Major reconstruction of central casing of open top baking furnace with a view to increase its lifespan and reduce the total costs comparing to full reconstruction

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Abstract

Anode baking furnace (ABF) is fundamental for the production of anodes with specifications and quality suitable for aluminum electrolysis. The anode baking furnace shell inside whom the refractory is installed is usually called "casing" or "tub" and is made out of various concrete elements. The casing is a critical component of the facility and usually faces very few modifications during its lifetime due to the magnitude and complexity of the work and therefore its impact on production capacity. Aluminium of Greece (AoG) operates with success its anode baking furnace since its start up, more than five decades ago. Thermal and mechanical stresses created by the baking process however affected the integrity of the concrete casing in the central part. Distortions, deformations and cracks were indeed visible in comparison to the outside part of the casing. This paper goes through the different phases undertaken by Aluminium of Greece in order to successfully develop and safely realize a major repair on its casing while limiting costs and impacts on production and anode inventory. The scope of work was indeed composed of the replacement of the casing walls in the central passage as well as the anode conveyor supporting structure with a limited impact on the refractory (insulation, headwalls and fluewalls). The article details the technical challenges and innovative solutions as well as the project and operation organization put in place in order to realize the work without any safety incident and in a strict schedule of ninety days. Finally, the start-up and ramp-up phases realized by Aluminium of Greece operation team in order to successfully manage old and new sections and bring back the furnace at steady production in a minimum time are detailed.

Keywords: anode baking furnace revamping, concrete casing, casing walls, headwalls, fluewalls.

1. Introduction

Anode Baking Furnaces (ABF) are fundamental for giving the anode its most significant properties, such as electrical and thermal conductivity, air and CO_2 reactivity, mechanical strength etc. To do so, green anodes are fed into pits and heated up to 1150°C. The main parts of the Baking Furnace consist of the concrete casing (composed of the casing walls and raft) and the refractory bricks for the thermal insulation and the headwalls and fluewalls.

AoG anode baking furnace is an open top ring type furnace designed by Aluminium Pechiney and erected in the 1970, Figure . It is composed of 78 sections with 6 pits per section (i.e. 7 flue walls). Four fires are operated at 26h cycle for a total output of approximately 93.000mt of baked anodes/year.

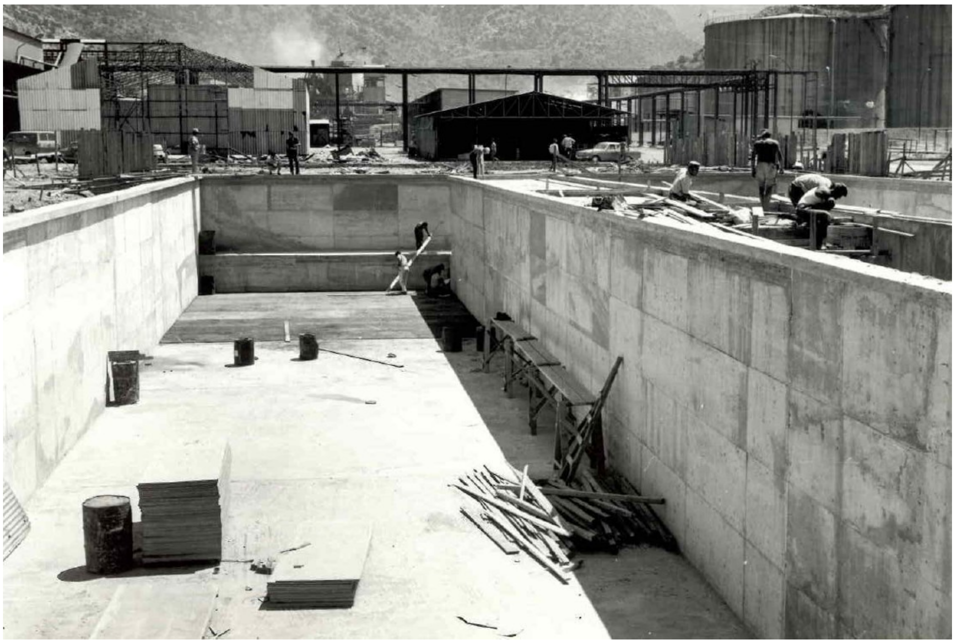

Figure 1. Aluminium of Greece concrete casing during furnace construction (1970)

After more than five decades of thermal and mechanical stresses due to continuous operation, concrete elements of AoG baking furnace display distortions, deformations and cracks. These defects are mostly observed under the central anode's conveyor where green and baked anodes are distributed in and out of the anode baking furnace. As they are supported by soil (AoG baking furnace casing is built underground), side concrete elements are indeed in a much better condition than the stand-alone civil elements in the central. Contrary to refractory and insulation wear (replacement or partial repair of headwalls, fluewalls, insulating walls etc.), concrete casing defects can hardly be fixed through daily maintenance routine and ultimately affect the anode baking furnace safety and operation. Defects with a magnitude of the ones observed on AoG furnace are usually managed with a full reconstruction project involving important financial resources.

This paper presents the different phases undertaken to successfully develop and realize a breakthrough project of partial reconstruction of AoG anode baking furnace concrete elements (central parts only) and their nearby refractories and insulation in ninety days. A tight and very carefully designed time schedule for every reconstruction phase allowed to minimize cost and production losses. Technical and administrative challenges will be reviewed in detail as well as the shut down and, after ninety days, the simultaneous start-up of the four fire groups. In particular, the strategy adopted in order to properly manage the moisture released from the new refractories will be discussed. Finally, the paper concludes with a summary of the benefits of this project.

2. Main causes ABF Revamping need at AoG

Through the decades and due to continuous mechanical and thermal stresses, the concrete casing of the baking furnace moved towards the center. As a result, the upper part of the central vertical casing walls eventually came in contact with the concrete slab and the foundation of the central platform of the anodes conveyor. The ongoing deformation of the concrete casing and the blockage of the vertical casing walls at their upper end, caused their deformation, Figure 2. Indeed, major cracks and inclinations to these walls were observed.

On the other side of the casing, the side vertical casing walls of the baking furnace were in a fairly good condition due to the fact that they rest on soil as AoG anode baking furnace is built underground. Therefore, only the central part of the concrete casing was decided to be replaced.

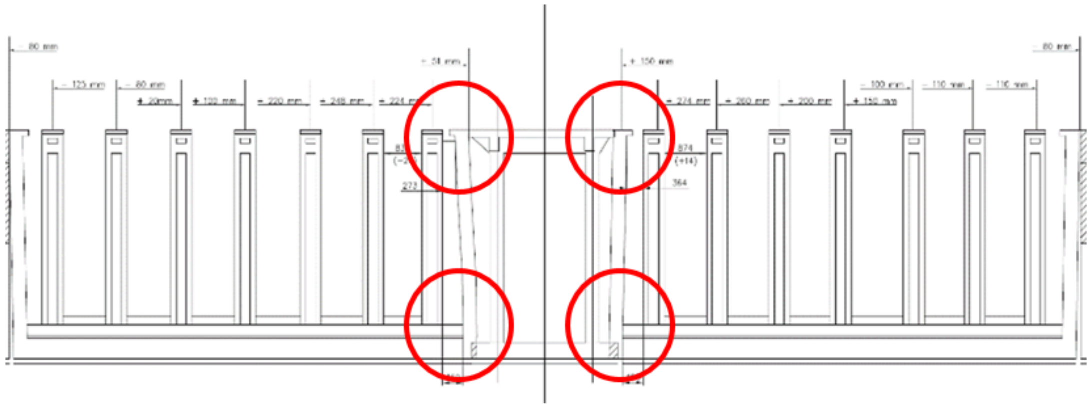

Figure 2. Cross section of ABF furnace. Location of main structural defects observed on concrete casing

A Project team was put in place and start working on designing the solution two years prior to the project execution in order to be able to positively address complicated technical & safety challenges identified.

3. Technical scope and challenges

As presented in Figure, the scope of the project on the 78 sections of the furnace has been:

- Demolition of external fluewalls, part of the headwalls and thermal insulation on the central conveyor side;
- Demolition of the casing central walls and the part of the raft;
- Dismantling of the anodes conveyor and its steel supporting structure;
- Installation of new casing central walls and pouring of new raft;
- Erection of new insulation, fluewalls and headwalls;
- Installation of new structure for anodes conveyor;
- Re-installation of existing anodes conveyor.

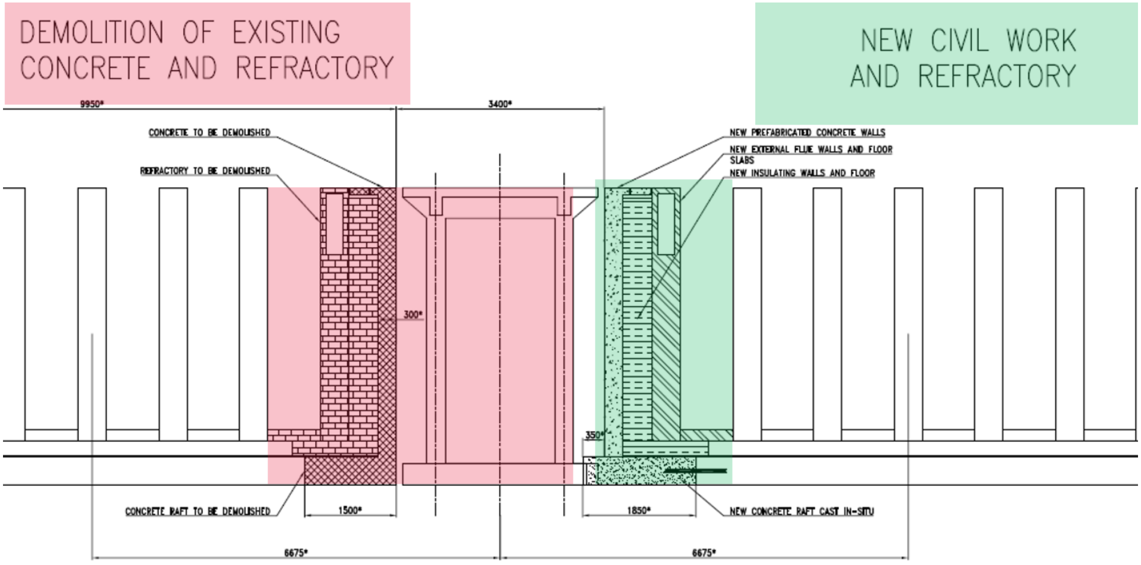

Figure 3. Cross section of ABF furnace. Refractory demolition & central conveyor removal

The main technical challenges to be managed for this partial reconstruction of the central part of the furnace as presented in Figure 3 were:

- Unknown condition of the raft and the internal part of the central walls condition (impossible to inspect);
- Very few repairs done in the past 60 years with only one repair performed in the central part of the furnace and the conveyor in 1988;
- Any intervention should be made 5 meters below the ground level as AoG furnace is built underground;
- Availability of three cranes only to realize all the materials movements
- Tight project schedule with a strict maximum duration of ninety days
- Safety management with all the above listed constraints.

3.1. Project management

The strong collaboration in place from the beginning of the project until the very end between AoG teams, suppliers, contractors and Rio Tinto – AP allows to safely and successfully respect the technical and schedule objectives.

An in-depth scheduling of the tasks with very regular update has been necessary in order to avoid any interaction between the various tasks to be made. Along with the traditional Gantt charts, Figure 4, a specific tool has been developed and used in order to manage the amount of people working inside the furnace.

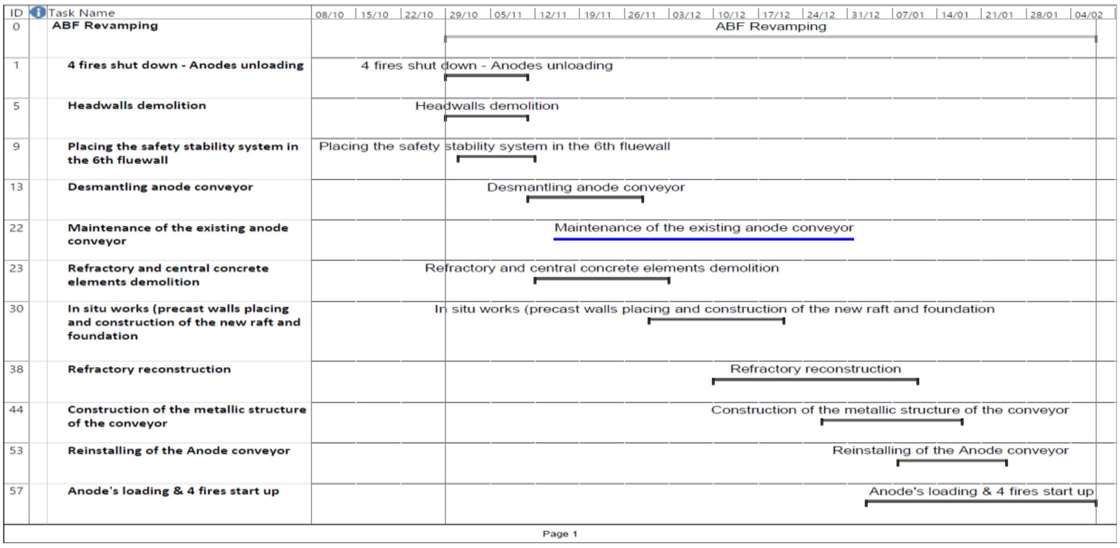

Figure 4. Gantt chart tasks

This custom-made visual algorithm was updated every 8 hours in order to obtain a top view of the furnace with a spatial illustration of each contractor team with their location and the number of people at work, Figure 5. This procedure ensured that there was not more than one worker at the same time at the same place, improving the overall safety of the project execution.

The system also allowed to identify and forecast high safety risks tasks. These tasks were the ones involving working at height, material distribution via cranes, checking lifting mechanisms, manual work tasks and the use of crawlers in the plant with employee's interaction in the same spatial field, Figure 6.

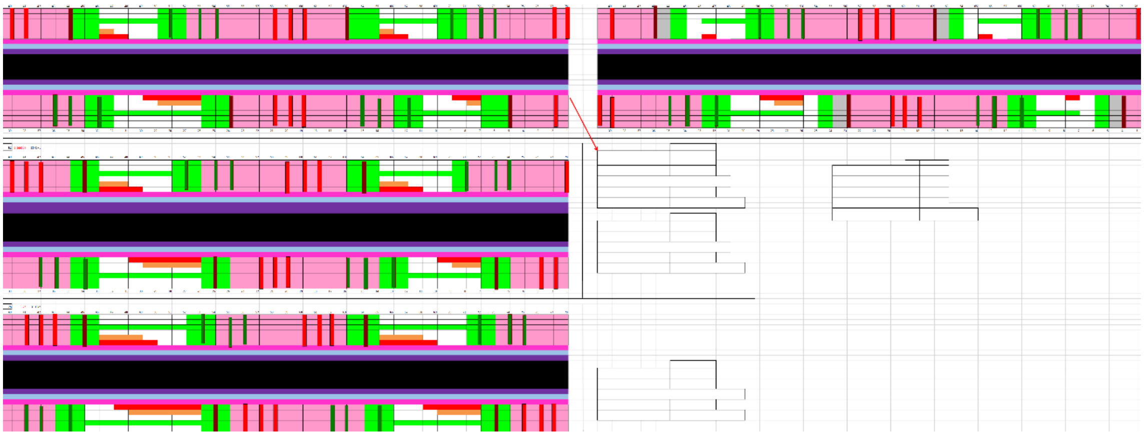

Figure 5. Custom-made Safety Application

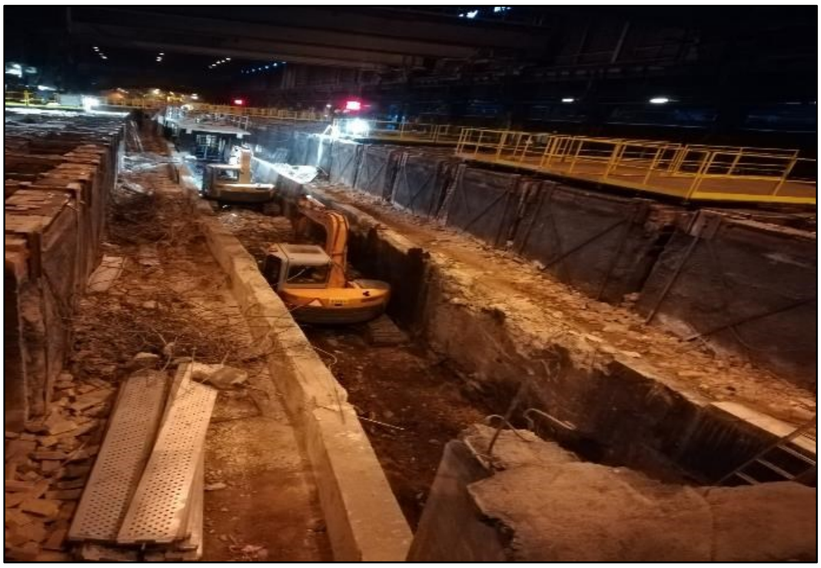

Figure 6. Crawlers in the Plant

In terms of AoG internal organization, the Carbon Department organization chart was heavily modified during the 90 days of the project in order to use the manpower in the most efficient way. The green anode plant was completely stopped, and new job descriptions were created. Positions of on-shift quality inspectors for the refractory & civil works, safety inspectors and storekeepers were filled.

In addition, training courses were organized not only for AoG's employees but also for the main contractors. All these courses were designed well before the project but realized just before the start of the project in order to motivate the entire team at the right time.

4. Project execution

4.1. Preparation work and demolition

The first phase of the preparation work has been to raise the baked anodes inventory in order to continue supply of anodes to reduction while the baking furnace will be stopped. It was also decided by AoG top management not to start the revamping works if all necessary materials were not on site. This allowed eliminating the risk of prolonging the project time schedule due to material delivery delays.

Before the beginning of the demolition phase of the project and as shown in Figure7, a supporting structure has been installed to prevent the 6th fluewall from collapsing while the raft would be cut and removed.

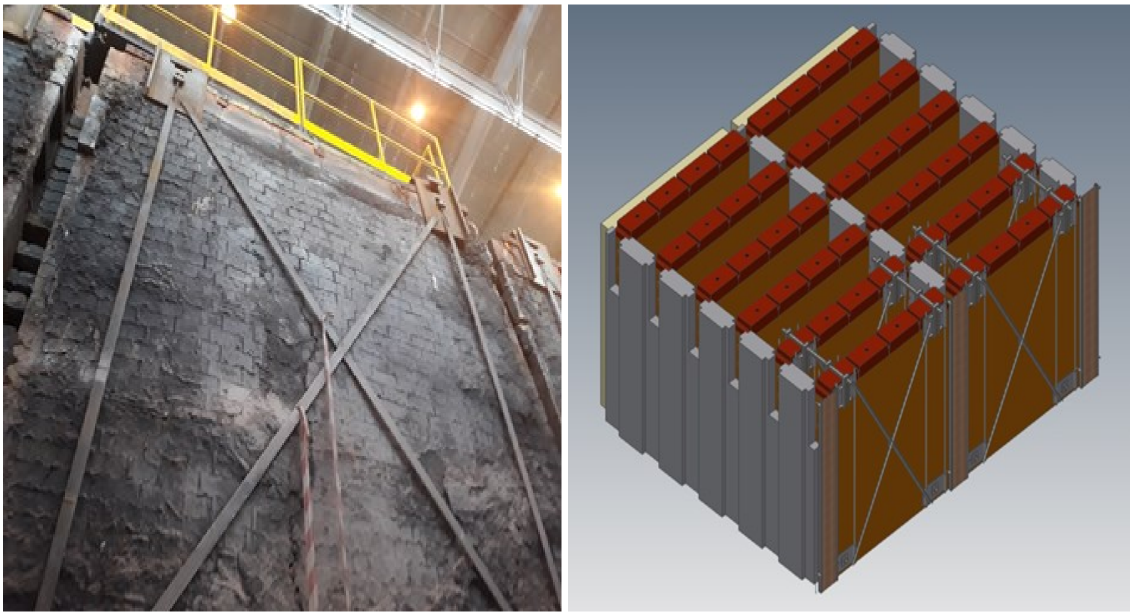

Figure 7. Stability system on the 6th fluewall

Moreover, the concrete slab of the conveyor had to be reinforced, Figure 8, in order to withstand the load of the 3 crawler machines used to demolish the insulating walls and the fluewalls.

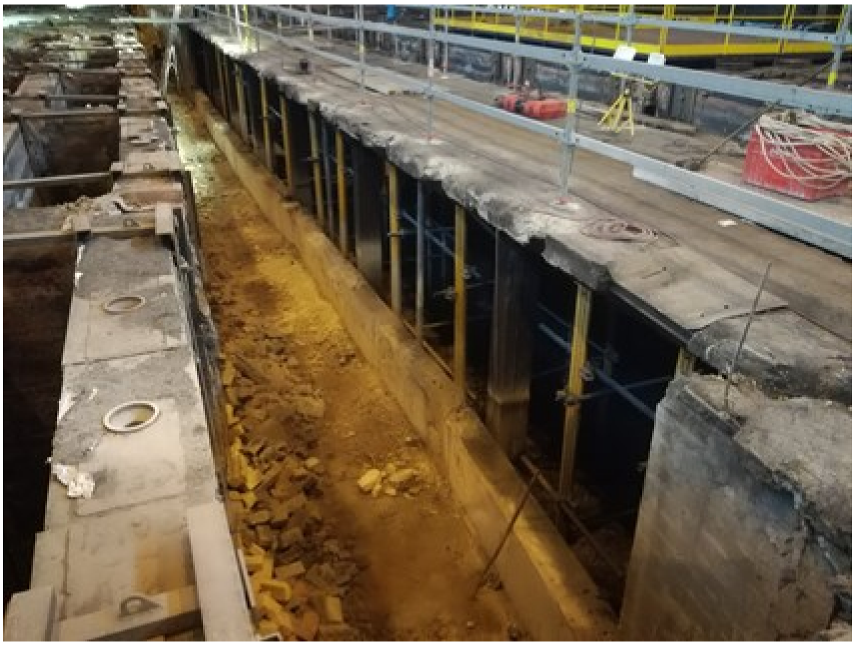

Figure 8. Platform reinforcement

Once the operations reached the bottom level of the anode baking furnace, two challenges were identified. Firstly, the condition of the raft was worse than the initial assumptions, Figure 9. It was decided by the project team to move the sawing line further away from the 6th wall than originally planned in order to provide extra safety margin against a risk of collapse of the fluewall. The damaged concrete of the remaining part of the raft had to be removed, in order to make the proper connection between the old and the new raft.

Figure 9. The existing raft condition after cleaning

Secondly, the end walls of the concrete casing at the crossover passage were suffering from major deformations. A metallic stability system was installed to maintain the end walls of the crossover, Figure 10.

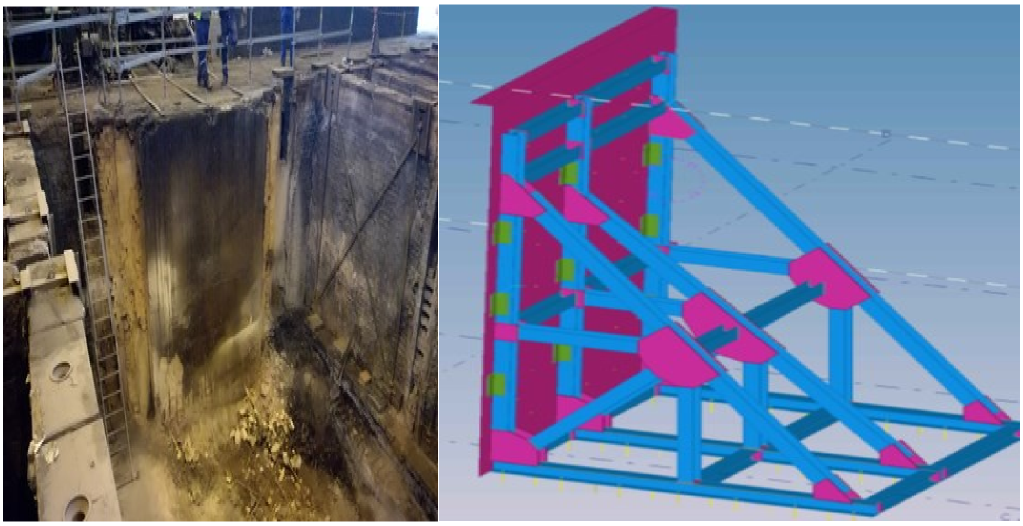

Figure 10. The east terminal crossover concrete wall (left) and stability structure used (right)

4.2. Erection

The new prefabricated walls were transported by crane and placed in their exact positions with minimum tolerances in orthogonality and linearity in order to guarantee at the end the right size of pits and the flatness of the furnace top surface, Figure 11. The new raft was then poured in order to obtain a flat surface for the refractory insulation in the casings and the new conveyor structure between the two casings.

Figure 11. New prefabricated walls and pouring of new raft

Contrary to the original design and in order to tighten the construction schedule, the conveyor supporting structure has been realized with a partially pre-assembled metallic structure, Figure 12. This design also has the benefit of allowing the casing walls to move due to the thermal loading created by the furnace operation as an expansion gap is left between the conveyor slab and the casing walls. The conveyor itself had to be modified at the end to accommodate the movement of its original position.

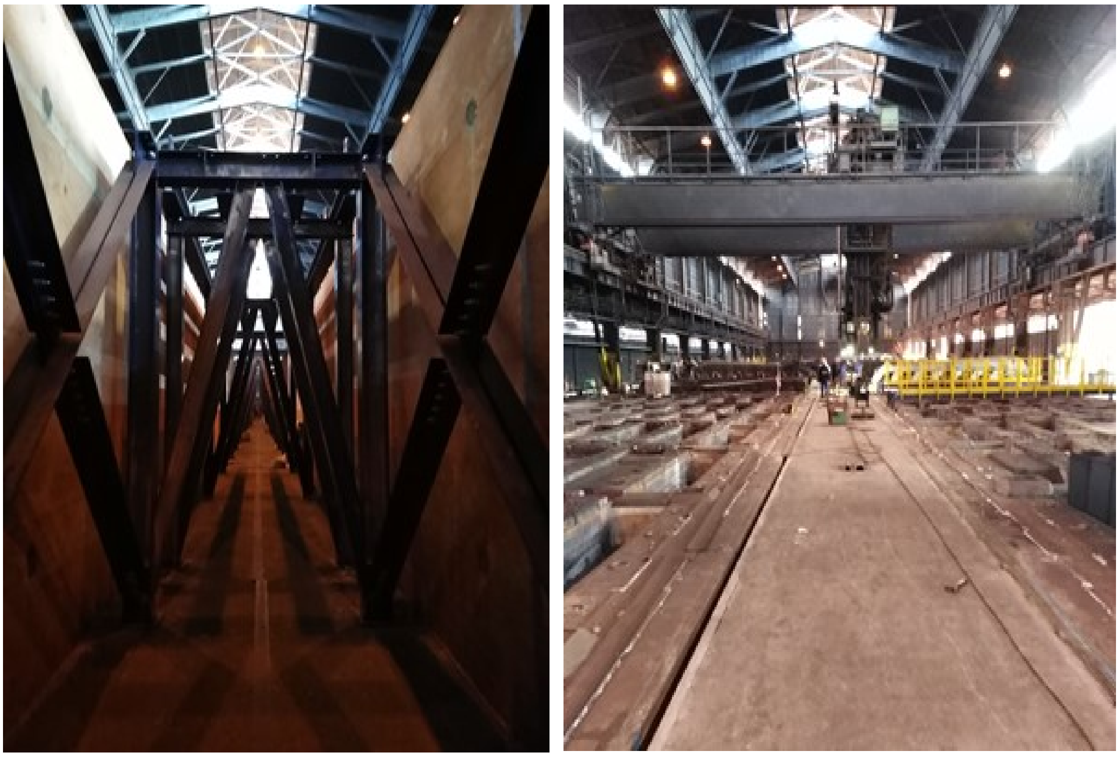

Figure 12. Metallic structure of the conveyor & the new collaborative slab

The refractory installation has been realized in 30 days with the installation of 78 external fluewalls, headwalls extremities, insulating floor and insulating walls. The main challenge was the large number of workers needed at the same time in a tight environment in order to install the refractory. This has been successfully managed by AoG project team through a very strict scheduling of activities as well as a continuous awareness of the workers about the coactivity risks.

Connections between old and new parts for the insulation and the headwalls was successfully managed by AoG bricklayers thanks to their strong experience, Figure 13. As new and wider insulating walls were installed, the position of the 6th fluewall has been adjusted in order to achieve a proper pit width.

Figure 13. Headwall reconstruction around old fluewalls

4.3. Furnace restart

The four fire groups were restarted simultaneously. Moreover, and due to the fact that 1/6th of the ABF was now new, it was necessary to design two different start up procedures for every fire. The new pits (pit #6) were indeed loaded with baked anodes and specific curves were applied in order to realize a proper dry-out. The other pits were loaded with green anodes.

5. Conclusion

For the first time a successful partial reconstruction of an ABF is reported. The main challenge tackled by AOG engineers was to reconstruct only the heavily stressed central casing elements with as less impacts as possible on the refractories (insulation, headwalls and fluewalls).

The strong preparation and execution follow-up realized by AoG allied with the technical expertise of Rio Tinto – AP allows to successfully realize the project in ninety days and achieve the main noteworthy results:

- Safety excellence (zero medical treatment cases, zero lost time injuries);
- Cost avoidance (compared to a full reconstruction solution);
- Minimum production losses;
- ABF Lifespan extension (given that the rest of the ABF structural elements are in fairly good condition).