Specific Engineering Challenges During the Large-Scale Structures' Mantling and Dismantling Procedures

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Mounting and dismantling of large-scale mechanical systems is a complex engineering challenge due to several factors, such as structural diversity and size of handled structures, limited maneuvering options, and absence of related literature, to name the few, all of which make each problem unique. Numerous disasters throughout the history created a need for a safe approach to the problem of executing such procedures risk-free, while preserving the structural integrity and functionality of the structures. One of the most reliable methods is the application of unique below-the hook lifting devices and the goal of this paper is to present the benefits of their use via two examples. Case 1 deals with dismounting of dated constructions in a densely populated area, with limited structural data provided. Case 2 is focused on mounting of a large-scale roof structure in harsh boundary conditions, with limited maneuvering space. Results presented in this paper represent a contribution to the field of below-the-hook lifting devices.

Keywords: *unique lifting devices, large-scale constructions, risk reduction, mounting and dismantling processes, FEA.*

1. INTRODUCTION

Large-scale structures or structural elements can often be segmented into components of smaller dimensions and masses before being mounted or dismantled, thus greatly simplifying the procedure. That, however, is not always possible due to various factors and, in such circumstances, those entities have to be positioned or dismantled as a whole, making the process a lot more challenging as their structural integrity must not be jeopardized in order to allow them to properly fulfill their designed purpose. This emphasizes the importance of proper planning and integrity calculations, as the neglect or improper execution of this phase may often lead to disastrous outcomes such as failure of structures and loss of human life, which has been confirmed by numerous examples from the past [1-4]. The procedures of mounting and dismantling are realized with the help of heavy-lifting machinery by connecting them to the structure via additional lifting devices, which must not affect the functionality of the structure. Such devices have to be sufficient in number and properly placed across the element in order to ensure smooth lifting and avoidance of critical stresses and deformations, caused by the so-called specific loads, which are the main causers of failures during the lifting procedure. Surrounding structures and possibly limited maneuvering space on the montage site, as well as harsh deadlines and other factors, add to the complexity of the process.

One of the most common solutions to all of the aforementioned challenges is the application of unique below-the-hook lifting devices, specifically designed and manufactured for a particular problem. Although designing and manufacturing such devices is a costly and time-consuming procedure, it is fully justified when one considers the much greater cost of a possible disastrous outcome which is avoided with their application, despite their limited use after their original purpose has been served, as most of them are used only once, or at best, several times. After years or decades of serving their purpose, most of the structures have to be dismantled in order to be repaired or replaced with new ones, lest they become a potential threat to the safety of their surroundings due to wear of the construction material, especially in urban areas, for obvious reasons. Surrounding objects may drastically limit the maneuvering options for the heavy-lifting machinery used in the process, making it a high-risk operation if not planned carefully.

A good example of such procedure occurred in 2015. in Belgrade, Serbia, when three thirty-year-old chimneys of a heating plant in an urban municipality of the city had to be dismantled in harsh boundary conditions, as both maneuvering space and structural data were very limited. This process will be explained in detail in Case 1 of this paper.

The aforementioned factors apply to the mounting processes as well because of the many similarities with the dismantling procedures.

In 2014, a sulfuric acid reservoir was being constructed in a sulfuric acid processing plant outside the city of Bor, Serbia, and its large-diameter roof (28.6m) had to be precisely positioned with limited maneuvering space caused by the presence of the existing objects and pipelines on the plant premises. Consequences of a possible failure are obvious, considering the nature of chemicals processed by the plant. The procedure is presented in detail in Case 2.

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2. CASE 1 – DISMANTLING THREE DATED CHIMNEYS OF A HEATING PLANT

In 2015, a problem of dismantling three dated chimneys of a heating plant in Belgrade, Serbia, has been presented to the authors of this paper.

After 30 years of service, it was deemed necessary to replace them with new ones, based on data obtained from measurements in 2012, which have shown a significant degradation of the chimney wall material. Unfortunately, further measurements inside the chimneys were not possible for safety reasons and thus data on further degradation of the wall was unavailable. This has been solved by removing the isolation at the top of the chimneys and ultrasonically measuring the thickness of the wall there, as that is the place where the wall is the thinnest. The obtained data was then compared with measurements from 2012, and in such way data for calculations was acquired.

The plant is located in an urban municipality of Belgrade, and is surrounded with residential buildings, which meant that the procedure needed to be done quickly and smoothly, with no margin for error. The surrounding object on the plant premises further complicated the challenge by limiting the maneuvering space and options as shown in Fig 1.

Such conditions, combined with limited structural data, made this a high-risk operation. The chimneys were 30 years old at the time, with each being 43.5m long, weighing 60t, and their tops being at 80m from the ground.

Having in mind the mentioned limitations, the initial solution was to conduct the chimney dismantling in a single phase, by lowering the complete structure in one piece. The lifting would be conducted using the already existing traverse [5], able to manipulate with structure of such weight and dimensions, and trunnions designed according to standard [6], predicted to be welded to the

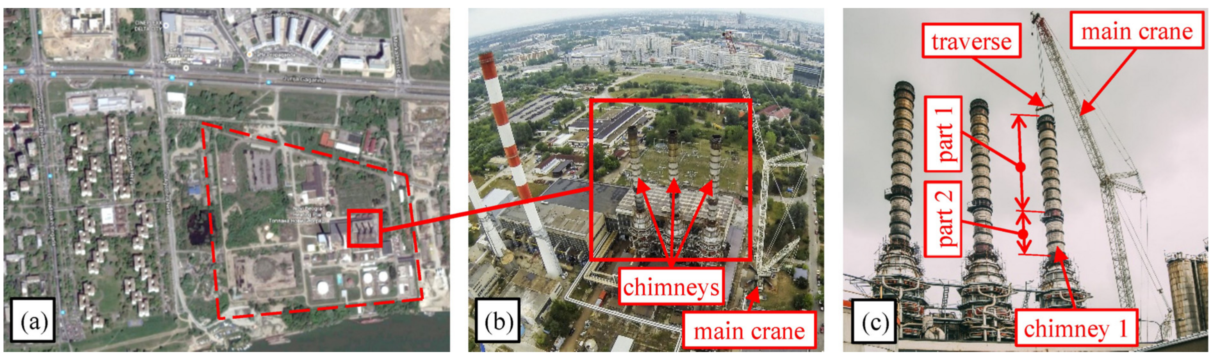


Figure 1: Location of heating plant: a) aerial view; b) chimneys which needed to be dismantled; c) beginning of stage 1

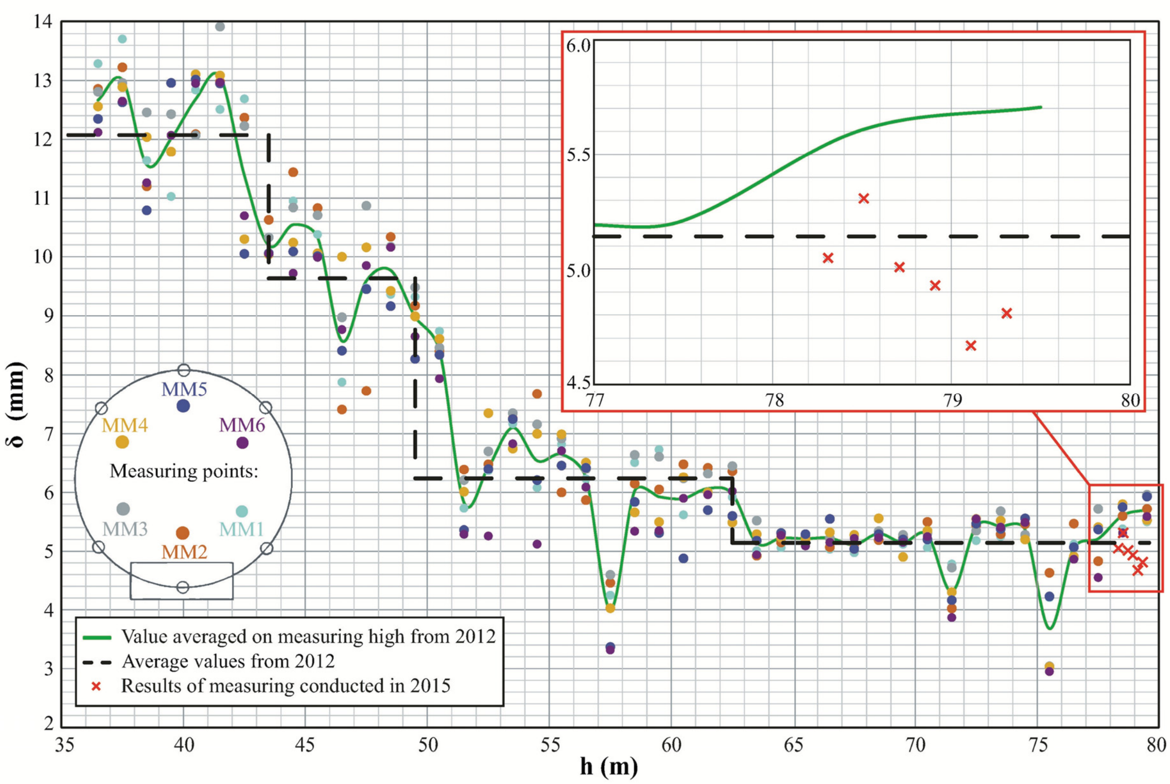


Figure 2: Results of chimney thickness measurements

highest segment of the chimney. In order to conduct FEA, thicknesses of chimney wall segments had to be adopted by averaging of data acquired in year 2012 along the height of chimney, Fig 2. However, despite performing well in linear finite element method simulations, such solution was discarded due to safety and technological reasons related to the process of attaching the trunnions. As such, another approach has been devised.

The plan was to segment each chimney into two parts of similar masses, reducing both the size of lifted objects and loads caused by their weight. Main crane, Fig 1 and 4, would be used in stage 1 to dismantle each chimney part by attaching it to the mentioned traverse,

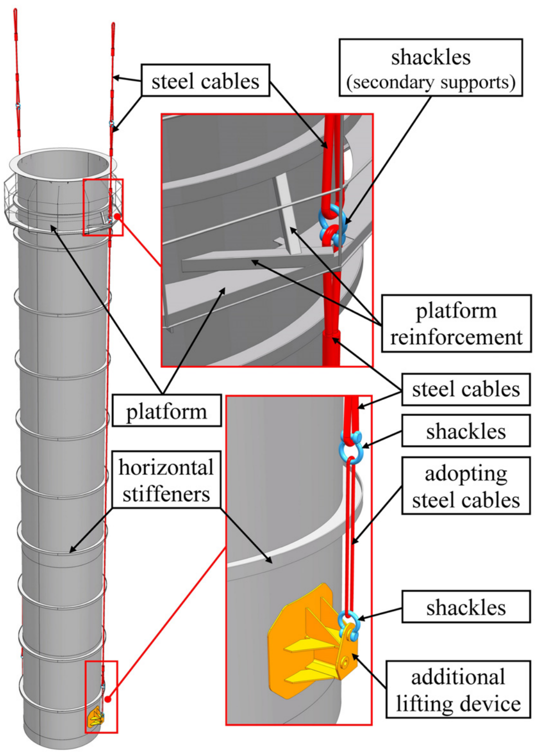


Figure 3: Lifting equipment

which is attached via steel cables to the specifically designed additional lifting device installed near the bottom of the part. This way loading method of obsolete construction with high level of degradation would be quite similar to operating one, thus eliminating the possibility of appearance of unforeseen deformations and stresses.

The problem appearing in stage 2, transmission of the chimney part in horizontal position via additional crane, was to provide secondary supports able to realize in air rotation of dismantled construction. These supports were improvised by using of the shackles already joining two pieces of steel cables in the level of highest platform, Fig 3. The platform was reinforced in order to withstand loads generated during construction rotation.

The schematic of the procedure is shown in Fig 4. A finite element stress analysis was conducted for both horizontal and vertical positions of the chimney parts, and the obtained stress and deformation values were in the allowed range (details are shown in Fig 5).

As this approach satisfied both safety and maneuverability requirements, it was adopted and the operation was given the go-ahead. The dismantling process was conducted in July 2015. It took 7 days to assemble the main crane and 10 hours per chimney segment to be cut, dismantled, prepared for transport and taken away. Each segment spent about 1.5 hours in the air during the dismantling. The alternative to using unique below-the-hook lifting devices was the use of scaffolding which, by the estimates of the investors, would take 60% more time and resources. The procedure itself encountered no unexpected problems. Although the main crane had to be positioned in such a way that, at moments, it was at its maximum reach, each of the chimney segments was dismantled smoothly and the traverse, originally designed for another problem, has performed well. The example presented in this Case illustrates the importance of adequately approaching the problem, but also demonstrates the possible versatility of application of the unique below-the-hook lifting devices, if designed properly.

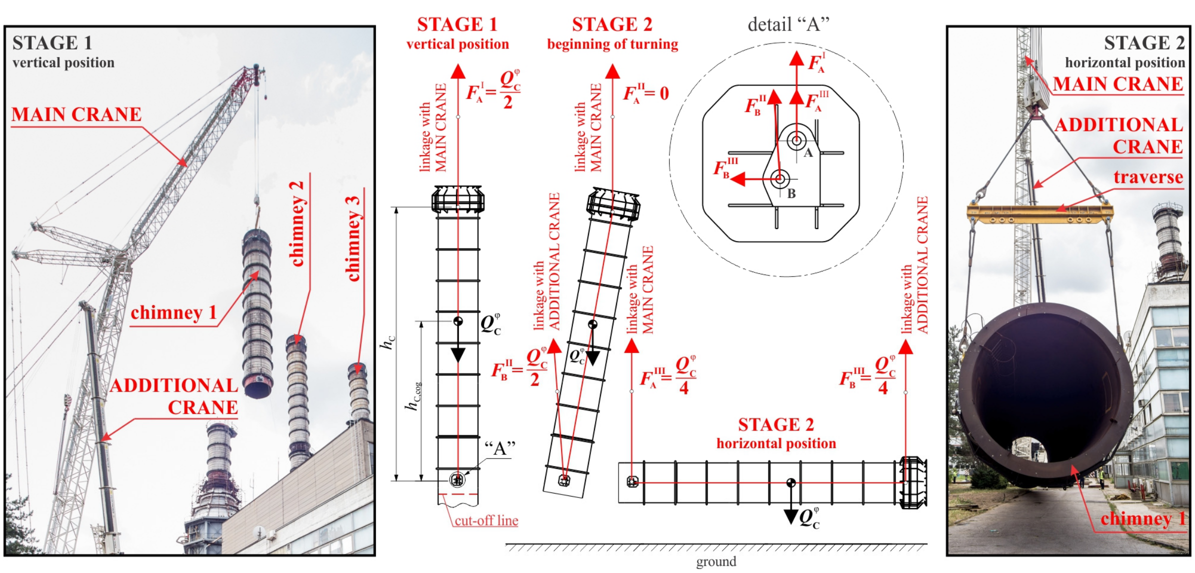


Figure 4: Dismantling stages

3. CASE 2 – MOUNTING OF ROOF FOR SULFURIC ACED STORAGE RESERVOIR

Copper mine near the city of Bor is the largest of its kind in Serbia, and among the most productive in the region. To meet the ecological regulations, a sulfuric acid processing plant has been built nearby to prevent the pollution caused by evaporation of sulfur-dioxide, a byproduct of copper exploitation. In 2014, a new sulfuric acid storage reservoir has been constructed on the plant premises, and its 28.6m diameter roof had to be mounted in limited maneuvering space caused by presence of the surrounding structures and pipelines whose possible damage would lead to a hazard.

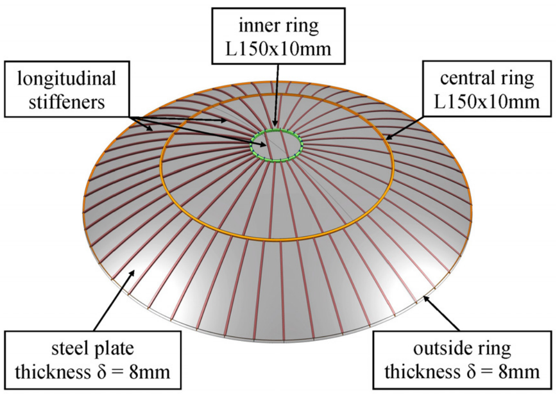


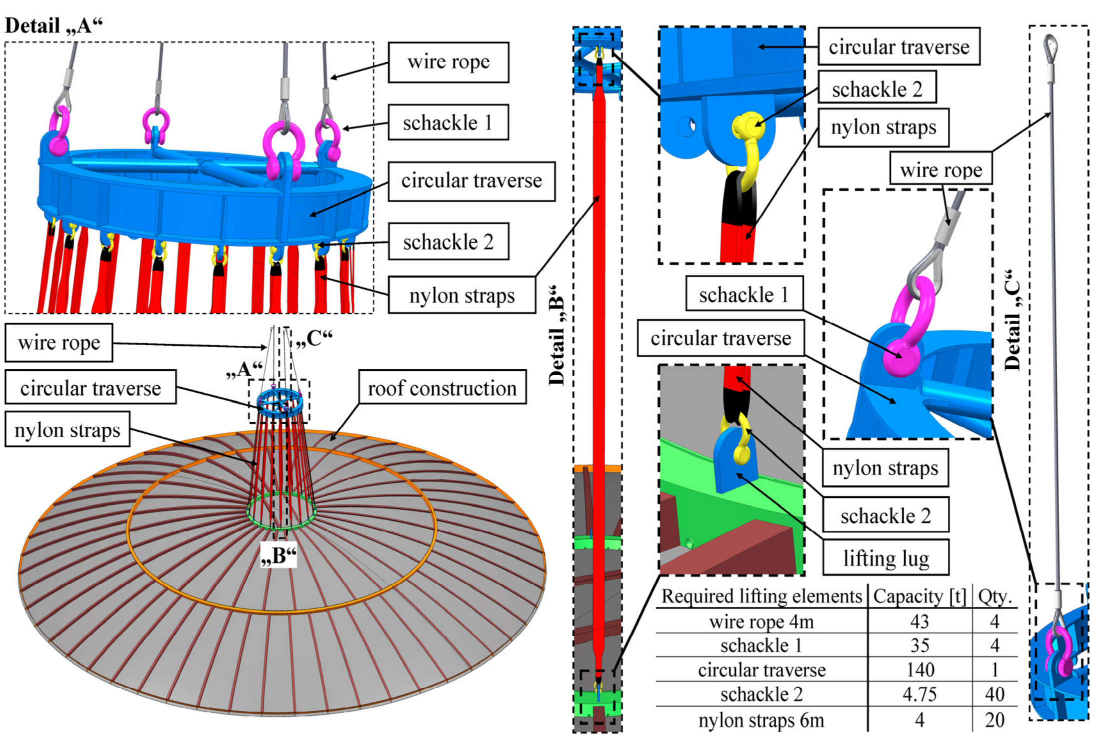
Figure 6: 3D model of the roof structure

The roof is dome-shaped, made of 8mm and 16mm steel plates and three ring girders, interconnected with a girder frame (L120x10mm and L150x10mm) positioned on the outer side of the roof, Fig 6.

With the above stated maneuvering difficulties and the shape of the roof in mind, it was decided to use a single truck crane and a circular traverse for the mounting procedure.

The idea was to attach 20 lifting lugs to the innermost girder ring of the roof structure, connect them to the traverse with nylon straps, and connect the traverse to the crane hook with steel cables, with shackles used for each connection, Fig 7. In order to check the validity of such approach, a linear finite element method stress analysis was performed, using the 3D model of the structure created from the original project documentation (which did not account for specific leaning and loading of the structure during the erection process). The results showed that the use of a circular traverse enabled uniform load distribution among the lifting elements and along lifted structure, Fig 8, which was not the case during mounting operation of cement clinkers silos cover presented in [5].

Deformation of the roof was to occur during the lifting stage, as it would increase in diameter by 6.4mm along the y axis, and decrease by 7mm along the x axis. The deformation along the z axis was 19mm, Fig 9. Such deformation is caused by large size and mass of the roof, and was to be expected. The deformation values obtained in the results meant that such deformation is of elastic nature, meaning that the original shape of the structure would be restored after the mounting process is completed, and its functionality will remain unaffected.



Required lifting elements	Capacity [t]	Qty.
wire rope 4m	43	4
schackle 1	35	4
circular traverse	140	1
schackle 2	4.75	40
nylon straps 6m	4	20

Figure 7: Elements for tank roof structure lifting [5]

Despite the maneuvering limitations, illustrated by the fact that the lifted structure barely passed by the pipelines (at the distance of just 50mm), the mounting procedure went smoothly and the roof has fitted perfectly to the reservoir, Fig 10, thus proving the elastic nature of the deformation and the adequacy of the whole approach to the challenge.

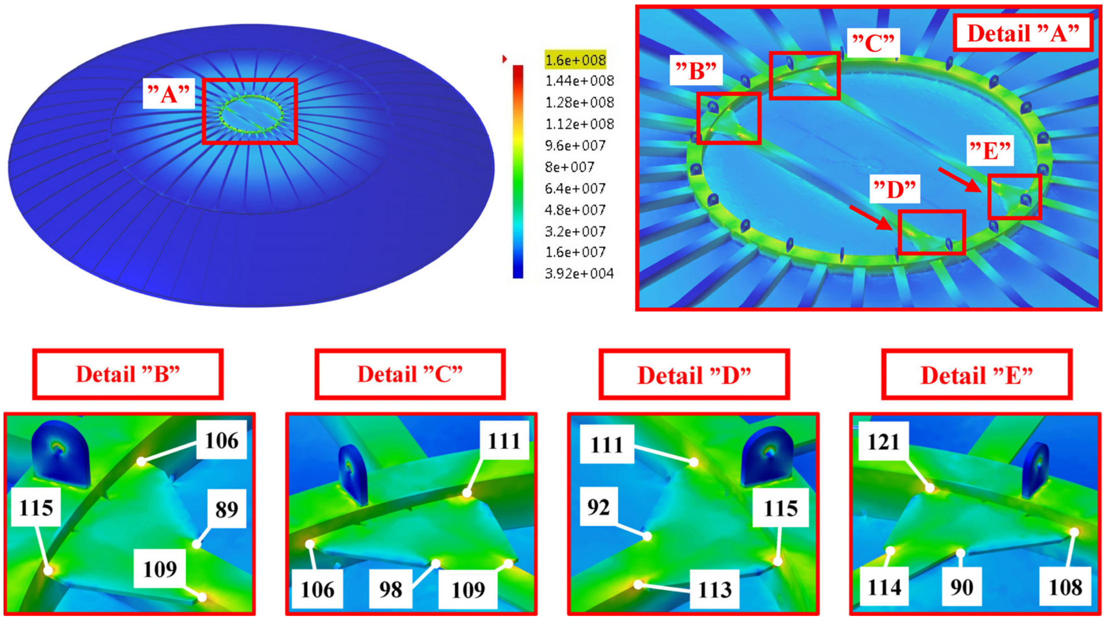


Figure 8: Tank roof structure stress field (values presented in details "B" to "E" are shown in MPa) [5]

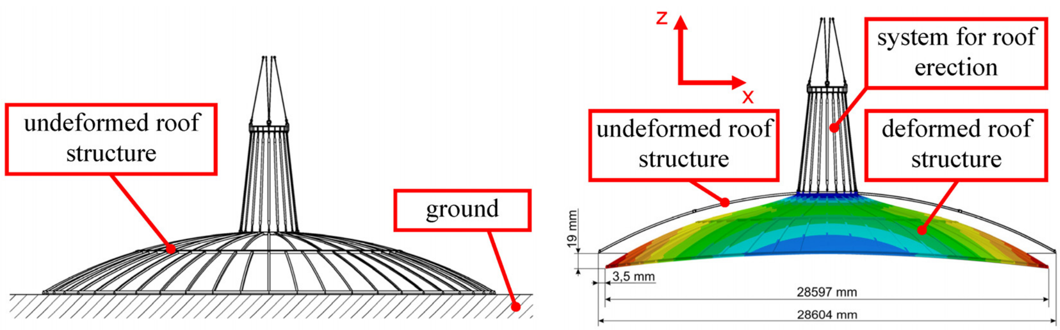


Figure 9: Tank roof structure deformation during lifting [5]

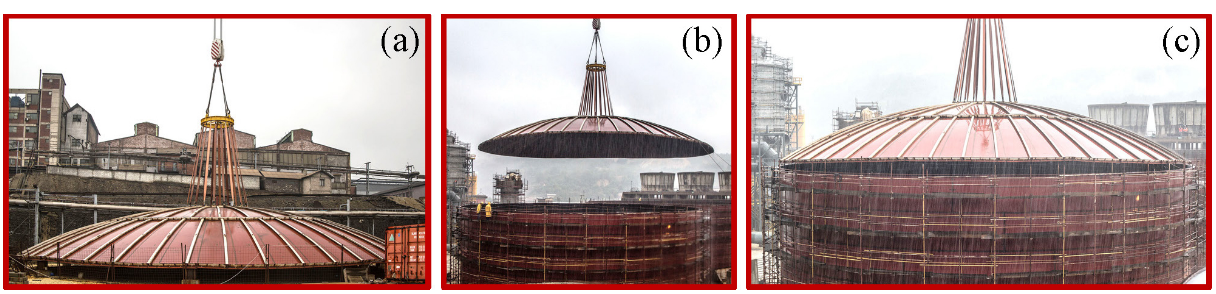


Figure 10: Mounting procedure of roof structure

4. CONCLUSION

Only a few large-scale structures are designed with mounting and dismantling processes in mind. As such, the original project documentation rarely covers the loads and stresses occurring during such procedures, and lifting supports are often overlooked. The application of unique below-the-hook lifting devices arises from the need for a reliable approach to problems of risk-free mounting and dismantling of such structures. This method has been proven safe on numerous occasions, even in harsh boundary conditions, and that alone heavily outweighs the cost and time consumption of their design and manufacture, which are largely influenced by lack of related literature, very limited coverage by standards, which give only general remarks concerning design of below-the-hook lifting devices for multiple cycles usage per day [7] and the structural diversity of objects that are to be handled, all of which make each problem unique. Their ability to efficiently preserve the structural integrity and functionality of large-scale objects and structural elements during the mounting and dismantling procedures makes their application a preferred method for overcoming such challenges and eliminating risks that, as shown by numerous historical experiences, accompany such operations.

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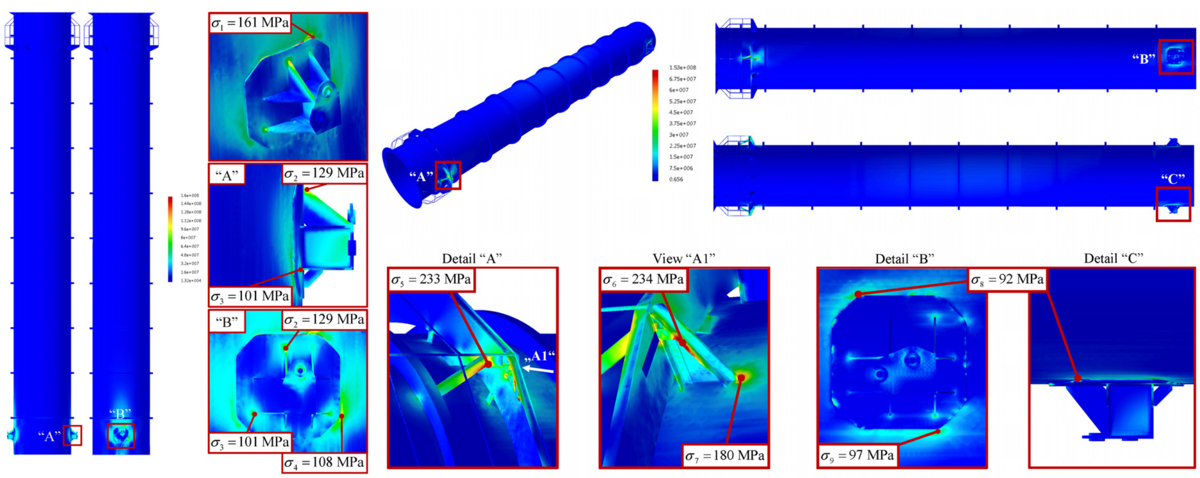

Figure 5: Stress states of part 1 in critical positions