

Integration of Composite Structures in Modern Day Architecture: Case Study of City Business Centre, Timisoara, Romania

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Abstract. In current day structural design the use of composite steel-concrete structures has become the norm; because of the advantages that each of these materials has to offer. Composite structures also have the benefit of a faster execution at a lower cost, compared to traditional structures. While the arguments in favour of designing composite structures are well-known and appreciated by civil engineers; there remains a question of integrating these structures in modern-day urban landscapes. Eastern European countries are welcoming a blossoming of culture, arts, economy and industry, which unavoidably and necessarily will lead to a change in urban landscapes. With an increasing amount of foreign companies opening offices in these areas, the need for modern office solutions has arisen.

The current paper presents a case study of an office building complex situated in the western part of Romania, in the city of Timișoara. The complex consists of 5 office buildings; all designed in composite steel-concrete structure, an underground parking lot, multiple terraces and adjacent promenade areas. Within the context of rapid growth and development of the city, the City Business Centre has offered high quality office spaces in the heart of the city, while considering the needs of the community. A very important aspect in the successful completion of the project was the efficient and professional collaboration between the separate project teams, between the owner, represented by the project management team, the architect, the structural designer and the building company. The successful joining of seismic structural solutions with modern architectural aesthetics has led to a dynamic, vibrant environment, making the City Business Centre the core of the region's business life, at the same time redefining Timisoara's architectural landscape. A testimony to the success of the project was the Civil Engineering Structural Designers Associations' (AICPS) 3rd Prize awarded for great performance and quality in structural design. The project was also awarded a „Green Building of the Year” award by the Romanian Green Building Council and also the „Office Development of the Year” in South-Eastern Europe awarded at the Real Estate Awards by an international jury of renowned real estate developers, consulting firms and investment banks. The project was also selected by the European Architects' Council to represent Romania in a Sustainable Architecture Exhibition at the European Parliament in Brussels.



1. Introduction

When talking of composite structures one usually refers to the use of at least two different structural construction materials, as for example steel, reinforced concrete, wood, aluminium etc. The current article will focus mainly on steel - reinforced concrete composite structures.

The use of composite steel-concrete elements in a structure has been around for many decades and continues to be more and more present around the world, as these structures have proven themselves to be quite efficient both structurally and economically. The material properties of reinforced concrete and steel are well known, with the concrete having a good compressive resistance and the steel a good tensile resistance. Combined, the two materials can assure a high resistance capacity, which also leads to slender elements, that are more economical and at the same time aesthetically pleasing.

The generally used composite structural elements include composite beams, which represent steel beams connected to the reinforced concrete slab by means of shear connectors; composite slabs, which are reinforced concrete slabs that have been poured into steel profiled sheeting; composite columns, which include a steel profile completely or partially encased in concrete.

While in some countries the use of these structures is prevalent, in others, mainly those from the eastern part of the continent, especially former communist countries, are only now discovering the benefits of such structures. The integration of new architectural currents and structural solutions into an existing urban landscape can prove a challenge, which sometimes when faced with professionalism and a good team of specialists, can also lead to a success.

2. Case-study: City Business Centre, Timisoara, Romania

2.1. *Geographical and social background*

A lot of eastern European countries are currently welcoming a new age of development, reflected in everything from everyday life, to art, to the different industries. In terms of the construction industry this development can be observed in new building being erected, often times contrasting with existing historical or communist era buildings.

Romania, which is located in central-eastern Europe, at a crossroads between the West and the East, presents a similar situation. Since most of the country was occupied for decades or even centuries, (notably being the austrian-hungarian occupation), most cities are filled with historical buildings from that time. Being subjected to a communist regime for approximately 40 years, the country was also filled with “monuments” of communist architecture.

Timisoara (Figure 1) is the largest city in the western part of Romania and third largest in the country. It represents an important industrial, commercial, medical and educational center. It was part of the Kingdom of Hungary in the 14th to 16th century, was under ottoman occupation for 150 years and also part of the habsburgic and austrian-hungarian empire for two centuries. Lastly in 1918 Timisoara finally became a part of Romania. And a very important part, since it is the place where in 1989 the spark appeared that ignited the Romanian people’s revolution, which put an end to communism in the whole country. After such a troubled past, Timisoara was left with a very multicultural background, a melting pot of different cultures, traditions, languages and last but not least, different urban landscapes.

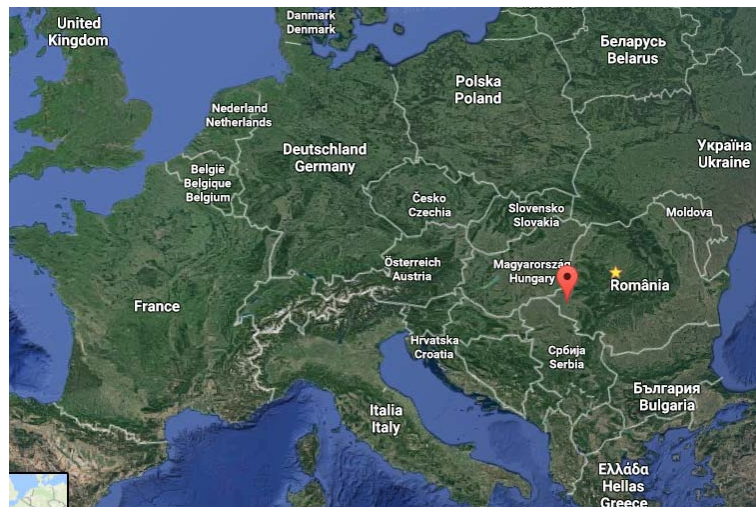


Figure 1. Geographical location of the city of Timisoara, Romania

Timisoara has the highest number of historical monument buildings in Romania (over 14.000), but sadly these beautiful baroque, art-nouveau and secession style buildings are overshadowed by “communist” buildings, erected in all the historical areas, including the city center. Most of these buildings are large prefabricated concrete panel buildings for collective housing. But since during communism the country underwent a wave of industrialization, the cities were also filled with factories. Timisoara was no exception. One of these buildings was represented by the “Bega” clothing company, located very close to the center of the city. Though a state owned company (since 1959), after the fall of communism it was privatized in 1994 and became a family business - ModaTim (Figure 2). In 2009 the clothing company relocated its facilities outside of the city limits, thus presenting an incredible real estate opportunity for the remaining plot of land.





Figure 2. a-c) The old buildings of the ModaTim clothing company - different views

Under these circumstances in 2006 a building project was started, consisting of 5 class A office building, the first of their kind in Timisoara. The project, quite impressive compared to other new constructions at the time, was to provide the city and its ultra-central areas with much needed quality office spaces, conference rooms, art gallery, commercial spaces, underground parking etc. While also rehabilitating the adjacent areas, the project has managed to add a special flavour to the city's business life.

2.2. Architectural Design

The City Business Centre building complex was finalized recently on the edge of the historical center of the city. It has successfully replaced several textile industry buildings erected in the seventies over the pre-existing 18th century Vauban type defense walls foundations. The area was part of the communist industrial framework of Timisoara, which started with the construction of the Textile Factory and the Civil Engineering High School and continued after the fall of communism (1990) with the construction of different public and private buildings, all developed in the absence of a coherent urban planning system or strategy.



Figure 3. Volumetric view of the area and the City Business Centre ensemble

The main objective of the City Business Centre ensemble was the development of public galleries and plaza, semi-public spaces, halls, foyers, conference center, commercial spaces and, at upper levels, a class office, all tied together in a compact pattern with the purpose of representing the first step of an urban regeneration project. The ensemble presents common elements for all five buildings with superimposed layers, with green terraces over the mezzanine and 5th floor, intermittent loggias with ceramic louvers creating a transparent inner space, and the unifying, dominant element – the mezzanine level, prevailing over the entire composition. A curtain wall type glass façade represents the outer skin of the buildings contrasting with the ceramic louvers and green terraces [1].

A pedestrian gallery between the northern and southern poles of the urban plaza generates a gate towards the first two buildings from the east and integrates the two atriums from the west. The longitudinal gallery following the site's north-south axis becomes the backbone of an ensemble where pedestrian passages host lively landscaped spaces, urban art and glass funnels. The south corner boundary is represented by the urban plaza, which became a generous amphitheatre, due to the existing level difference. Although the initial project featured an emblematic work of art in this location, an archaeological surprise offered a whole new perspective and purpose for this particular space.

2.3. Archaeological findings

During foundations work, defense walls including a XVIII century sluice used in the defense system around the bastion emerged while digging and construction on the site halted in order for the history museums archaeology team to come and assess the finding.

Historically, the city of Timisoara played an important defensive role during the Ottoman Empire and the Austrian- Hungarian Empire occupations. Surrounding swamps and moats made the fortress of the city difficult to be conquered. After the Austrian conquering of the city in 1716 new defense walls were built and hydro-technical systems for regulating the water levels of the moat within and surrounding the fortress. Because of the low bearing capacity of local soils all the new buildings were constructed on top of wooden pile foundation.

After careful consideration of the unique discovery of the historical hydro-technical system, the decision was made to disassemble and reassemble everything within the newly constructed urban plaza. While keeping the original orientation, everything (approximately 400sqm) was translated by 30 meters to the east and lifted at a height of approximately 5m. An open-air museum was conceived, with exhibition panels (that present information about the fortress defense walls and water monitoring system of the sluice), suspended viewing terrace and night time architectural lighting system. The display of the architectural findings demonstrates the benefits of urban regeneration, the importance of the collaboration between engineers, architects, archaeologists and local authorities and can engage people in the rescue and valorisation of historic heritage sites and buildings.

This particular example is the proper symbol for a technological innovative city, while enhancing the atmosphere of the pedestrian gallery and plaza - a surprise exhibition dedicated to Timisoara's modern history [2].



Figure 4. Archaeological discovery and relocation to the out-door museum in the urban plaza

2.4. Structural Design

The structural design objective was to create an 10 storey office building (Figure 5), consisting of underground parking level, ground floor, mezzanine, 5 storeys, penthouse and utility terrace level, while considering loading from permanent and live loads, snow and wind loads and seismic action.

Timisoara is located in the Banat region of Romania, its second most important seismic region with characteristic low depth earthquakes. This fact is very important in the structural design of buildings in the region and must be taken into consideration during the design phase [3]. Composite steel-concrete structures have an adequate behaviour in the case of seismic action and are well suited in this case. The importance class of the buildings is class III and seismic zone D. Design values for Timisoara's seismic zone were considered to be $a_g=0.16g$ and $T_c=0.7s$ [4].

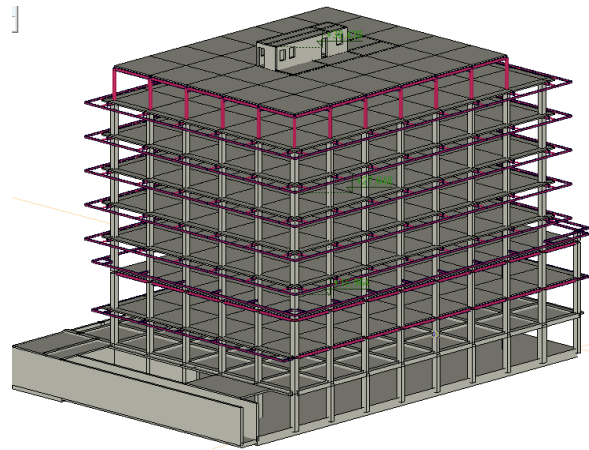


Figure 5. Steel-composite structure - numerical design model

The structural solution best fitted for the design of the structure consisted of composite steel-concrete frames on two directions, transversal and longitudinal, with a reinforced concrete vertical diaphragms central for the central tube, housing two staircases and the elevator shaft (3 elevators). The frames included both composite beams and composite columns.

Composite steel-concrete structures have the benefit of quick on site erecting, leading to a lot of storeys being built in a short period of time compared to classic reinforced concrete structures which need extra time for the concrete to reach its complete resistance (after 28 days).

The structural analysis was performed on the 3D numerical model considering serviceability limit state conditions (SLS) and ultimate limit state conditions (ULS), as indicated in Eurocode 4 [5]. The relative displacements for each level were calculated and all within normative limits, with the highest value reached by the mezzanine floor of 11 mm (maximum admissible 20mm). Afterwards stress diagrams were used in order to establish the design values of the stresses, for axial force, bending moment and shear force.

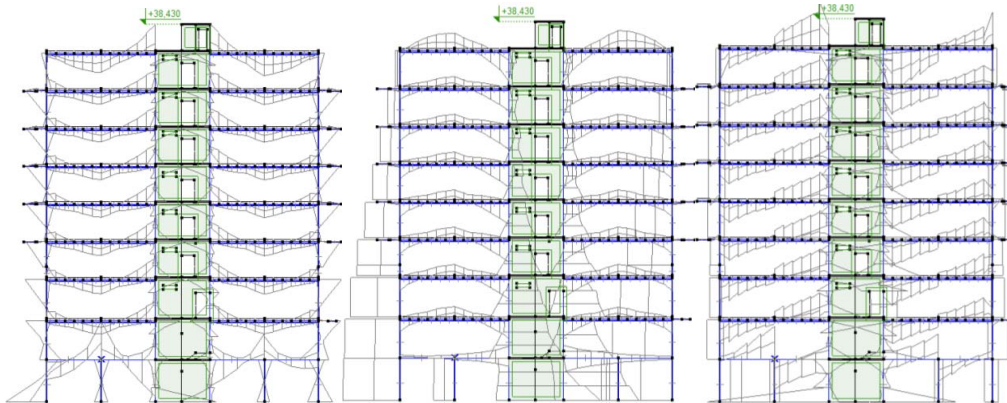


Figure 6. Stress diagrams – Bending moment M , Axial Force N , Shear force T

For the beams two different profile sections resulted (Figure 6 and Figure 7), an HEA450 profile and a more slender IPE450 profile, using S235 steel grade. Since the beams are realized in composite solution, steel Nelson shear stud connectors were used to assure the composite behaviour of the beams. They were positioned in two rows along the whole length of the beam.

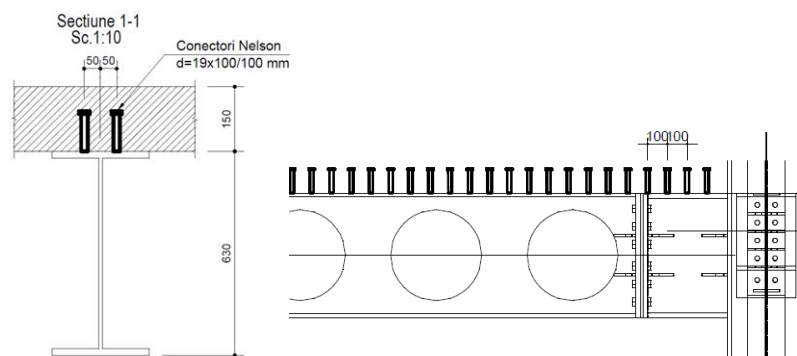


Figure 7. Composite HEA450 beam details: Cross-section; Beam-column connection detail.

The initial beam profiles were used in order to obtain castellated beams with circular openings (Figure 9). All of the heating, ventilation, air conditioning (HVAC), electrical and fire-prevention equipment was installed through the beam web openings. By reducing the necessary height for installation of the different types of equipment in the ceiling an additional level could be added to the structure, while still maintaining the limit for medium height buildings as prevalent in the area.

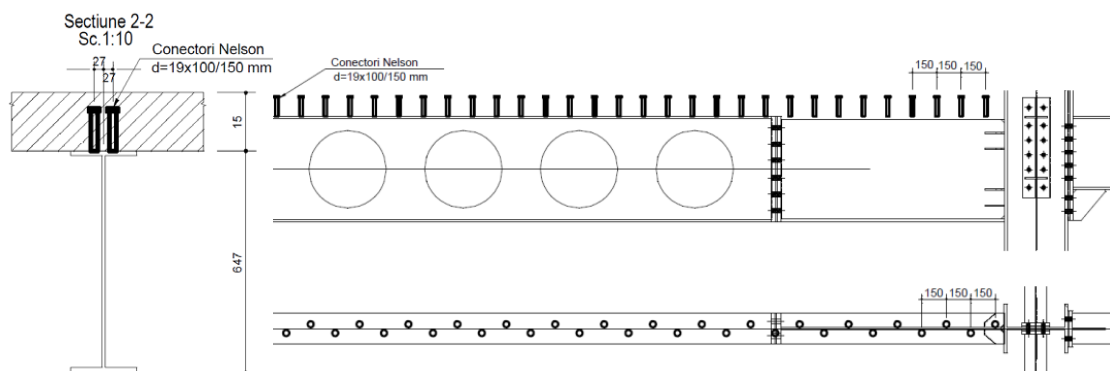


Figure 8. Composite IPE450 beam details: Cross-section; Beam-column connection detail.

The column analysis for compression, bending, shear and combined axial force-bending moment calculation resulted in a HEA300 steel S235 profile, encased in a concrete rectangular cross section of 45x65cm for the columns on the perimeter of the building and a HEA500 steel S355 profile encased in an almost rectangular concrete section with 65x65cm dimensions, as seen in Figure 8 and Figure 10.

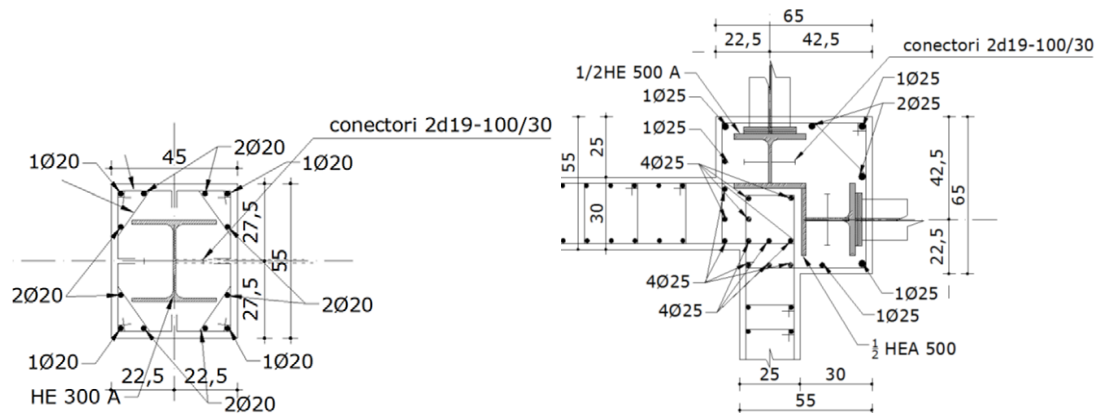


Figure 9. Column cross-section: Left- Exterior perimeter column; Right - Central column.

On both sides of the web of the column profiles studded shear connectors were applied in one row along the length of the column in order to assure the complete interaction between the steel profiles and the reinforced concrete. For all the concrete elements a concrete class of C20/25 was used.

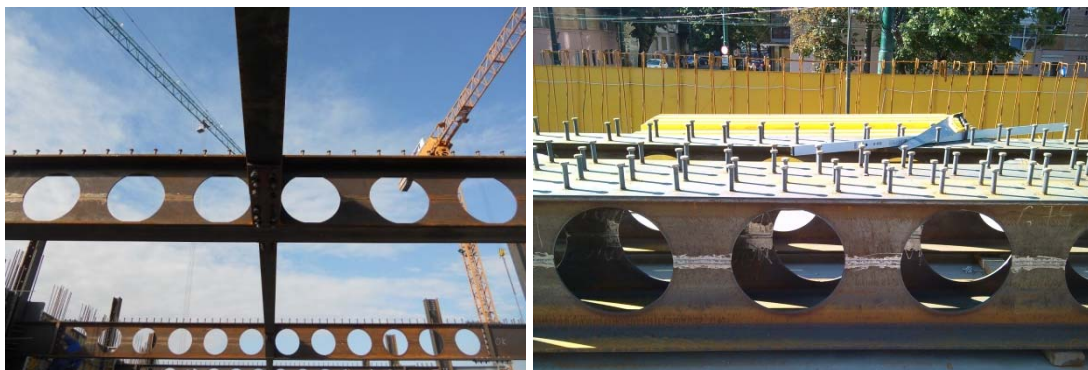


Figure 10. Castellated beams during construction



Figure 11. Composite columns during construction

3. Discussions

3.1. *Advantages of composite steel-concrete structures*

The advantages of composite steel-concrete structures range from structural, to financial, even logistical. From a structural point of view these types of structures are quite appropriate for seismic areas, combining the resistances of both steel and reinforced concrete, leading to smaller cross sections (less material means less costs), more efficient use of space, and more flexibility in design. The castellated beams allow placing equipment through them, leading to a more effective use of floor height. The time efficiency of erecting such a structure is another important advantage, which also makes composite structures an economically competitive solution.

3.2. *Conclusions*

Even though the position is very close to the city centre, the presented area used to be very unremarkable, consisting mostly of industrial buildings and brown fields. The new office buildings project has achieved its first goal of obtaining an efficient ensemble as speculative investment. Another goal of the project was to connect main pedestrian routes transforming the ground floor and the mezzanine in public and semi-public spaces (Figures 11, 12, 13).



Figure 12. Aerial view of the City Business Centre ensemble

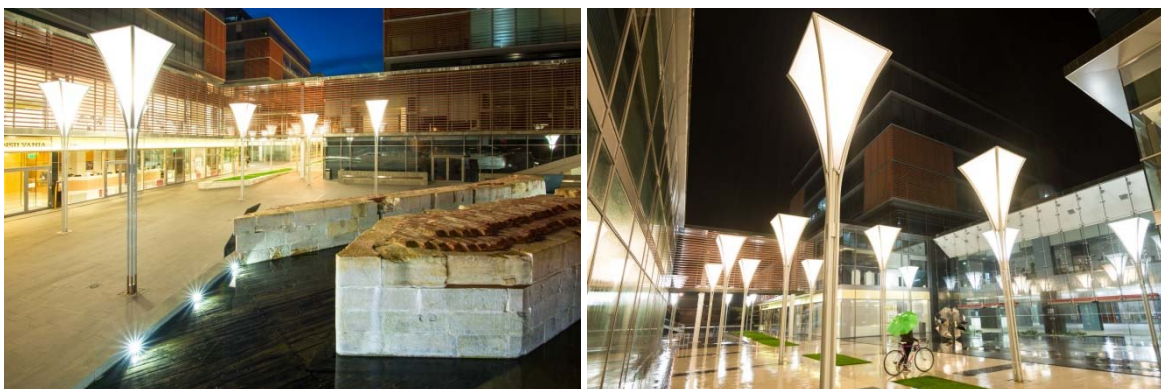


Figure 13. View of the pedestrian zone between the buildings

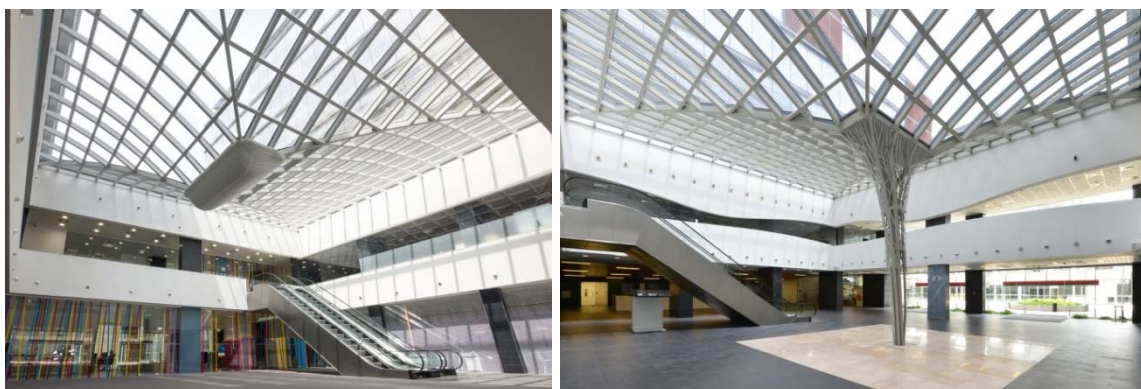


Figure 14. Lobby areas – Building C and E

The use of modern composite steel-concrete structural solutions allows for a greater flexibility in architectural design, with more spacious buildings, suited for a whole range of destinations, from offices, to art galleries, conference rooms and commercial spaces. The structural elements do not inhibit the aesthetic of the building, but enhance the possibilities of different architectural elements and design solutions, while still ensuring the necessary structural resistance.

Conceived as a gate to the city, the City Business Centre ensemble was expected to regenerate the whole west part of the city centre. During initial discussions and design, it was established that the urban plaza will represent an optimal out-door exhibition space to feature art pieces and locally found archaeological artefacts, [2]. The successful joining of seismic structural solutions with modern architectural aesthetics has led to a dynamic, vibrant environment, making the City Business Centre the core of the region's business life, at the same time redefining Timisoara's architectural landscape.

Acknowledgment

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