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A singular structure: Monopost made in composites

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Abstract

This work presents the design process, the analysis, and the performance of a cylindrical hollow monopost, made entirely in composites. It is about a translucent structure of height 40m, external diameter 1.60m and the average wall-thickness 11mm. The material is a polymer made up of vinylster resin and reinforced by glass fiber (GFRP). The manufactured processing used is *filament winding*. Moreover, due to geographical emplacement where it is situated, the structure has to support wind velocity value above 180Km/h and its elastic modulus of the material does not exceed 25GPa.

Eventually, we was able to achieve an optimum solution and strentgh structure, considering and developing differents types of approaches and analysis, such as linear, non-linear and buckling.

Keywords: *Filament winding, GFRP, monopost, composites, non-linear and buckling analysis.*

Fig. 1. Photograph of night view with iluminated monopost in Caudete (Albacete).

1. Introduction

The present monopost has several special and singular features: from the geometry to the structural behaviour, or from the type of material to the technology of manufacture.

Prerequesites were given by the costumer. It would have to be: a light structure, with simple and clean shapes, with translucent parts. And later, they would be able to establish inside monopost all the light devices and telecommunication system. At the same time, the material had not do interferences on the signals, and they could access inside the monopost to make any necessary operations.

Fig. 2. Photograph of day view of monopost and surrounding area.

According to previous determining factors, we considered a variety of different structural solutions and combined with several type of materials. All in all, we had to take the follow decisions:

- A material would have...
  - To be light and translucent.
  - To have well-finish superface and with maintenance.
  - Not to cause interferences on signalling.
- A transversal section could maximize its internal surface.
- A fabrication technique had to be reliable, fast and economic.
- A stiff and strength group of elements to support external loads.
- A special accessories, which allow them, to operate later all inside devices.

2. Description of structural elements

The geometric shape of the structure is hollow cylinder, its transversal section is continous, its visible height 40.0m and its external diameter 1.60m, resulting a slenderness ratio equal to 25.

Initially, due to the asembly jig and the technology proccess, it was build in four parts of 10.3m of length. Neverthless, due to the optimization of road-transport, it was joined in point of origin two and two pieces, giving two parts of 20.6m of length (Figure 3).

Fig. 3. Photography of joining both parts before road-transport.

Eventually, in the definitive siting, it was assembled both parts (Figure 4). The total height of the complete-assembly structure is 41.2m, However, there is part of the monopost is buried 1.20m inside the footing, therefore, the visible height is 40.0m.

Fig. 4. Photography of the complete-assembly before holding monopost up.

In the next figure 5, it tabulates all the wall-thicknesses of the each part of the monopost:

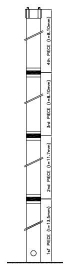
Piece	Height	Thicknesses	Diagram
1st	From 29.7m to 40.0m	**8.1mm**	
2nd	From 19.4m to 29.7m	**8.1mm**	
3rd	From 9.1m to 19.4m	**11.7mm**	
4th	From 0.0m to 9.1m	**13.5mm**	

Fig. 5.

3. Several peculiarities

The figure 6 (left) shows how the monopost was crowned. Using a cover, which its diameter was Ø1.80m and its thickness 10mm,. Besides of the cover, it was joined externally to the structure using six radial flaps (#1.0x0.1m/t=10mm). The figure 6 (right) shows the internal reinforcement of the cover, which were six flanges (#0.8x0.1m/t=10mm). It also displays the sheaves placed inside the cover to raise and put all the illumination and telecommunication devices up. In both, it is noticed two breather pipes, which are used to provide natural ventilation inside the monopost from the bottom to the top.

Fig. 6. External and internal details: flaps, pipes, sheaves and flanges.

There are not singularities in the intermediate parts. In contrast, in the fourth tram was drilled a big hole (Ø0.60m) placed one meter above the floor. This orificie has two purposes: on the one hand, to make possible the last concrete dumping on the footing, and on the other hand, to make easier later operations and maintenances from the inside space of the monopost. The surrounding zone of the hole was reinforced with a increase of 10mm on its thickness and it was closed with a screwed hatch that had small holes to make the external air entry easier (Figure 7).

Fig. 7. Photographs of details about the main gate.

In the joint lines between different pieces, it was increased their eacthicknesses using external and intenal reinforcements, to imitate the bamboo cane. These joined zones are not traslucents due to the reinforcements (Figure 8).

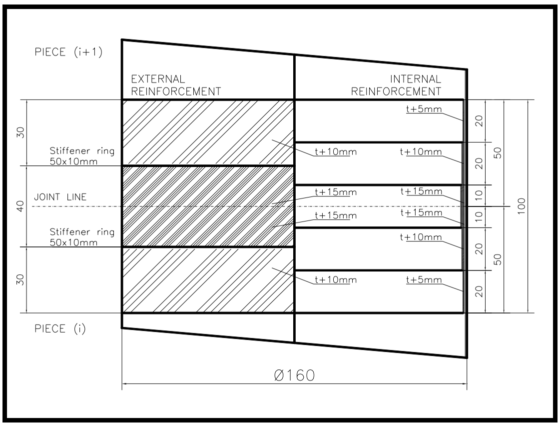


Fig. 8. External and internal reinforcements only in joint lines.

Figures 9 and 10 show the dimensions of the footing and the anchorage system to join with the monopost. By calculation [2-3], it was established a radial distribution of sixteen corrugated steel forks (Ø20), which were anchored in the bottom of the footing. After the first concrete dumping, they were assembled using steel screw bolts (J-shape). The figures also shoew, the buried part of the monopost and the layer of granulated dust marble that was thrown in each side of the monopost, so that, it will improve the friction between both materials.

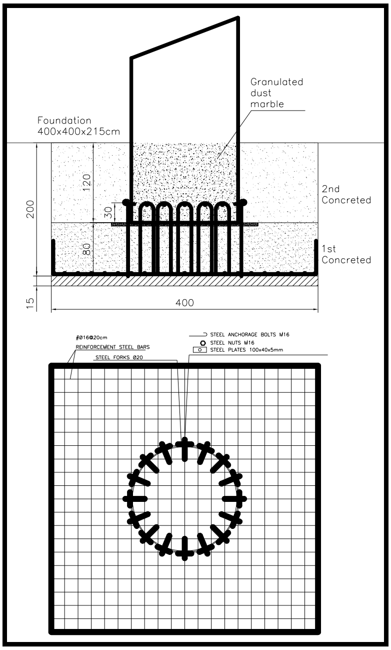


Fig. 9. Layout of the forks in the footing.

Fig. 10. Photographs of anchorage system: forks, screw bolts and monopost.

4. Material and manufacturated technique

The monopost was made using a composite which was compounded of 65% glass fiber and 35% resin. The thermosetting matrix was vinylester, transparent, therefore, to obtain translucent pieces. It was also added red pigment in the finished surface. The *filament winding* was the technology used in this project. The joined parts was made by hand estratification.

Despite being automatic process to produce hollow revolution shapes and where the placing of the fibers is really exact, it is recommened to carry test methods out following the rules written in the references [5-9]. So, we were able to determinate exactly the mechanical characteristics values of the material. The figure 11 tabulates the mechanical values achieved in the normalized tests.

Mechanical caracteristics	Obtained test values	
Tensile strength (MPa)	450	
Yield limit (MPa)	250	
Elastic modulus, E_L (GPa)	25	

Fig. 11. Experimental results. Tensile test from extracted specimens.

5. Actions on the structure

The geographical situation of the structure has determined notably the wind action on the same one. According to the instructions of the Eurocode 1 [1], it was considered a logarithmic variation of the wind pressure depending of the height, and also it was adopted a distribution of eolian external coefficients depending on the covered angle as the figure 12 shows.

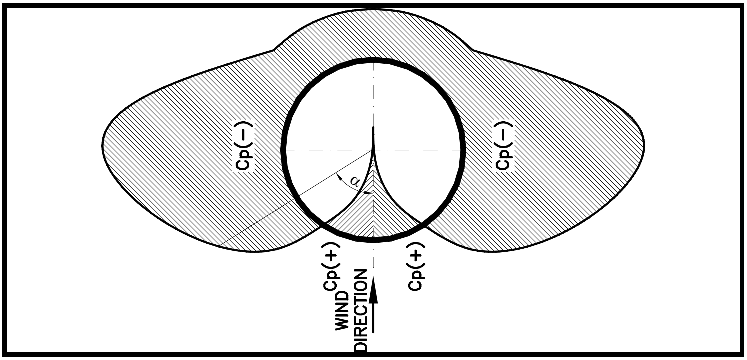


Fig. 12. Scheme of eolian coefficients around the cylinder accordind to Eurocode 1.

The self-weight of the material was obtained by test methods [5-9], resulting 1765.2 DN/m^3, and therefore, the weight of the structure was 4324.5DN.

6. Analysis y results

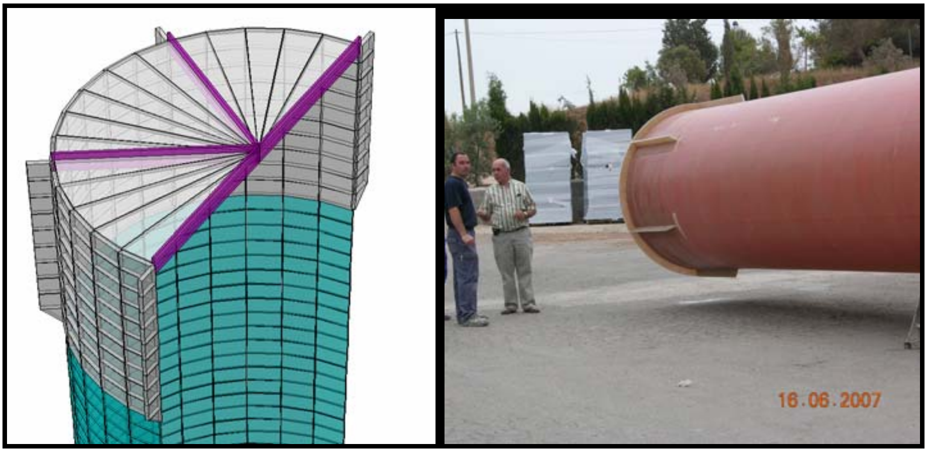
In the analysis of the structure, it was considered the influence of these parameters:

- Slenderness (λ_G = 25).
- Stiffness (E_L = 25GPa).
- Wall-thicknesses (t = [8.1÷15.7mm]).
- Wind and self-weight loads.

In addition, it was defined a hyperstatic model of finite elements of the all geometry e (including: holes, reinforcements, flaps, etc.). The number of finite elements which was discretized, is shown in the figure 13:

JOINTS	FRAMES	SHELLS
12.966	6	12.985

Fig. 13



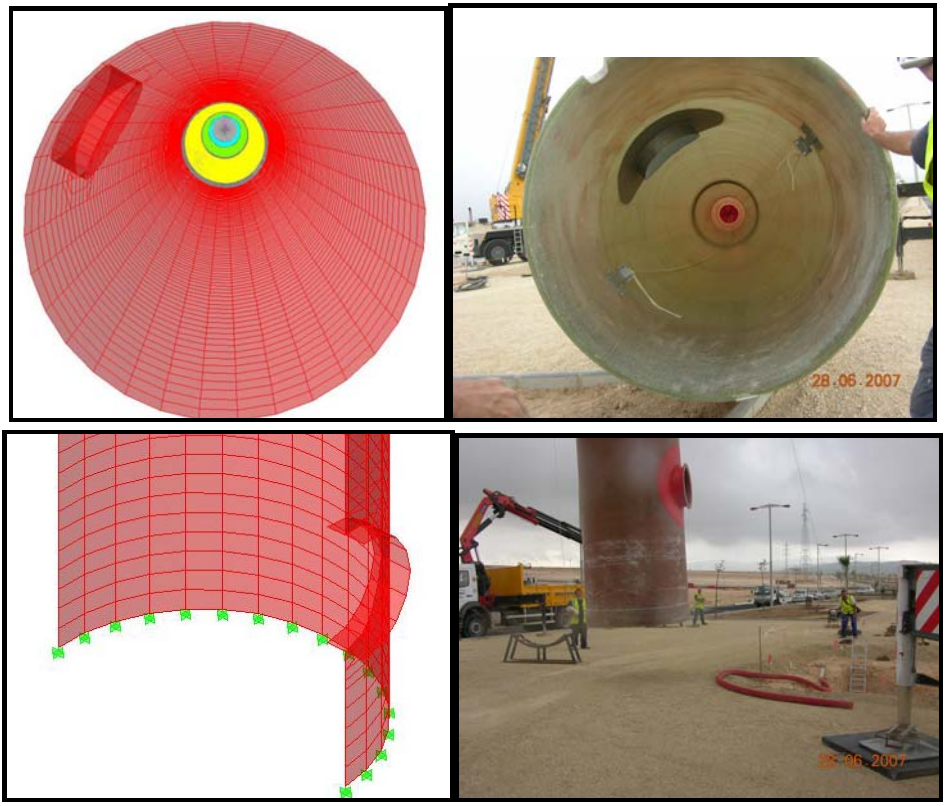


Fig. 14. Several details of the FEM model of the monopost.

Afterwards, it was set out all sort of required analysis, and through an iterative process , it was modified several elements to achieve the definitive model to sure its structural integrity. At the end, the executed analysis were:

- Static, elastic and linear.
- Static, elastic and geometrically non-linear.
- Buckling.

From the results of the non-linear analysis, we have to remark the value of the maximum rotation joint was 0.015 radians. (This value is minor than the maximum admissible 0.02 radians, recommended for good transmission of signs). On the other hand, the maximum horizontal displacement was 0,328m.

Another important result were the buckling mode factors obtained with applied loads and definited thicknesses. The figure 15 tabulates these values:

Mode	Values
1	0,289
2	1,004
3	0,809

Fig. 15. Buckling factors.

4. Conclusions

On the basis of obtained results of the different analysis, it is possible to conclude that: the behavior in service, the stability and the integrity of the structure are ideal for this singular monopost.

This project is not any more than the result of the research and the development in the application of the composites in buildings, which allows the innovation in the scope of the construction with composites and increases the knowledge, not only in the theoric study but also its real application in the construction of these structures.

Fig. 16. Photographs of the singular monopost.

References

[1] Eurocode 1: Actions on structures.

[2] Eurocode 2: Design of concrete structures.

[3] Eurocode 3: Design of steel structures.

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[5] UNE-EN-ISO 14125: *Materiales compuestos plásticos reforzados con fibra. Determinación de las propiedades de flexión.*

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[7] UNE-EN-ISO 527-1: *Plásticos. Determinación de las propiedades de tracción. Parte 1: Principios generales.*

[8] UNE-EN-ISO 527-4: *Plásticos. Determinación de las propiedades de tracción. Parte 4: Condiciones de ensayo para plásticos compuestos ortótropos e isótropos reforzados con fibras.*