Factsheet no. 3: HIDROTIM office, Timisoara, Romania

Project summary



Client: SC HIDROTIM SA, Timisoara / Romania (for SIEMENS Romania LTD) Contractor: KLITEHNIMA LTD, Timisoara / Romania Architect: ARHITECT TRAMBITAS LTD, Timisoara / Romania Structural engineers: GECONSTRUCT LTD, Timisoara / Romania Steel fabricator: KLITEHNIMA LTD, Timisoara / Romania

Description of the existing building

The existing steel structure, located in Timisoara, Romania, had the initial destination of a hydraulic testing laboratory for hydraulic power steel equipment. The building was erected in the 60s as a single storey industrial hall of steel structural elements with crane, having thermo-insulated roofing and wall cladding. The continuous roof purlins were built using the classic solution of hot rolled I24 profiles. A corrugated steel sheeting connected to the purlins sustained the other roof layers.

The main geometric dimensions of the hall were the following:

- Span L=21.00 m;
- Bay T=9.00 m;
- Bay number = 3;
- Eaves height of transverse frame h=+18.29 m (with respect to level $\pm 0,00$ m);
- Ridge height of transverse frame = 18.84 m;
- Level of crane bracket = +13.435 m.



Existing hydraulic laboratory building - industrial hall with crane



An electric crane of 12.5 tones capacity was provided, with a span of 19,25 m. The level of crane girder rail was +14,00 m. In view of supporting the crane girder the columns were designed with variable built-up cross-section as described in next figures. The column base was restrained supported on the foundation block at level –0,90 m by means of four anchoring bolts M48 grade 4.6.





Existing hydraulic laboratory building - transversal and longitudinal frames



Existing transversal frame – measured dimensions

+18.28 +14.00 +10.50 +4.25 +4.25 +0.00 -0.90

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Design process

Requirements of the investor (issued in 2004)

The investor (i.e. SIEMENS Ltd via HIDROTIM Ltd Timisoara) was requiring the transformation of the existing industrial hall into a five storey office building (ground floor + four story). A partial basement was also in view. A main stair of concrete and a secondary steel stair were also required (the latter with evacuation role in case of fire, explosion or earthquake).

By this vertical division of the structure, the resulting story height resulted of approximately 3,5 m, which was adequate to the new function of the building, considering also the presence of the services. A false ceiling was provided at each level to hide this technical area. The hereby presented vertical division of the structure is realised by means of steel-concrete composite decking on corrugated steel sheeting supported by the steel main and secondary beams. The same decking act as horizontal diaphragms by transmitting the wind or earthquake forces to the vertical bracing systems. According to beneficiary requirements and to existing code regulations (at that time), the following loading ware considered for the new structure:

- 1) Permanent loading (concrete decking plus false ceiling): $g_2 = 3 \text{ kN/m}^2$;
- 2) Technological loading (suspended services): $g_5 = 0.30 \text{ kN/m}^2$;
- 3) Live load according to the Romanian Code STAS 10101/2A1-87: $q_2 = 3 \text{ kN/m}^2$;
- 4) Snow load according to STAS 10101 / 21 91: p_zⁿ = 0.90 kN/m² (for Timisoara, zone A of snow);
- 5) Wind load according to STAS 10101 / 20 90: $g_v = 0.30 \text{ kN/m}^2$ (for Timisoara, zone A of wind);
- 6) Earthquake loading according to the Romanian Code P100 92.

Conditions imposed to the new structure

In order to fulfil the investor requirements, the new structure (with its new loadings) had to comply with the following conditions:

- To avoid excessive deformations and solicitations of the existing steel frame elements which they cannot follow and could undergo local buckling phenomena;
- To avoid local buckling modes (as for example local buckling of the web), considering the fact that even the resulting consolidated cross-section are of class 3 and actually not adequate for a multi-storey structure;



- To avoid excessive solicitation of the existing foundation blocks which could exceed their capacity and lead to complicated and expensive consolidating measures;
- To avoid generating excessive tension in the anchoring bolts M48 grade 4.6 of the existing frames, beyond their capacity, implying difficult consolidations.

Choice of the new structural configuration

As previously shown, the new structure was built by introducing into the existing 21 m span frame two new intermediate columns made of HEB hot rolled European profiles, at 1/3 and 2/3 of the span. Also, in the central third of the span, a system of reversed V concentric bracing was inserted, thus transforming the frame into a non-sway frame. This has the role of reducing the lateral deformations of the structure and thereby to protect the existing frame from excessive deformation, which could appear in a multi-storey building working under earthquake and which such a frame has not enough ductility to follow. On the other side, 3 completely new transverse frames were inserted at mid bay, between the existing frames, bringing the structure from 9.0 m to 4.5 m bay length. These are not braced in their plan in order to allow for free circulation. Longitudinal bracing was also provided both in the perimetral longitudinal frames as well as in the central longitudinal frame. This created a strongly reinforced structural core to attracts internal efforts, thereby protecting the existing frames, foundations and anchoring bolts, from excessive solicitation as required. A similar role is played by the reversed V bracing distributed on the perimeter of the building trying to create somehow a "tube-in-tube" strengthening effect. The described distribution of the transverse and longitudinal bracing has allowed to obtain the following values for the first 5 eigen periods of the structure, as shown below.

Eigen	Value	
period	[sec]	
T1	0.409	
T2	0.396	
Т3	0.322	
T4	0.145	
T5	0.139	

Table 1. Ligen values of new structure	Table 1	.: Eigen	values	of new	structure
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The resulting T values indicate the obtainment of a rigid space structure, as required. Another observation would be that the first two eigen periods are of close value which indicates similar stiffness of the structures on both transversal and longitudinal directions (under seismic loading), as recommended by the design code.

Deconstruction and Construction processes

The deconstruction / demolition consisted of several phases, all related to the official 2004 construction permit, issued by the competent authority, which did not allow for the complete demolition of the former hydraulic laboratory building (located in a central zone of the city of Timisoara, mostly populated with multi-storey concrete dwellings). This condition in the permit text obliged the customer to a reuse of the steel structure with structural measures to comply with the newly defined function.

The successive phases implied by the deconstructions were the following:

- partial demolition of the laboratory infrastructure including a very solid experimental pull built of reinforced concrete and existing ground floor decking (with embedded steel rails serving to previous laboratory procedures);
- complete deconstruction of the existing cladding and roofing of the laboratory building (already obsolete and incapable of serving the new function);
- complete deconstruction of the runaway crane and crane girder (built of steel);
- complete deconstruction of the existing bracing system that unfit to serve the new function, leaving the main frame system and its foundations to serve as a basis for the conversion / reconstruction





Demolition of the existing concrete pull used for hydraulic experiments



Partial demolition of the existing decking with embedded steel rails for laboratory use

Reinforcing measures for the existing structure

The existing structure consisted of elements with built-up cross-section made of welded steel plates, being framed (according to the cross-sections classification) in class 3 or 4 depending on the stress level. However, the destination modification from "industrial hall with crane" to "multi-storey office building" also implied a change in cross-section class from 3 or 4 to 1 or 2 by consolidation. This modification was required in view of avoiding local instabilities and to provide an acceptable ductility of subsequent elements. The mentioned consolidation applied to the following structural elements:

- Column bottom branch of existing frame;
- Column upper branch of existing frame;
- Rafter of the existing frame.

The bottom branch of the existing column is built of welded steel plates with the inner flange of a hot rolled I32 profile. This particular cross-section has been found of class 4 (because of the web depth 1400 mm per width 10 mm). Since at both extreme fibres of the cross-section the high value of the axial effort combined with the bending moment has led to compression stress the class checking is done with the following formula:

$$\frac{d}{t_w} = \frac{140}{1} = 140 > 42 \cdot \varepsilon \tag{1}$$



The condition of web framing into class 3 was not fulfilled, revealing a class 4 wall. Consequently, the cross-section has been consolidated according to figure below to provide:

- Web class modification by wall slenderness reduction (in order to reach at least class 3), i.e. web depth is divided in three as presented in the figure;
- Outer flange consolidation by to halves of IPE 360 European profile to undertake important axial and shear forces (coming mainly from the longitudinal bracing);
- Inner flange consolidation by two welded, plates also to undertake important axial and shear forces (coming from the new structural configuration of the existing frame with reversed V bracing).



Consolidation of the existing columns cross section: (a) bottom, (b) upper branch



Consolidation details (as built)

The upper branch of the existing column was also made of welded steel plates. Class 3 was found for the crosssection as a result of web class. The cross-section consolidation and obtainment of class 2 was achieved by means of the two halves of IPE 360 (continued from the bottom branch as shown in figure). Also the circulation openings in the web has been closed by a welded steel plate of thickness 10 mm.



The rafter of the existing transverse frame was found to be of class 3 and is accepted in this state considering its relative low level of solicitation and deformation (which excludes local buckling) in the resulting non-sway frame.

Constructional measures

The main structural modifications performed in view of fulfilling investor's requirements were the following:

- a) Two intermediary steel columns of European hot rolled profiles were provided inside each of the 4 existing frames at 1/3 and 2/3 of the span (figure below);
- b) Steel beams were provided at each of the required levels to sustain the new composite decks. These beams are rigidly connected to the new central columns and pinned to the existing columns. Vertical V bracing elements were also provided (figure below).



Transversal frames after conversion

- c) Three new intermediate frames were provided at mid-bay, between the existing frames (figure below). Thus, the bay of the new building becomes 4.5 m instead of 9.0 m;
- d) Secondary beams at approx. 2.35 m centres, connected to the main beams by hinges, were provided at each level to sustain the decking;



e) The main stair, placed in the core area of the structure, is made of concrete supported by a masonry tube with the elevator also contained in a central masonry tube;



- f) The secondary stair made of steel, was located outside the building and suspended to the main structure;
- g) In view of providing structural stability under horizontal forces, a vertical longitudinal V bracing system was included according to figure below;
- h) At roof level, the required diaphragm effect is achieved by providing a perimeter system of X bracing plus high corrugation sheeting, directly connected to the steel frames by cartridge fired pins.

Besides the reinforcing measures for the steel, supplementary foundations were cast on site to support the new inserted structural elements



Supplementary foundations cast in situ

Other features

Role of the composite decking in adapting the existing structure to its new function

The composite decking (concrete + steel) which was chosen as a solution to sustain the loading of each story, also plays a very important role in the space work of the structure. A trapezoidal sheet of 1.0 mm thickness (steel with f_y = 320 N/mm2) working also as form work, together with Nelson shear connectors of 19 mm diameter and 90 mm height (steel S235 J2G3+C450 with f_u = 450 N/mm²) placed on the main beams and on the secondary beams were chosen.



Trapezoidal steel sheet and Nelson shear connectors



This decision has led to the following advantages:

- a) An improved horizontal diaphragm effect of the deck concrete plate;
- b) The possibility to use a lower net thickness for the concrete plate (in this case 7 cm) allowing for a decrease of the level masses with very important consequences in seismic action;
- c) Decrease of both steel and concrete consumption by the effect of beams composite work.



Construction phases of the composite decking at the 4th level

Conclusions

The following key aspects of the process have been identified:

- Reuse of the existing building means that the steel for the new project come from what is already on site. For the particular situation, an estimated 50% of the steel was already existing (plus subsequent infrastructure);



Combination of existing and newly added steel structures by reconversion

- The availability of drawings and specification of the building can save time, facilitate the design process and increase reuse opportunities;
- Good quality data on the existing structure is essential. The existing drawings have been checked with on-site measurements, determination of the structural characteristics has been performed;



- Deconstruction of a building, rather than demolition, is economically viable but managing the materials with the necessary care requires supplementary time; this must be considered in the whole schedule;

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- Deconstruction requires space for storage of the reclaimed materials;
- Steel frames can be readily strengthened and adapted at low cost.

As a result of the performed structural reconversion, the existing industrial hall with crane, already obsolete in the central area of the city of Timisoara, was transformed into a 5-storey office building, having a much better environmental and social impact. Due to the cross-section class of the existing structural elements, only a low dissipation of the seismic energy by the final structure (q=2) has been considered during the structural analysis, leading however to lower earthquake loading. The analysed structure, built both of old and new structural elements, is in function at present time.



Office building in function at present time

In conclusion, the reuse of the steel in this building contributed significantly to improving its environmental performances, and offers a model for other projects.

Further information

The information in this case study is based on interviews with the following organisations involved in the project:

- GECONSTRUCT Ltd
- ARHITECT TRAMBITAS Ltd.