



Stručni rad/Professional paper
Primljen/Received: 3. 4. 2019.
Prihvaćen/Accepted: 27. 5. 2019.

MODELING OF URBAN VILLA STRUCTURE

Donata Ramljak, M.Sc.

Faculty of Civil Engineering, University of Mostar

Vlaho Akmadžić, Ph.D.

Faculty of Civil Engineering, University of Mostar, vlaho.akmadzic@gf.sum.ba

Abstract: Considering the development of tourism in the coastal area, there are more and more demands for the construction of urban villas. Therefore, this paper presents the structural response for the design solution of an urban villa located in the Croatian coastal area. The original architectural design of the villa is the work of Mexican architect Elias Rizo and is recorded under the name of "VR Tapalpa House / Elias Rizo Arquitectos". Several variant solutions were modeled. A load bearing system consisting of a mixed wall part (left lamella) and a skeleton part (right lamella) suggested itself as the final optimal structural solution.

Keywords: urban villa, load bearing system, modeling

MODELIRANJE KONSTRUKCIJE URBANE VILE

Sažetak: S obzirom na razvoj turizma u priobalnom području, sve češće se pojavljuju zahtjevi za izgradnjom urbanih vila. Stoga se u ovom radu prikazuje konstrukcijski odgovor na projektno rješenje urbane vile smještene u Hrvatskom primorju. Originalni idejni arhitektonski projekt vile djelo je meksičkog arhitekta Elias Rizo i evidentirano je pod nazivom „VR Tapalpa House / Elias Rizo Arquitectos“. Modeliralo se više varijantnih rješenja. Kao konačno optimalno konstrukcijsko rješenje nametnuo se nosivi sustav sastavljen od punostijenog dijela (lijeva lamela) i skeletnog dijela (desna lamela).

Ključne riječi: urbana vila, nosivi sustav, modeliranje



1. Introduction

Considering the development of tourism in the coastal area, it is a fact that civil engineers more and more often face demands for construction of urban villas of more challenging designs. For each of these challenges, it is necessary to find the corresponding structural response. This paper presents such response for the urban villa located in the Croatian coastal area. The original conceptual architectural design of the villa is the work of Mexican architect Elias Rizo and is registered as "VR Tapalpa House / Elias Rizo Arquitectos" [14], and shown in Figure 1 and Figure 2.



Figure 1. View of the right lamella [14]

The building occupies an area of 966.5 m². The left lamella consists of two floors, while the right lamella consists of one floor. Considering the distribution of space, the left lamella consists of a garage, a tool area as part of the garage, four bedrooms, corridor, a living room and a staircase. On the other side, the right lamella consists of a large dining room, two living rooms, kitchen with storage and a toilette.



Figure 2. View of the left lamella [14]



Figure 3. View of the front face [14]



Figure 4. View of the back face [14]

The building is located in the Croatian coastal area at an altitude of up to 100 m a.s.l. It is subjected to the action of wind at speeds up to 30m/s and horizontal excitation of the ground typical of seismic zone VIII. Load analysis was made in accordance with European standards.

For the purposes of structural analysis, a numerical model (Figure 5) was created using the Tower7 3D Model Builder computer program. Several densities of the finite element network were generated during the calculation [10], and the network with finite element size equal to 0.30 m was shown as the optimal one. It is important to point out that the program modules for dimensioning reinforced concrete, steel and timber elements were used.

The Tower software package for soil modeling uses the Winkler spring system. For modeling the foundations using Winkler springs, a modulus of subgrade reaction of 10000kN/m³ was set [1], [2], [12]. The concrete class C30/37, reinforcement quality B500B, structural steel S235JR, and laminated wood were used.

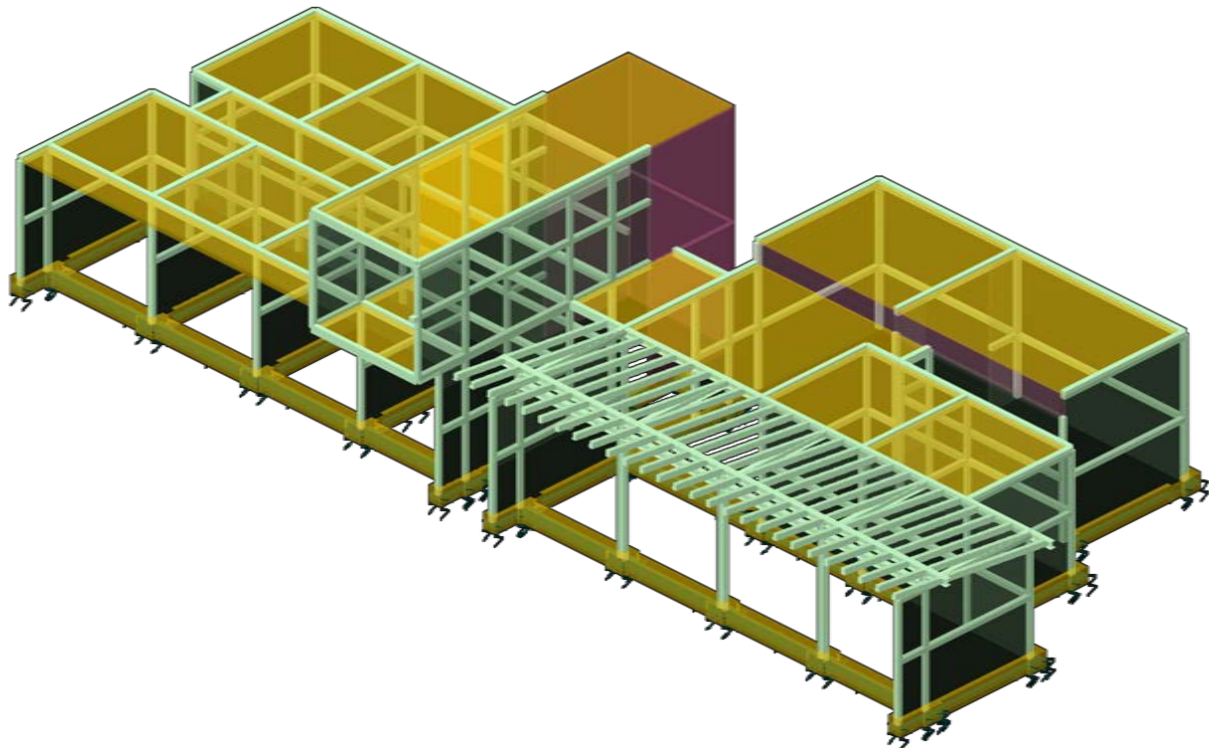


Figure 5. 3D view of the structure

2. Description of the structural elements

The vertical load of the structure is set as a surface load on horizontal and inclined elements of the structure in accordance with the global coordinate system. However, on the slope formed of wooden beams, the surface load is converted into a line load coinciding with the geometric position of wooden elements. Finally, this load, together with the dead weight of the structural elements, is transferred to the strip foundations over the vertical elements [3], [4].

The freezing depth, which is from 40 to 60 cm for the coastal area, required the foundation to be placed at the level of -0.50 m in relation to the ground level. Considering that they are in an environment that is exposed to air salt but is not in contact with seawater, according to the Technical Regulations for Concrete Structures in this case it is defined that the protective layer for foundations is $c=5.5$ cm.

The masonry walls of this urban villa are specific in that they are lined with stone, which resulted in the adoption of slightly wider dimensions of foundation strips. Their cross section is 70x50 cm. They are adopted in the entire structure, except that there are expansions around columns of 15 cm on both sides of the foundation strip. For the purpose of constructing foundation strips, 10 cm thick base concrete was placed.

The monolithic load-bearing system consists of masonry walls 25 cm in thickness, reinforced concrete carcass 25 cm in thickness, 20 cm thick slab, 25x40 cm sized beams, as well as tie beams and tie columns sized 25x25 cm. Due to the great floor height, the reinforced concrete tie beams are set at a height of 2.42 m and serve as stiffeners of masonry walls. A typical frame is shown in Figure 6.

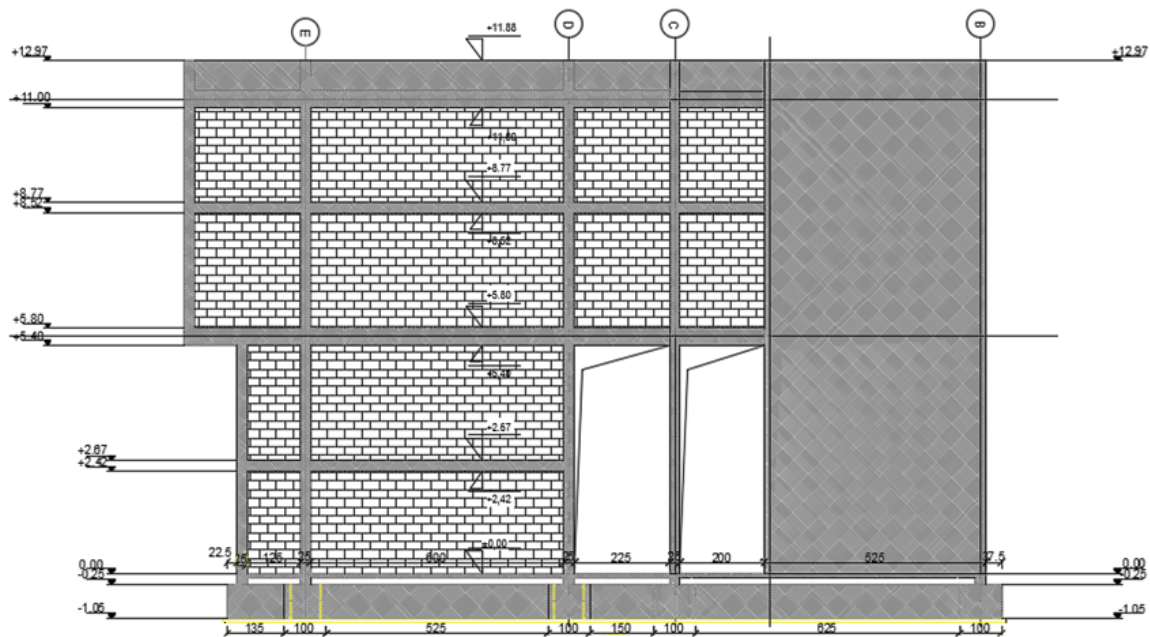


Figure 6. Typical frame

The skeleton system consists of steel frames [5], [6], [7]. Frame columns are made of rolled-steel sections HEA (IPBI) 400 and beams of sections HEA (IPBI) 360, quality S235JR. All elements of the steel structure satisfied the ultimate limit state (stress, stability) and serviceability limit state control. A typical frame is shown in Figure 7.

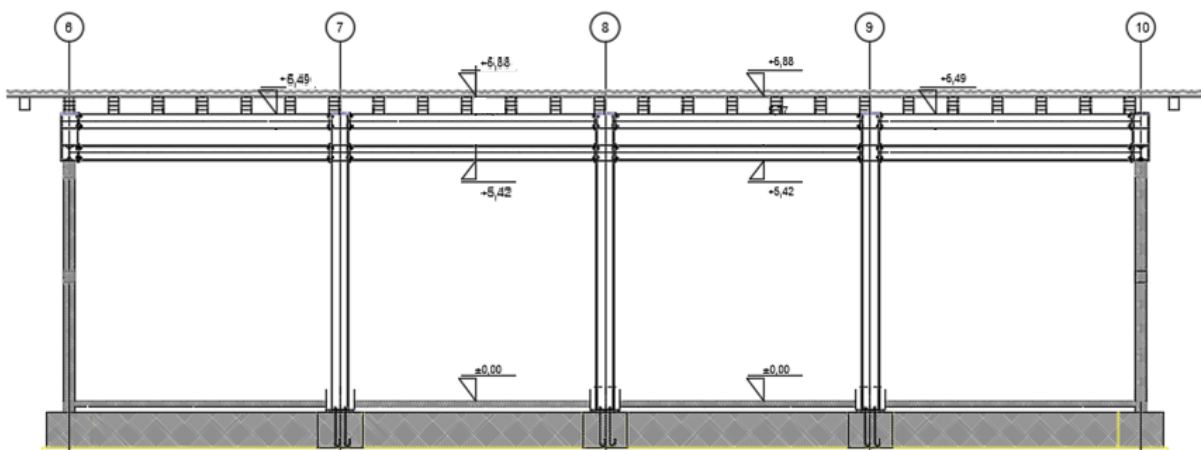


Figure 7. Steel frame

3. Connections

From a constructive point of view, the structure was interesting in terms of connecting structural elements made of different materials. The first of such connections is the connection between steel column and reinforced-concrete foundation. The steel column is made of sections HEA 400, and, as shown in Figure 8, it is connected with the foundation over a base plate $\#600 \times 300 \times 30 \text{ mm}$ using four M20 10.9 bolts.



Certainly, it is very difficult to construct a perfectly flat reinforced-concrete floor slab and foundations. For this reason, after mounting steel columns at the same level in the entire structure, a larger or smaller gap remains under individual base plates. This space is subsequently filled with the grouting mass, which is better than the foundation concrete in terms of quality by one class.

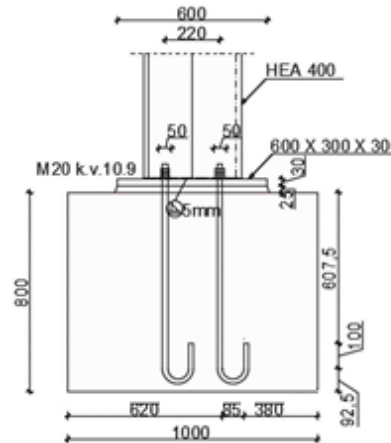


Figure 8. Steel column - foundation connection

The second type of connection is the connection between roof wooden beam, frame steel section and reinforced concrete structure (Figure 9). The sloping wooden beam 220x300mm in size is connected with the steel beam using gusset plates $\#100 \times 335 \times 10$ mm and bolts 2M20 8.8.

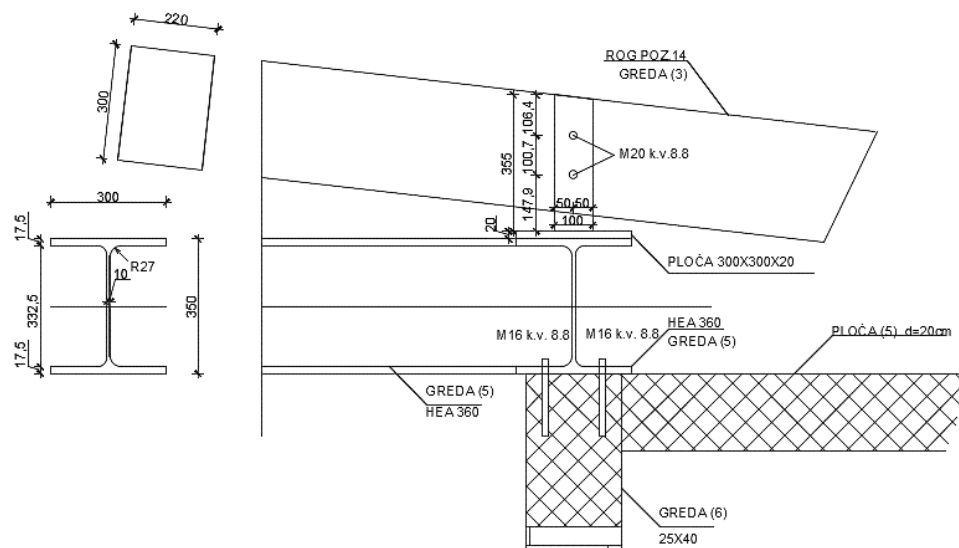


Figure 9. The connection wooden beam - steel section - reinforced concrete structure

The gusset plate is connected by fillet weld to the face plate $\#300 \times 300 \times 20$ mm. This was done in order to leave the possibility of connection to the horizontal steel beam by bolts. The option of welded connection of this plate and steel beam was pursued for the purposes of this paper. Further, the steel beams on this part of the structure are made of sections HEA (IPBI)



360 and welded together. The steel beam resting on the reinforced concrete structure is connected to it by bolts M16 8.8. It is important to note that during construction it will not be possible to achieve a perfectly flat surface of the reinforced concrete structure, which should be taken into account.

That is why a more correct detail on this part would be to require leveling of the surface under the steel section before mounting it on the reinforced concrete structure. Or, if this is not possible, to plan grouting the space between the steel beam and the reinforced concrete structure. It is important to note that this type of connection is present only on the skeleton part (right lamella), while conventional flat roofs are present in other parts of the structure.

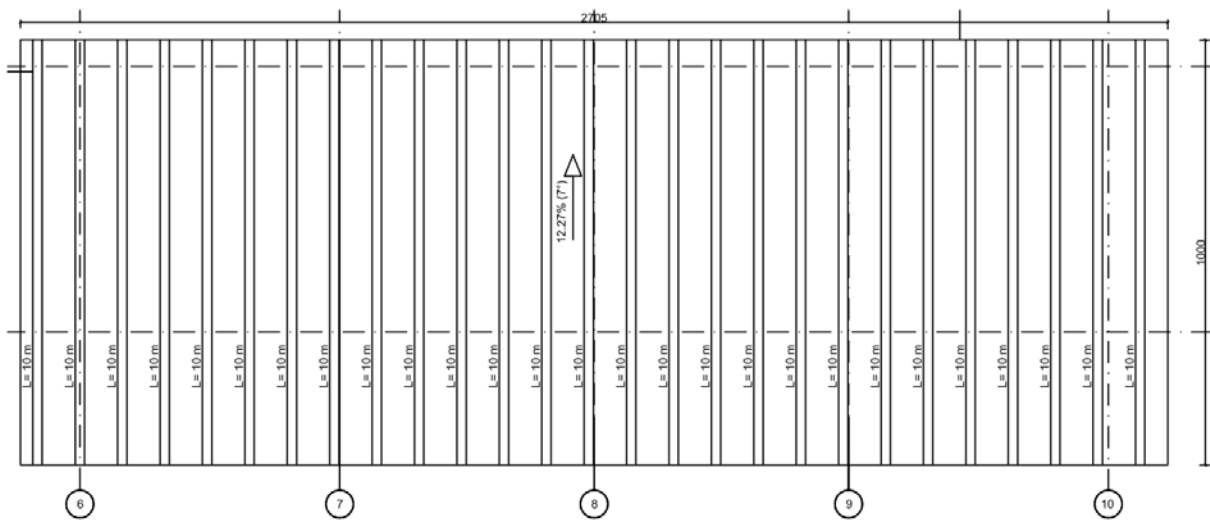


Figure 10. Sloped roof

4. Conclusion

In this paper it was aimed to show that, as the market develops, engineers are faced with increasingly complex tasks, in the widest sense of the word. To solve these tasks, it is necessary to know the materials and tools [8]. In the case of modeling of structures, complex tasks inevitably lead to the development of many variant numerical models. After a more detailed analysis, the variant that most faithfully and optimally describes and solves the design task offers itself as a solution.

In the presented example, a number of numerical models of the subject structure were also analyzed, but only the final variant is presented due to the space limitation in the paper. For the sake of example, one of the important dilemmas in the modeling of the left lamella will be pointed out. The architectural requirement was that the floor slab looks like a structure made of massive wooden beams over which a reinforced concrete slab is made. A composite wood - concrete structure suggested itself as a logical choice. However, considering that this was not reconstruction but construction of a new structure, all indicators sided with the reinforced concrete slab. What tipped the scale is the fact that a reinforced concrete slab gives the designer more freedom in case of interior redesign.

On the other hand, in the analysis of the right lamellae, the architectural concept was on the side of a steel structure. Namely, the numerical model variant that considered prefabricated reinforced concrete elements gave much larger dimensions, which would hardly fit into this architectural concept.



5. References

1. Akmadzic V., Vrdoljak A., Ramljak D., Influence of the subgrade reaction coefficient modelling on the simple 3D frame, Proceedings of the 29th International DAAAM Symposium, Katalinic, B.(Ed.). 2018.
2. Akmadzic V., Vrdoljak A., *Determination of the soil coefficient reaction value—software solution*, e-Zbornik: Electronic collection of papers of the Faculty of Civil Engineering, Vol. 8, No. 15, 2018, pp. 22-29, ISSN 2232-9080.
3. Akmadzic V., Vrdoljak A., *Influence of soil reaction coefficient on 2D steel frame behavior*, 3rd International Conference on Engineering Sciences and Technologies ESaT2018, High Tatras Mountains, Slovak Republic, 2018.
4. Akmadzic V., Vrdoljak A., *Behavior of the 2D frames for different approach to soil modelling*, Advances and Trends in Engineering Sciences and Technologies III, CRC Press, Taylor & Francis Group, 2018.
5. Androić; B., Dumović; D., Džeba, I., *Metalne konstrukcije 1*, Institut građevinarstva Hrvatske, Zagreb, 1994.
6. Androić; B., Dumović; D., Džeba, I., *Metalne konstrukcije 2*, Institut građevinarstva Hrvatske, Zagreb, 1994.
7. Androić; B., Dumović; D., Džeba, I., *Metalne konstrukcije 3*, Institut građevinarstva Hrvatske, Zagreb, 1994.
8. Mihanović A., Trogrlić B., Akmadžić V., *Građevna statika II.*, Fakultet građevinarstva, arhitekture i geodezije, Split, 2014.
9. Prskalo M., Akmadzic V., Colak I., *Numerical modelling of raft foundations*, Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Zadar, Croatia, ISSN 1726-9679, ISBN 978-3-901509-73-5, Katalinic, B. (Ed.), 2010. pp. 0851-0852.
10. Ramljak D., Akmadzic V., *The influence of the mesh density and concrete quality on the results accuracy in thin plates*, XVIII Anniversary International Scientific Conference by Construction and Architecture VSU'2018, Sofia, 2018, Volume 1, pp.341-350.
11. Smoljanović H., Balić I., Trogrlić B., *Stability of regular stone walls under in-plane seismic loading*, Acta mechanica, June 2015, Volume 226, Issue 6, pp. 1881–1896.
12. Vrdoljak A., Akmadzic V., *Improvement of students' engineering skills in numerical modelling of the structural systems*, Proceedings of the 18th International Symposium INFOTEH-JAHORINA, University of East Sarajevo, Faculty of Electrical Engineering, Jahorina, RS, B&H, March 20–22, 2019.
13. Zovkić J., *Drvene konstrukcije I*, Građevinski fakultet Osijek, 2015.
14. <https://www.archdaily.com/476582/vr-tapalpa-house-elias-rizo-arquitectos/52fc461ce8e44e3cd0000057-vr-tapalpa-house-elias-rizo-arquitectos-photo>