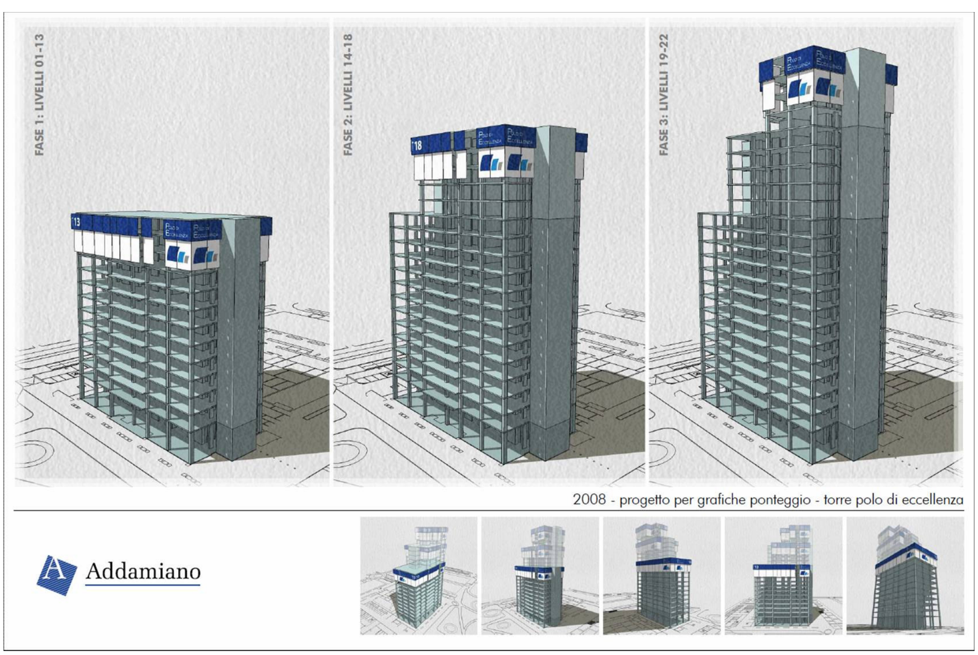


Figure 17 *Rail climbing system (RCS), © Addamiano Engineering*

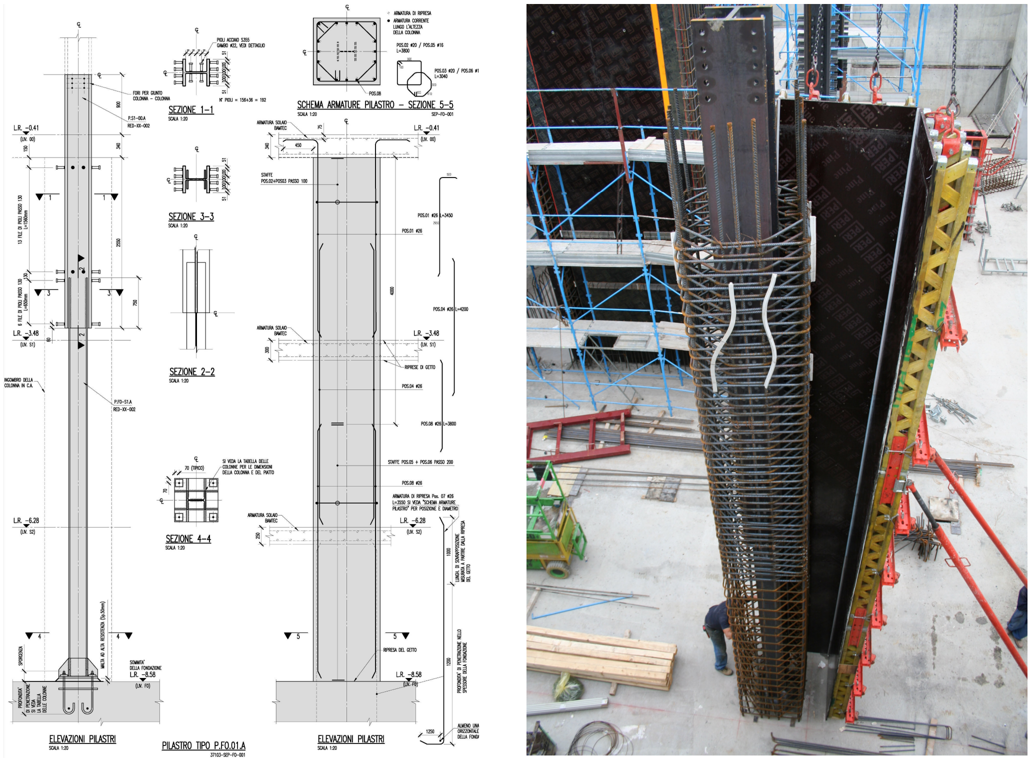


Figure 18 *Structural detail – Load transfer steel to concrete at basement, © Arup*

Steel and concrete work compositely at the basement where high strength requirements are achieved together with a good fire protection. The detail above shows how the loads are transferred from the above steel column to the concrete column below. Shear studs welded either on column flanges and web together with stirrups are designed in order to gradually unload the steel column and transmit the force from the superstructure to the reinforced concrete section at the basement. This detail minimizes the complexity of the waterproofing at the interface between steel and concrete lying on the facade line at the ground floor.

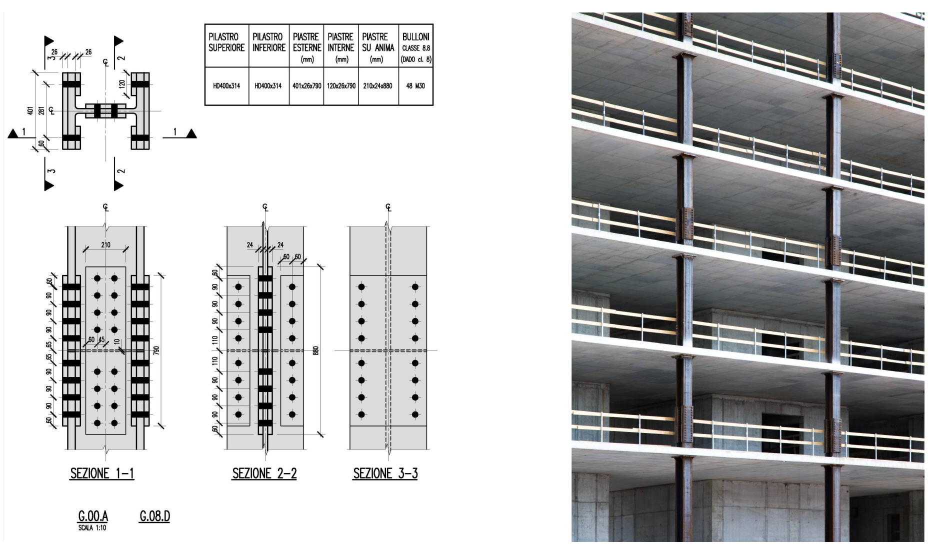


Figure 19 *Structural detail – Column splice, © Arup*

Desio tower, 90 m high, has been built within a budget of 350 euro/m² in 11 months (first pouring of the foundations on 9 October 2008, uppermost slab cast on 3 September 2009). This is a competitive duration compared to other similar Italian projects. This duration is usually considered sufficient to build a reinforced concrete structure 60m high currently in Italy. This is the result of the adoption of a composite structure made of relatively advanced materials and technologies.

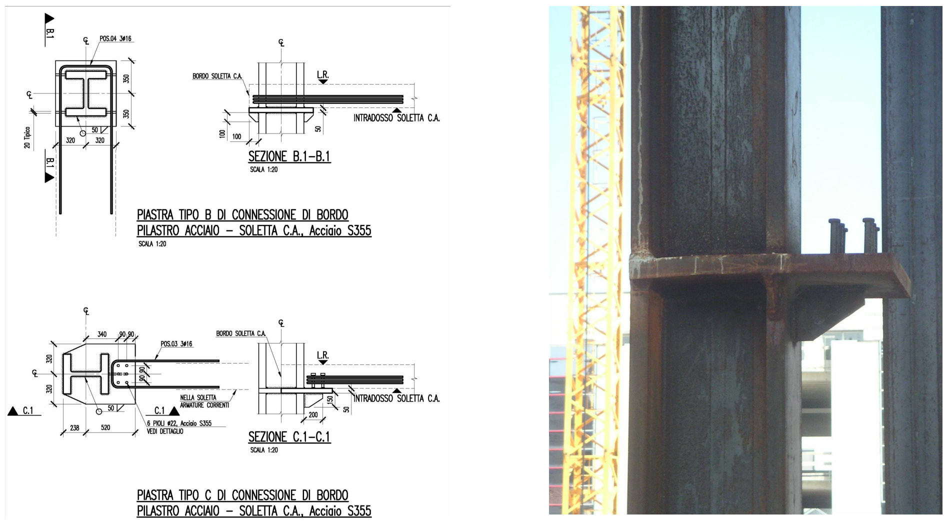


Figure 20 *Structural detail – Column-slab joint, © Arup*

Figure 21 *Structures overall view, © ArcelorMittal*

Foundations

The geotechnical design carried by Arup Milan includes mat foundation design and soil deep stabilisation through jet grouting mono-fluid and bi-fluid injection technique.

Figure 22 *Raft foundation reinforcement, © Arup*

Along with the jet grouting design the following activities have been performed by Arup:

- On site assistance;
- Monitoring on site tests;
- Supervision during on site and laboratory trial inspections.

The raft foundation is 50 m × 25 m in plan, 1.4 m deep and located at 9 m below the original grade. The raft design has been carried out by using the software GSA-Raft, which performs soil-structure interaction analyses based on the provisions of the Italian code DM 14 January 2008.

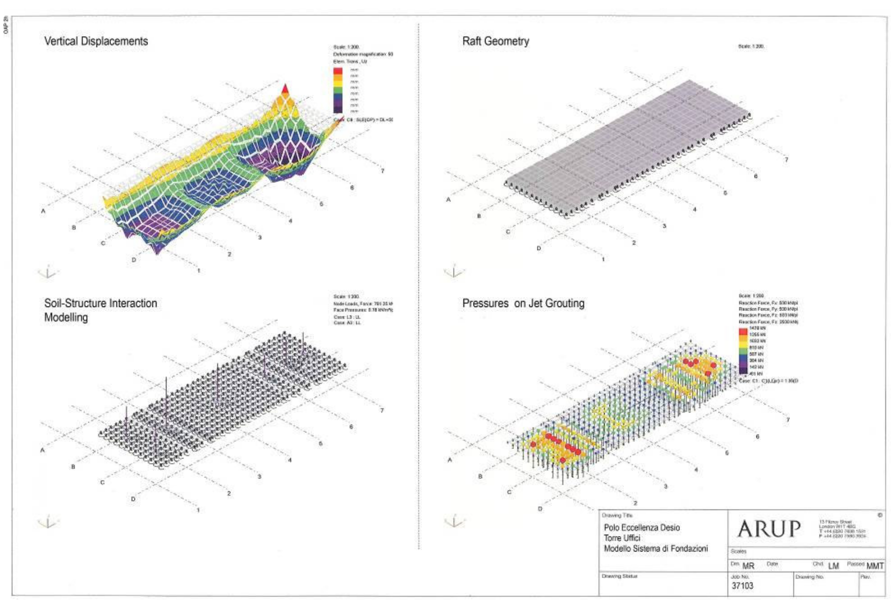


Figure 23 *Soil-structure interaction, © Arup*

Credits

Client:

Polo Tecnologico Brianza: Giosue' Addamiano (amministratore unico).

Project management:

Addamiano Engineering: Emanuele Formenti, Emiliano Rossetto.

Project

Architects:

Massimo Roj - Progetto CMR with Vigano' & Vigano architects and Addamiano Engineering

Structures and geothecnics:

Arup (vertical structures and foundations): Maurizio Teora, Ambrogio Angotzi, Luca Buzzoni, Lorenzo Marengo, Angelo Mussi, Riccardo Abello, Mario Rossato, Vito Sirago.

CSE (slabs design): Daniele Mietto.

Services MEP:

Tekser: Guido Davoglio.

Independent supervisor:

DLC: Franco Cislaghi, Stefano Borsani.

Construction

Reinforced concrete structures:

Addamiano Costruzioni with Minerva Costruzioni and Farina Calcestruzzi: Luigi Trotta, Paolo Mascetti.

Steelwork:

Arcelor Mittal Commercial Long Italia: Mauro Sommavilla.

Cometal: Franco Berselli.

Works supervisors:

Emanuele Formenti (general supervisor), Giuseppe Fontana (structural works supervisor).