



DIFFERENT STRUCTURAL SOLUTIONS FOR MULTISTOREY BUILDINGS

CASE STUDY :
RESIDENTIAL / MULTI PURPOSE BUILDING



RESIDENTIAL BUILDING, ROME - PROJECT: BIOEDIL PROGETTI

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BIBLIOGRAPHY



DIAMANTE TOWER, EX VARESINE AREA, MILAN - PROJECT: KOHN PEDERSEN FOX ASSOCIATES PC

INTRODUCTION

This analysis concerns a case study of multi-storey building for residential / multi purpose use (commercial and / or office), designed and realized in three different structural solutions, one in one reinforced concrete and two in steel.

The wealth of technology solutions available to professionals working in the construction sector is, at present, an enormous heritage to draw from in consciousness however, that the “wise” choice is not necessarily the simplest but must take into account various economic, social, environmental and so-called “intangibles” factors. For this reason, a qualitative and quantitative survey has been carried out, of which this document is a first step referring mainly to the supporting structures, which represent a state of the art of the pros and cons of the most common constructive systems.

Why the world of private construction and, in particular, a multistory building?

First of all, because the construction sector is a key component of both Italian and European economies. In Europe, the weight of the construction sector on the steel industry is 35% of consumption [1] (the second sector, Automotive, has a weight of 18%) and the economic indicators identify in private buildings and residential a trend of recovery (mainly in Poland and Hungary).

In Italy, where the use of steel in the construction industry has risen in from 2005 to 2015, from 18% to 33% [2], investment in construction during 2017 [3] was 124.561 million Euros. In the housing sector, 64.059 million Euros were invested, accounting for 51.4% of total investments.

BUILDINGS INVESTMENTS – Millions of euros

	2017	2014	2015	2016	2017 ^(*)	2018 ^(*)
		<i>Variazione % rispetto all'anno precedente</i>				
TOTAL	124.561	-5,2%	-1%	-0,4%	+0,8%	+1,5%
Housing:	64.059	-4,2%	-1,9%	-0,8%	+0,1%	+1,2%
New House	17.815	-14%	-6,8%	-5,1%	+0,5%	+3%
Maintenance	46.244	+1,5%	+0,5%	+1%	+0%	+0,5%
Non residential:	60.502	-6,3%	+0,1%	+0%	+1,6%	+1,8%
Private	38.025	-7,1%	-1,2%	+3,4%	+4,4%	+4,8%
Public	22.476	-5,1%	+1,9%	-4,7%	-6%	-3,2%

Ance processing on Istat data

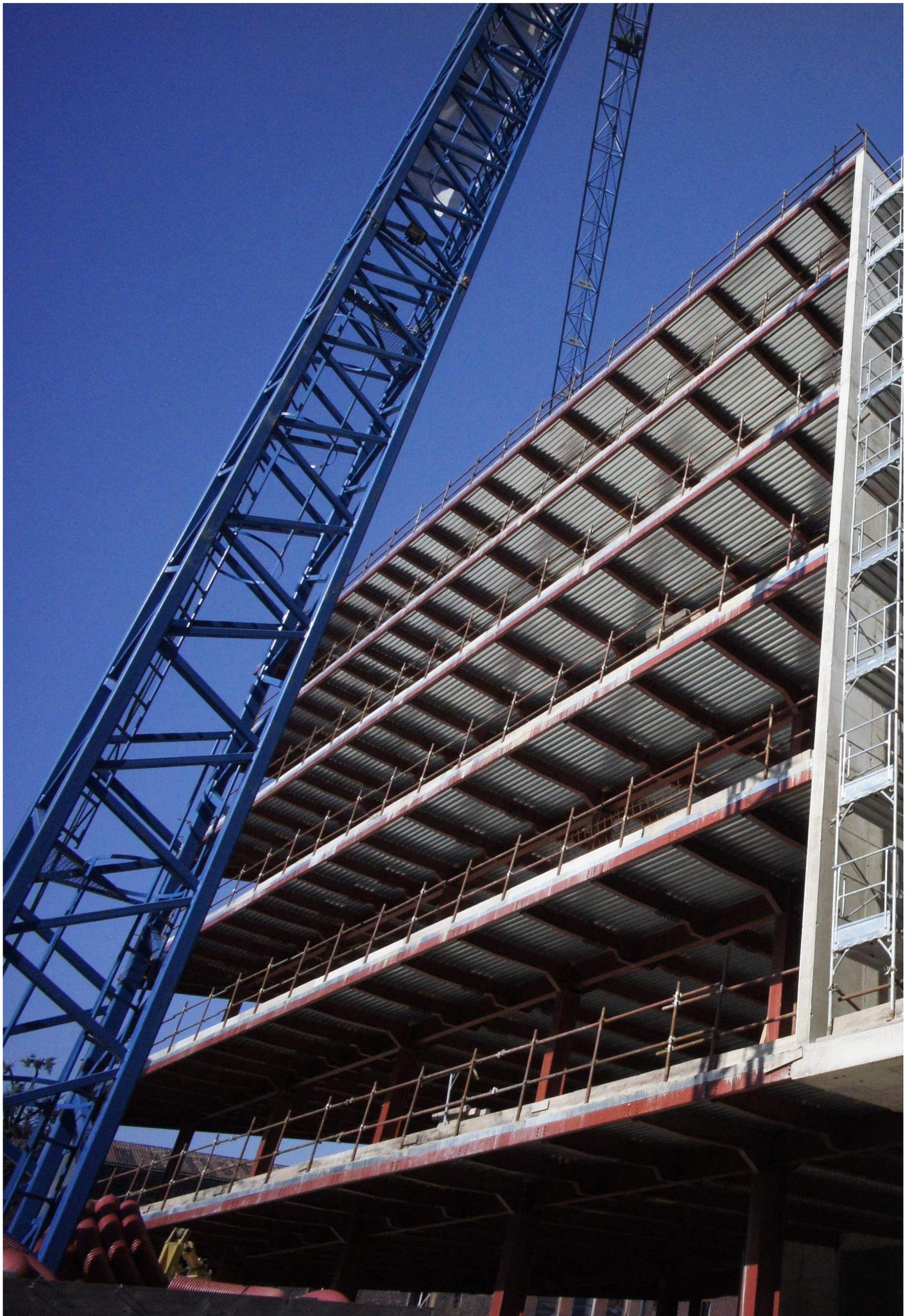
* Net investments of ownership transfer costs

° Ance estimates

SOURCE: ANCE CONJUNCTURE - JANUARY 2019

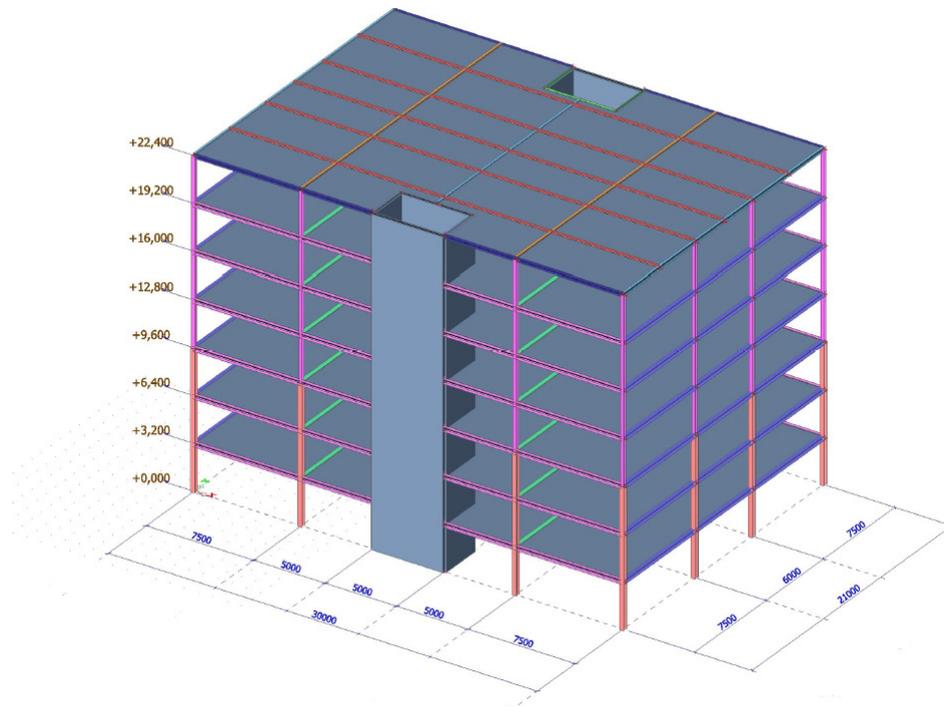
With a slight growth trend, the construction industry can offer insights to designers and investors. It does not also forget that the Italian heritage has largely exhausted its useful life, with buildings that need interventions of complete redevelopment.

This analysis aims to provide a state of the art of modern multistorey buildings by comparing the advantages and disadvantages of different solutions.



NATIONAL INSTITUTE OF MOLECULAR GENETICS, MILAN - PROJECT: POLITECNICA INGEGNERIA E ARCHITETTURA

1. BUILDING TYPE



SCHEME AND SIZE
OF THE TYPE STRUCTURE

The considered case study is a building with **7 floors above ground**, a parallelepiped plant of **30x21 m** and an area of **630 m²** per floor.

The height of the building is between 22 and 24 m (depending on the solution adopted) and there are two reinforced concrete cores for the stairwells and elevators along the 30 meter side.

The structural mesh is provided in modules of 7.5x7.5 to the four corners and modules 5x7.5, 7.5x6 and 5x6 meters for the central parts. The floor planes are provided as “modular”, for example: 4 units high floor housing, 6 lower floors, possibly larger storeys for offices and / or shops on the ground floor.

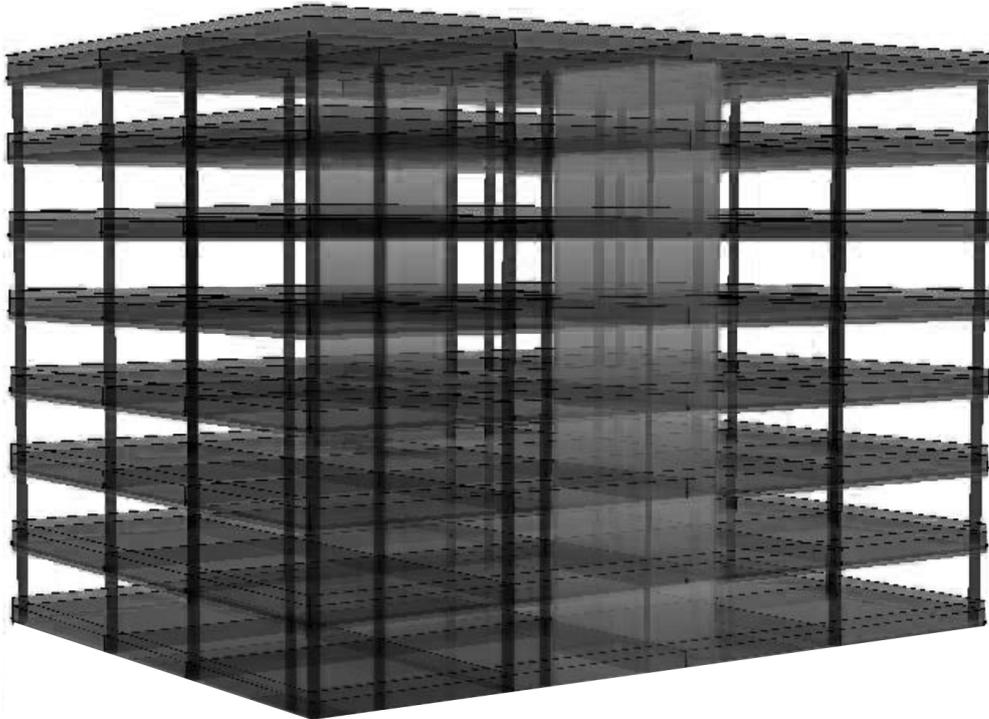
For the climatic and the earthquake loads, reference was made to the municipality of Modena, which has similar characteristics to other cities in the Pianura Padana area such as Milan.

The snow load was thus assumed to be 1.2 kN / sqm and the buildings were designed in class 3 seismic zone according to Italian regulations. The study case can be applied to other cities falling into seismic class 3 such as Florence, Pescara, Bari, varying the snow load.

The relevant reference regulations are the NTC 18 and the Eurocode with its National Annexes (NADs). The building is designed for fire resistance equal to R60.

The three structural solutions considered have been named for reading comfort “CONCRETE”, “STEEL 1”, “STEEL 2”.

1.1 “CONCRETE” Building



The CONCRETE building has a structure entirely in reinforced concrete characterized by pillars in descending square cross-section with the development in height of the building and floors filled with 30 cm thick.

The pillars section is 50x50 cm in size on the ground floor to reach a 30x30 section on the 7th floor.

The reinforcement of the slabs is made with double cross-link in improved B450C-reinforced steel bars - slow armature.

There is, on the pillars, a puncture reinforcement.

The reinforced concrete floors are made with the use of “Skydeck” provisional filling, with partial disarming.



SOLES AND FORMWORK TYPE

LOADS

Roof loads:

Floor covering in reinforced concrete plus extensive green roof (optional): 8.75 kN / m²

Snow load: 1.2 kN / m²

Wind loads:

For $0 \leq z \leq 5\text{m}$: $q_w = 0.67 \times c_p$ kN/m²

For $5 \leq z \leq 25\text{m}$: $q_w = 1.08 \times c_p$ kN/m²

Slabs loads :

Operating load (cat. B): 2.00 kN/m².

Permanent floor load: 7.5 kN/m².

Permanent load insulation-finishing-installation-trams-countertop package: 3.8 kN/m².

External facade weight: 1.00 kN/m².

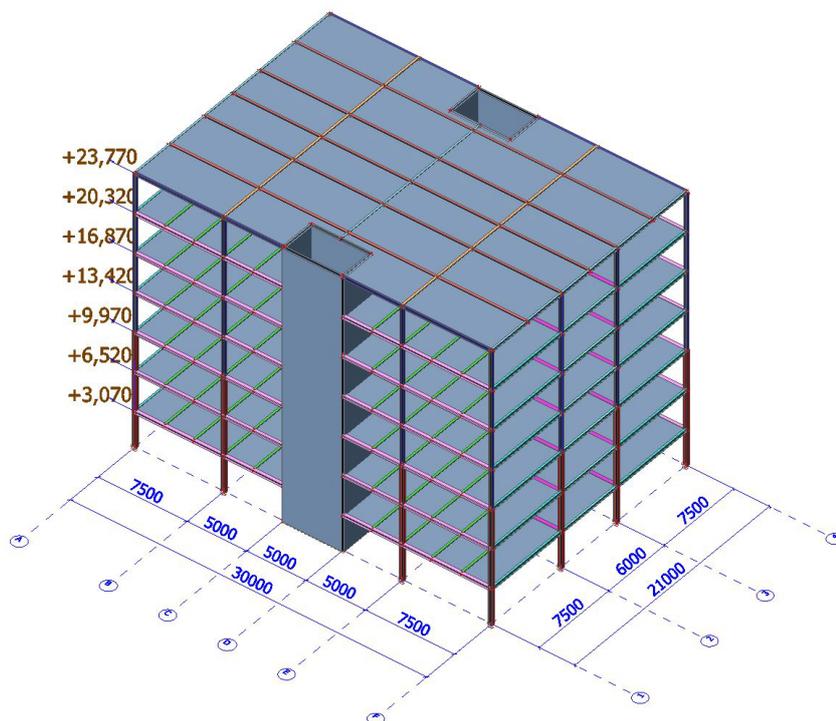
MATERIAL

For reinforced concrete, are foreseen C25 / 30 and C35 / 45 concrete and B450C reinforced steel.

Cast concrete quantity: 1.611 m³

Steel rebars quantity : 283 t

1.2 'STEEL 1' Building

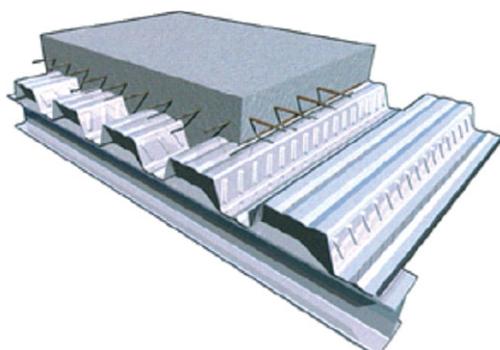


The 'STEEL 1' Building has steel columns in hot rolled profiles or chollow sections, the main and secondary beams are in hot rolled profiles.

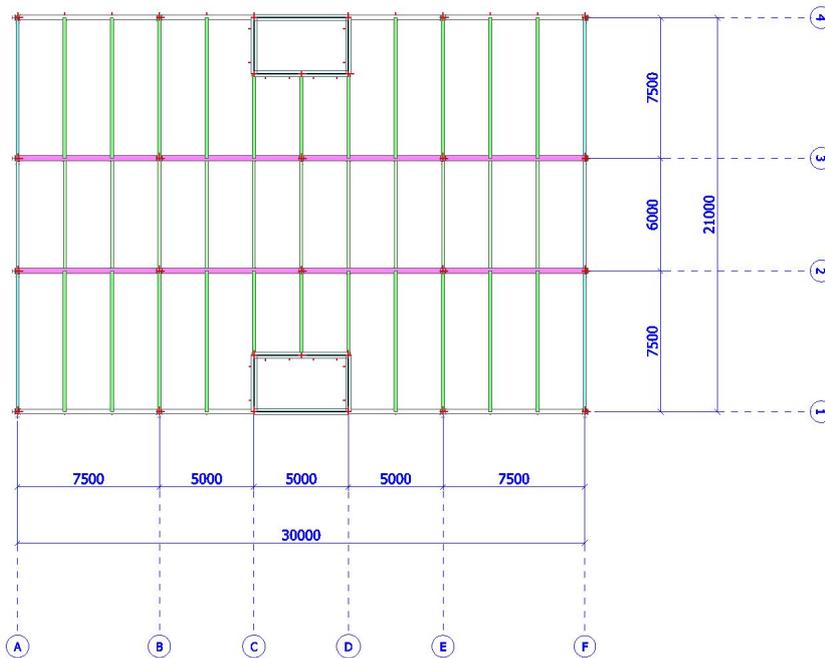
The floor slabs and cover are made of corrugated steel sheet type "Hi-Bond" 55 mm sp. 10/10 with concrete fill for a total height of 100 mm. There are no bracings groundwater and wall being the horizontal actions delegated to the concrete nucleos, an economical solution that allows you to have planes and facades completely free of bulk while guaranteeing the safety of wind and earthquake loads.

The execution class according to EN 1090-2 is EXC2.

The steel profiles are S355 quality and treated with a primer hand, plus intumescent coating.



DESIGN AND SITE VIEW
OF CORRUGATED STEEL
FOR CASTING



PLAN VIEW
PRIMARY AND SECONDARY STRUCTURES

LOADS

Roof loads:

Corrugated steel sheet plus extensive green roof (optional): 2.45 kN/m^2

Snow load: 1.2 kN/m^2

Wind loads:

For $0 \leftarrow z \leftarrow 5\text{m}$: $q_w = 0.67 \times c_p \text{ kN/m}^2$

For $5 \leftarrow z \leftarrow 25\text{m}$: $q_w = 1.08 \times c_p \text{ kN/m}^2$

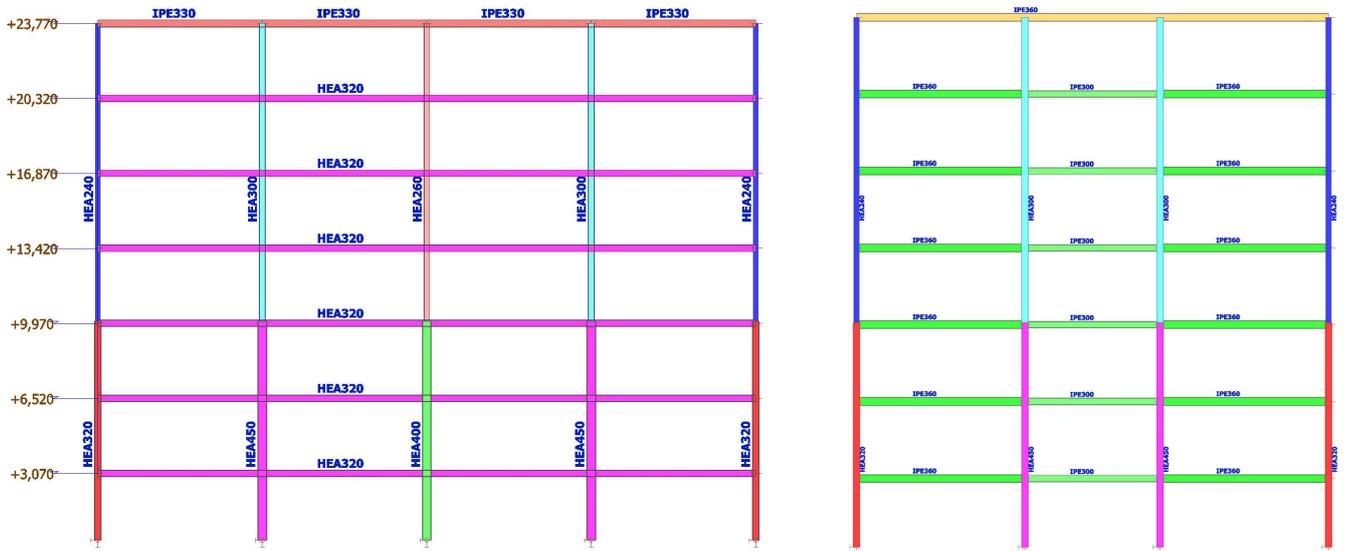
Slabs loads:

Operating load (cat. B): 2.00 kN/m^2

Permanent load of hi-bond + casting: 1.9 kN/m^2

Permanent load insulation-finishing-installation-trams-countertop package: 3.8 kN/m^2

External facade weight: 1.00 kN/m^2



SECTIONS

MATERIAL

Steel structure:

Total weight structure: 210 tons

Steel structures total weight / ($n_{\text{floor}} \times \text{floor area}$) = $210.000 \text{ kg} / (7 \times 630 \text{ m}^2) = 47 \text{ kg/m}^2$

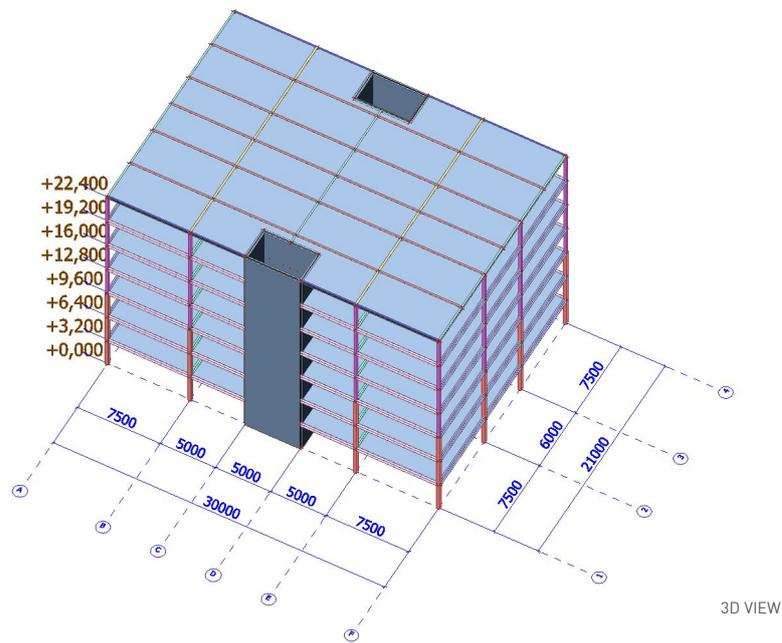
Slabs and cover:

4.200 m² of corrugated sheets slab

Other materials:

Concrete cores for lift shaft and staircases, supplementary casting and welded mesh for casting

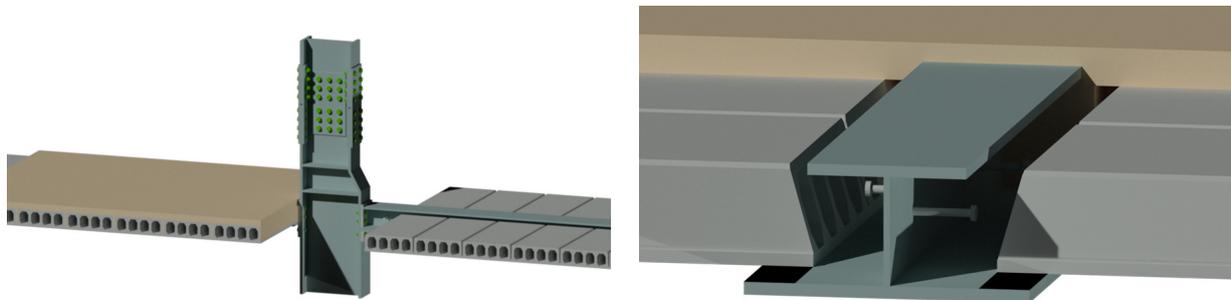
1.2 'STEEL 2' Building



The Building 'STEEL 2' is characterized by vertical and horizontal steel elements and multiple roofs in pre-pressed RAP-type slab plates, designed to form a slim floor system of 250¹ mm height and a 50 mm additional casting.

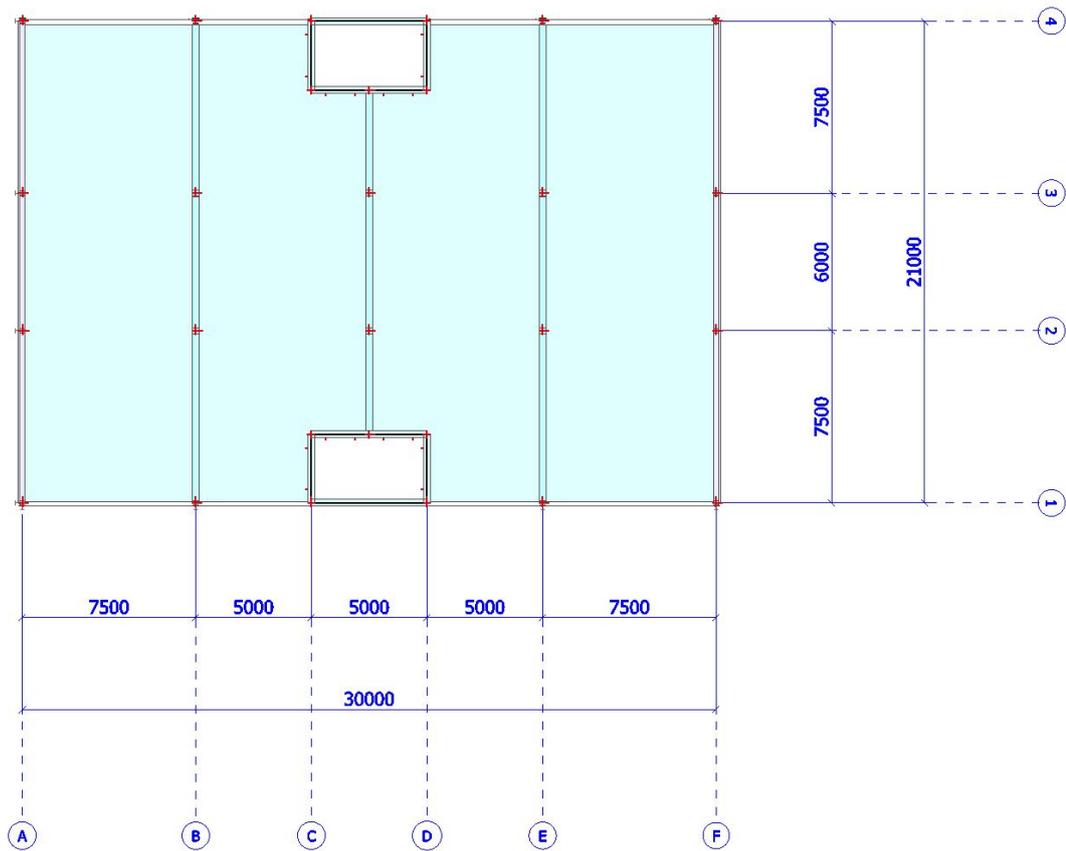
The structural mesh is in hot rolled profiles or thollow sections, the beams are in hot rolled profiles welded to the columns.

As for STEEL 1, are not provided for bracing flap and the wall, the execution class in accordance with EN 1090-2 is EXC2. The steel profiles are S355 quality and treated with a primer hand, plus intumescent coating.



"SLIM FLOOR" SYSTEM, EXAMPLES

1. It is possible to adopt the same structural system with RAP with floor height of 200 mm.



SLAB TYPE, PLAN VIEW

LOADS

Roof loads:

RAP floor covering plus extensive green roof (optional): 6 kN/m²

Snow load: 1.2 kN/m²

Wind loads:

For $0 < z < 5\text{m}$: $q_w = 0.67 \times c_p$ kN/m²

For $5 < z < 25\text{m}$: $q_w = 1.08 \times c_p$ kN/m²

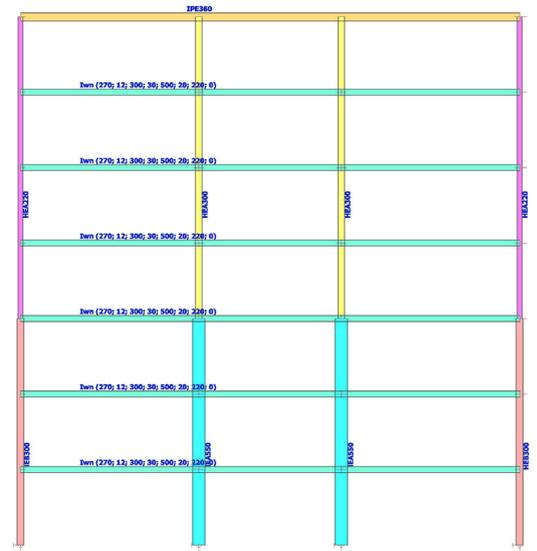
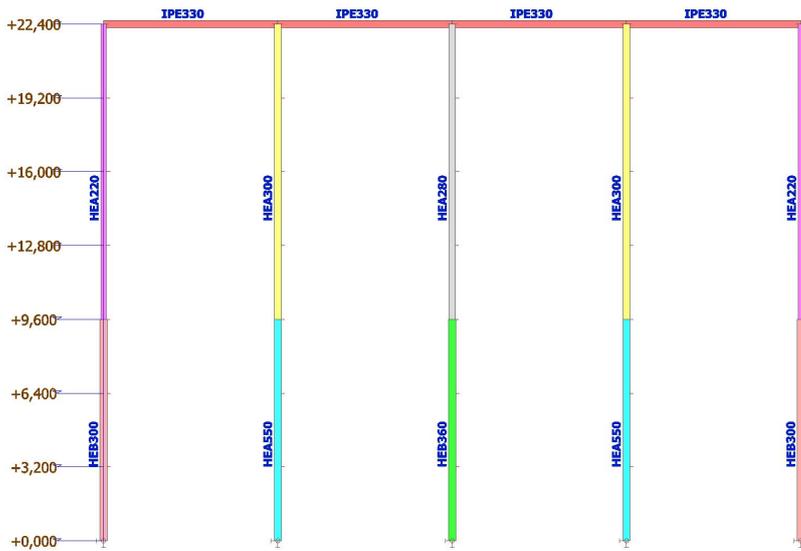
Slabs loads:

Operating load (cat. B): 2.00 kN/m²

Permanent load RAP + casting: 4.75 kN/m²

Permanent load insulation-finishing-installation-trams-countertop package: 3.8 kN/m²

External facade weight: 1.00 kN/m²



PROJECT SECTION

MATERIAL

Steel structure:

Total weight structure: 157 tons

Steel structures total weight / ($n_{\text{floor}} \times \text{floor area}$) = $157.000 \text{ kg} / (7 \times 630 \text{ m}^2) = 36 \text{ kg/m}^2$

Slabs and cover:

4.200 m² of alveolar floors

Other materials:

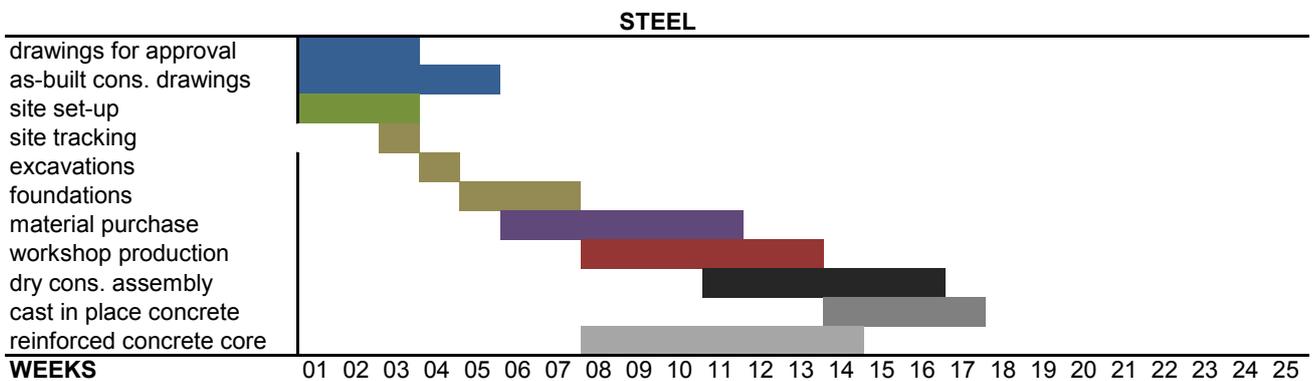
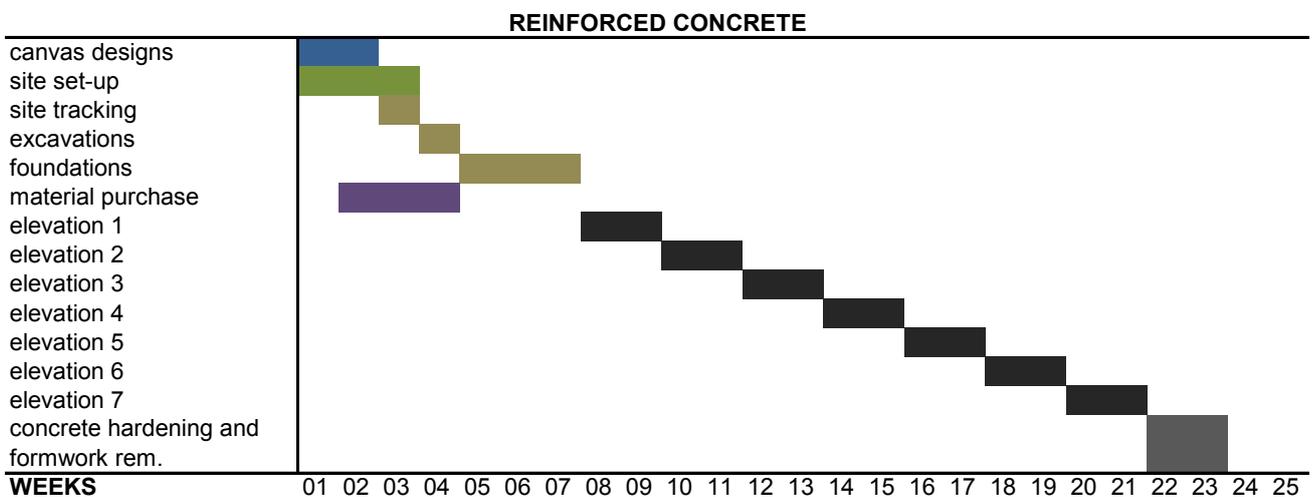
Concrete cores for lift shaft and staircases, supplementary casting and welded mesh for casting

2. COMPARISON BETWEEN SOLUTIONS: PROS AND CONS

INTRODUCTION

In comparison, the foundations were taken of the same type and depth (in fact, the two steel solutions, having a massively reduced mass with respect to the solution in c.a, lead to an important saving in foundation). The prices of steel and concrete products derived from the price of the Milan Chamber of Commerce. The final cost is also comprised of construction, machining and installation of the structures.

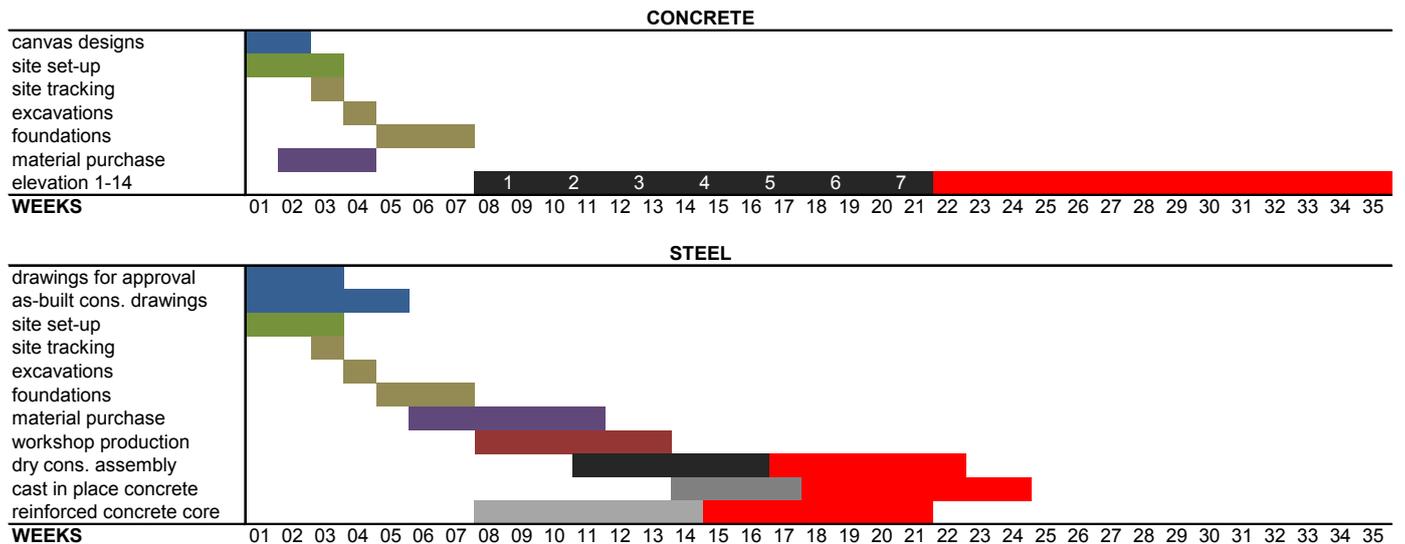
TIME COMPARISON



TIME COMPARISON TAKING AS THE START OF THE CONTRACT BEGAN

In comparison to the times, for the present study case, a 7-story building, there are some differences. The design phase of the constructors / builders is longer for steel structures, as well as supplying the material. At the arrival of the material at the steel manufacturer, follows the production of the elements in the workshop, including painting. Preassembled in the workshop, the structures are later put into operation with a “meccano” pattern and with considerably lower times than a wet system.

In conclusion, for the construction of STEEL buildings 17 weeks are required, for the CONCRETE building 23 weeks are required.

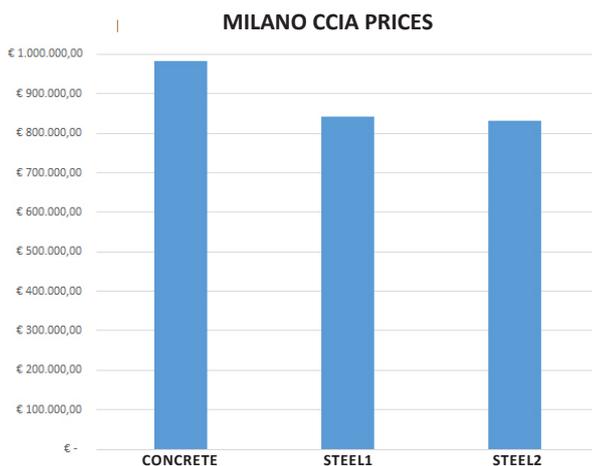


COMPARISON OF THE TIMES BY ASSUMING 14 FLOORS

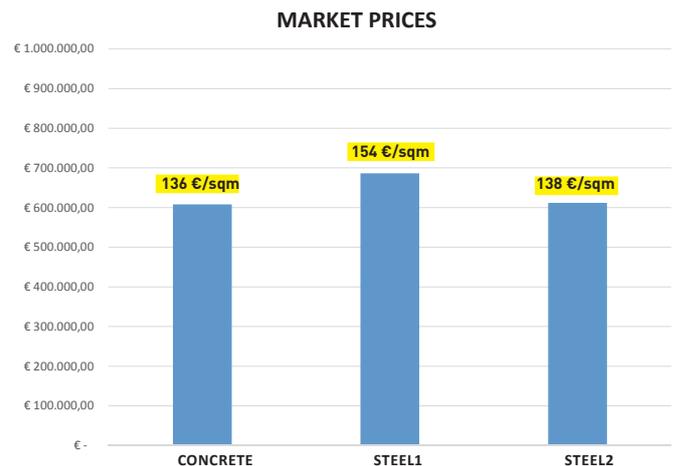
In the above timeline, the additional times required in the event of building a 14-story building are shown in red. Including ripening times and dropping the CONCRETE building could be done in 37 weeks while the STEEL building in 24 weeks.

The time gap would then go from 6 weeks to 13, equivalent to approximately 3 months of net gain for the steel solution.

COSTS COMPARISON



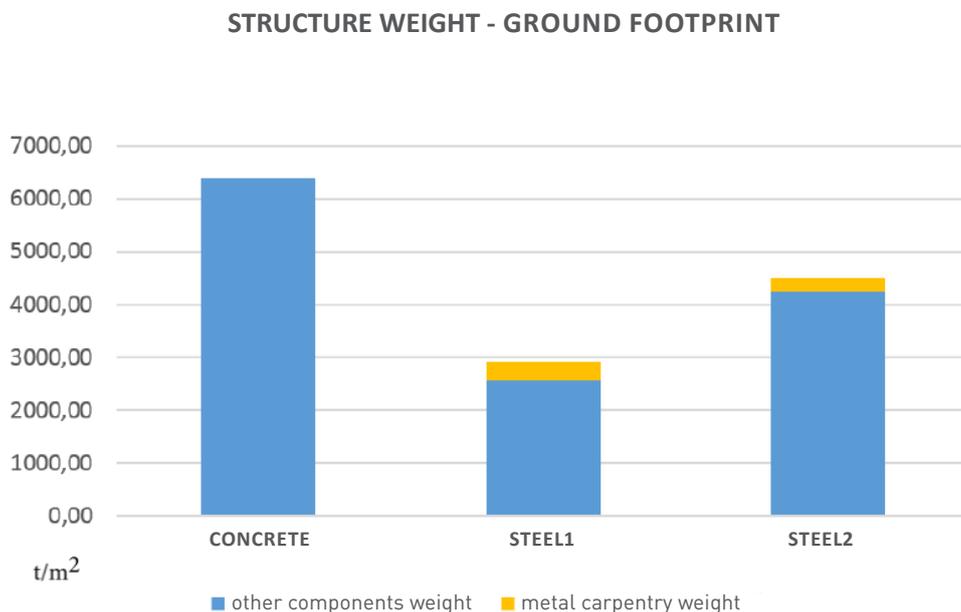
COSTS IN THOUSANDS OF EUROS OF DIFFERENT CONSTRUCTION SOLUTIONS ACCORDING TO CCIA PRICES IN MILAN



COSTS IN THOUSANDS OF EUROS OF DIFFERENT CONSTRUCTION SOLUTIONS ACCORDING TO MARKET PRICES

WEIGHTS COMPARISON

We also wanted to compare the weight of the structures taken in this case study, a variable that affects the resistance to horizontal actions and excavation and foundation works.



COMPARISON FOR THE DIFFERENT CONSTRUCTION SOLUTIONS IN TERMS OF RELATIONSHIP BETWEEN THE WEIGHT OF THE STRUCTURAL COMPONENTS WITH RESPECT TO THE FOOTPRINT AREA EXPRESSED IN t/m²

SUMMARY OF RESULTS: PROS AND CONS

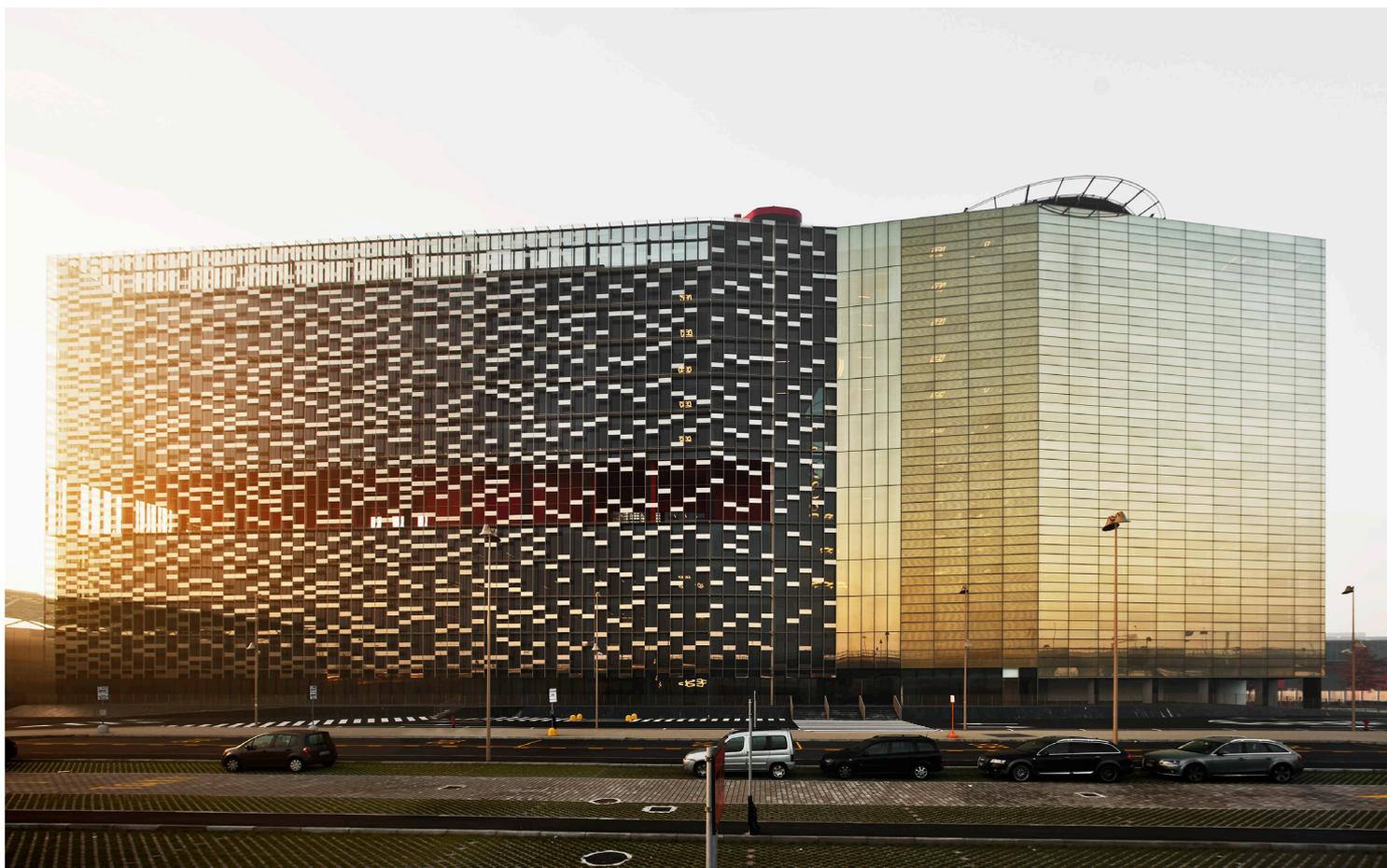
From comparisons, it is clear that **both steel solutions are more advantageous** in terms of saving time and at the same or slightly higher cost than a concrete solution put into operation.

The CONCRETE building is also much heavier than those in metal carpentry.

The comparison to the buildings STEEL 1 and 2 reveals some differences. STEEL 2 allows a great savings in floor height, comparable to the solution in reinforced concrete with slab. The STEEL 1 building also requires a greater amount of material, with main and secondary beams, unlike the alveolar flooring that only needs main beams.

The case study with corrugated sheet metal slabs is however much less heavy and can be advantageous with a larger number of floors or in areas of high seismic activity or poor bearing capacity of the soil.

3. CONCLUSIONS: HOW TO MAKE THE BEST CHOICE



WIND HEADQUARTER, RHO (MI) - PROJECT:
5+1 AA ALFONSO FEMIA GIANLUCA PELUFFO

Modern building cannot fail to take into account some additional aspects besides that of more immediate understanding: the direct cost of construction.

One of the aspects to be considered closely related to the cost of time is that of timing: an investment or project that falls within the expected times of realization is undoubtedly advantageous by allowing you to plan with certainty the market strategies. However, a typical approach of the past years, in which constructive speed was inversely proportional to the quality of the built, has to be avoided.

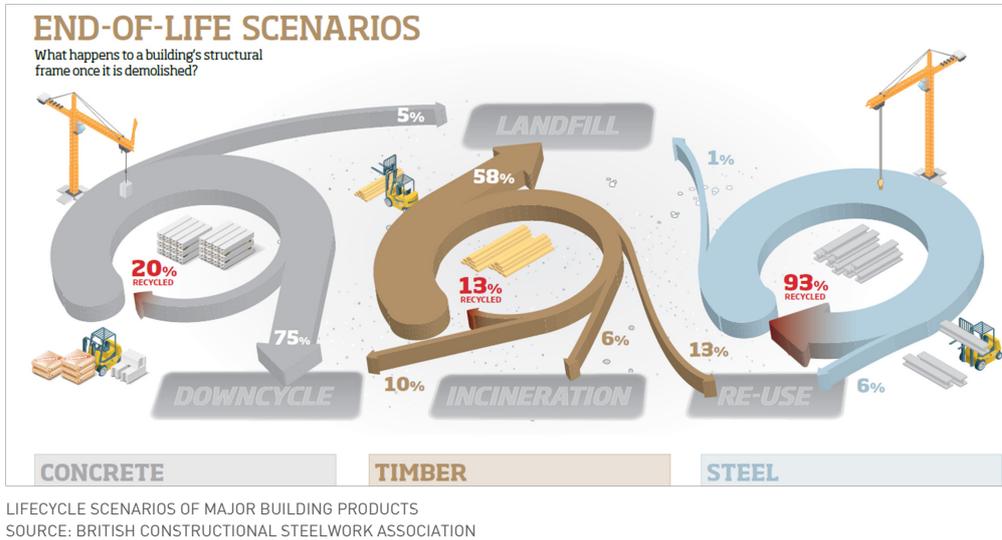
SEISMIC SAFETY

Steel constructions are seismically safe thanks to their lightness and ductility that can reach energy dissipation levels excluded from other structural materials.

A steel solution has a lower seismic mass than an reinforced concrete, a feature that, added to a constructive process involving prefabrication in the workshop and dry connection, leads to the creation of light structures subject to a more contained horizontal actions.

ENVIRONMENTAL SUSTAINABILITY

The aspect of environmental sustainability is indispensable both from a normative point of view, with energy certification as a mandatory parameter, and on the world's policy of safeguarding and protecting the planet. **Steel is the recyclable material for excellence**, the product derived from steel recycling (99%) is a high-quality material, the remaining 1% is recovered as quality inert for road use.



Concrete at end of life can be recycled to 20% and destined for inert production by 5%, 75% is destined for downcycling. One of the features that makes steel truly unique is that it can be built with prefabricated elements that, at the end of the useful life of a building, are easily dismantled so that they can be recycled and reused. This means that a steel structure can be “resurrected” without consuming other raw materials.

Emblematic in this regard is the case of EXPO Milano 2015 where 80% of the temporary works of the buildings were made of steel precisely for the possibility of recycling, explicitly required in the masterplan. Not only: steel buildings used for EXPO have been moved to other locations and reused with various functions without the need for demolition.

The latter figure highlights another of the winning attributes of the material at environmental sustainability level: durability. Appropriately protected steel keeps its properties intact, helping to extend the life of the building.

CONSTRUCTIVE TECHNOLOGY

A key factor that can have a significant effect on the timing of construction of a multi-storey building is the technology used.

With a stratified dry steel construction system, the processes are totally industrialized: the load-bearing structures are entirely preassembled in the workshop in mechanical elements, allowing the installation on site in considerably faster compared to entirely wet systems times.

The site is optimized and the scrap practically non-existent; the lifting and laying means are generally much lighter and the ability to intervene in problem areas due to the presence of pre-existence, infrastructure or particular conformation of the ground is considerably higher than that of a traditional shipyard. In dry constructions, the casing is also of reduced thickness, allowing tailor-made modulation of performance levels.



PALAZZO GRASSI THEATRE, VENICE
TO THE LEFT THE INTERVENTION AREA, FROM THE VERY LIMITED MANEUVERING SPACES TO THE RIGHT OF THE STEEL CONSTRUCTION SITE
PROJECT: TADAO ANDO ARCHITECT & ASSOCIATES.

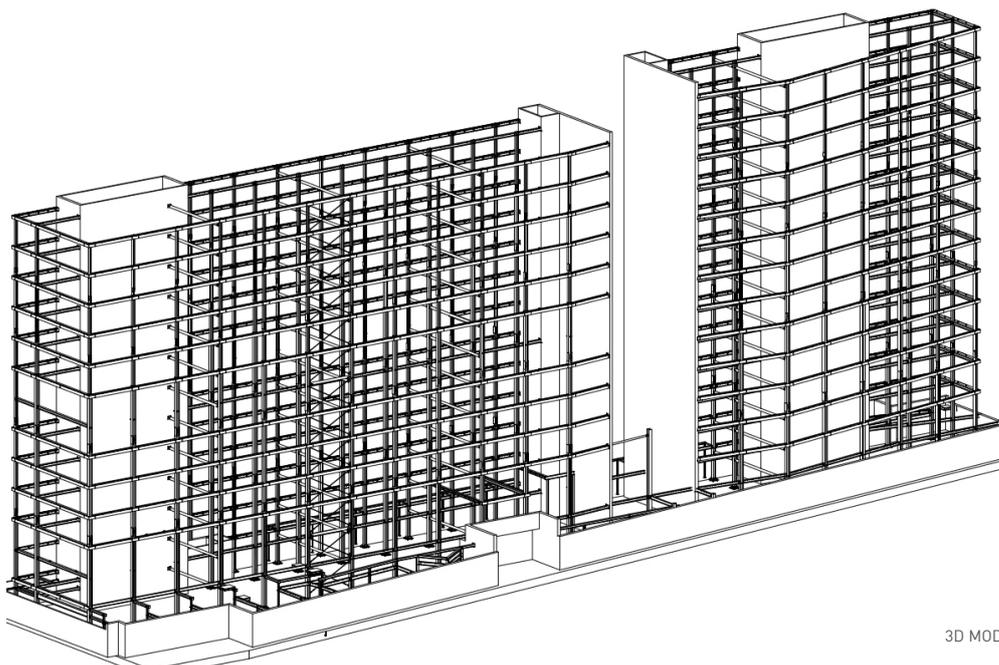
The steel site is therefore faster and easier, but not only that: it is also more “safe” both from the point of view of the more skilled manpower, and from the point of view of the material.

Construction steel is traced from production, ranging from the first processing processes in the service centers / distributors to the factory prefabrication and on-site assembly through European standards that guarantee its quality.

The high-speed and quality of the built-up result in the economic environment as a profitability of the building.

Lastly, it is increasingly important the engineering of the entire constructive process, from modeling to structural calculation, from purchases to production, from testing to maintenance, which creates a dialogue between the different operators of the supply chain (buyer, architects, engineers, management of works, plants, suppliers, etc. .).

The use of a BIM platform allows for optimum process and material optimization, thus guaranteeing timing and cost of construction. Steel products are perfectly integrated within the most commonly used software in this field.



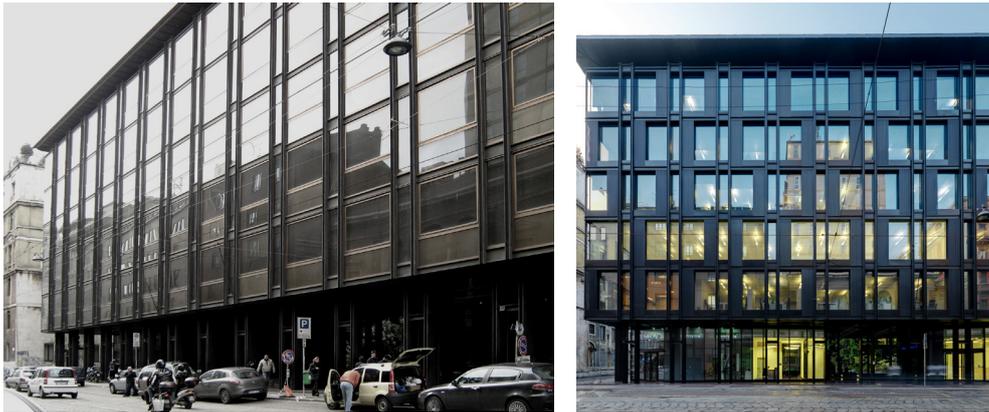
3D MODEL OF A MULTI-STORY BUILDING

IMMATERIAL FACTORS

Linked to environmental sustainability is the concept of **circular economy**.

The circular economy assumes that products keep their value as long as possible or that, at the end of their life cycle, they can be reinstated in the economic system without any particular energy consumption. Both from the point of view of the material and from the point of view of the “product-building”, the steel is pole position and the metal constructions are winning.

A steel building can easily change its intended use without the need for substantial or invasive structural interventions. Also, working on a steel building for a restyling of it is undoubtedly simpler than refurbishing a building built with low durability materials.



FROM LEFT TO RIGHT: PRE-INTERVENTION AND POST REQUALIFICATION "LA SERENISSIMA", MILAN - RESTYLING PROJECT: PARK ASSOCIATI. MADE IN THE 1960S WITH STEEL BEARING STRUCTURES, IT HAS BEEN UPGRADED WITH ENGINEERING AND MINIMAL CONSTRUCTION WORKS.

Among the intangibles, it is worth mentioning the social benefits [4] of a building, as defined in UNI EN 15643-3: among the parameters indicated in the assessment of social benefits are the entries:

- adaptability
- maintenance
- health and comfort
- impact on adjacent structures
- security

A steel building with stratified dry technology offers excellent performance in the listed parameters. It can be readily adapted, using mainly cold-formed galvanized profiles and plasterboard plates for internal partitioning; maintenance is easier and longer in the long term.

The speed of the construction site and its cleanliness means that the impact on the neighborhood is less prolonged and intrusive, a good design steel also tends to be more easily integrated with the surrounding context.

Finally, it is certainly worth considering the value analysis of a building.

Without going into the specificity of the methodology [5], the subject of various European norms, legislative references and publications can be summarized in the equation: value = quality + services / cost + timing.

Where steel construction offers reduced costs and time, it is also capable of delivering high quality, both from the material and constructed point of view. An accurate project and efficient construction can also provide excellent services to the investor and to the end user.

BIBLIOGRAPHY

- [1] Economic and Steel Outlook Outlook 2019-2020 - Eurofer.org, May 2019
- [2] Survey on the use of materials in the non-residential construction market in Italy, analysis of the diffusion of steel products - trend of the last ten years and future developments in the real estate market - Fondazione Promozione Acciaio, November 2015
- [3] Economic Development Center Observatory - Ance, January 2019
- [4] UNI EN 15643-3: 2012 Sustainability of buildings - Building evaluation - Part 3: Reference framework for the evaluation of social benefits
- [5] AIAV - Italian Asset Management and Value Analysis - aiav-valore.it

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COMPARATIVE STUDY DEVELOPED BY:



via Vivaio 11 20122 Milano | Italia
tel +39 02.86313020
promozioneacciaio.it

WITH THE TECHNICAL CONTRIBUTION OF:



via Edison 15, 39100 Bolzano | Italia
tel +39 0471 065000
pichler.pro