Geometric documentation of mining industrial historical heritage: application to a Cornish pumping engine house from the ancient mining district in Linares-La Carolina (Jaen)

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Abstract

Cornish pumping houses represents one of the most unique architectural elements of the historical industrial mining heritage located in the old mining district of Linares-La Carolina (Jaen), specifically related to the process of pumping water from the mines. They were imported from the region of Cornwall (UK) and they settled with great profusion in mid and late nineteenth century.
However, while being aware of its importance, the absence of their graphical information linked to lack of protection, it make a progressive deterioration in addition to the numerous cases of looting that they are suffering, so their status is ruinous .
The importance to know them from the viewpoint of architecture lie in, from its three-dimensional model, it is possible simulate the location of its functional elements with their true dimensions and therefore it would be possible to create the animation of the process of its operation.
In particular, it has obtained the three-dimensional model of the Cornish pumping powerhouse of the San Vicente well in the town of Linares (Jaen), thanks to the support of a CAD software widely established that along with the planes can be used for dissemination of that historical heritage.

1 Introduction

The historical industrial mining heritage is a typology of cultural heritage that every day becomes more relevant and, therefore, it is the subject of several studies.

So, in 2008 it was approved the Letter of El Bierzo for the conservation of industrial mining heritage in Spain [1]. The result of this commitment, the initiatives have been more numerous every day, developing parks, museums and interpretation centers in different areas where it was produced the decline of mining. This way, it is allowed the promoting the mining tourism or industrial tourism.

These initiatives have been developed in the old mining district of Linares-La Carolina (Jaen) which became one of the three major productions in all of Spain, mainly due to the 'boom' in lead mining. Fundamentally, it was facilitated by the technological advances of the Industrial Revolution that came to light in the late nineteenth and early twentieth centuries. Not surprisingly, the mining landscape of Linares-La Carolina is one of 100 outstanding examples of industrial heritage by TICCIH (The International Committee for the Conservation of Industrial Heritage) [2].

In fact there are case studies that highlight the importance of Andalusia in Roman times as a significant source of lead, particularly in the Sierra Morena area at north of the Guadalquivir River, and, specifically, in the district of Linares [3].

In the other hand, the pumping engine house is an example of industrial mining heritage linked to the extractive phase of mineral [4], as well as pit-head gear, derricks of the masonry, cages, houses extraction machines, boiler houses, industrial smokestacks, compressors or electrical substation.

Its water drainage function of the mines was critical and therefore the importance of their study.

This communication tries to rescue from oblivion an example of industrial mining historical heritage such as the pumping Cornish houses for putting in value and diffusion through graphic engineering.

2 Cornish's technology

The description of the technology from the Cornish innovation, it is perfectly reflected in the following quote:

"In 1806 Trevithick proposed to replace the wagon boiler of a Boulton and Watt pumping engine on Dolcoath mine by one of his cylindrical boilers and to work the engine with steam at 25 lbs per square inch. The steam valve was to be shut early in the stroke, so that the remainder off the stroke would be made by expansion of the steam already in the cylinder, just as Watt had tried with low pressure steam. Nothing was done at the time, but in 1812 Trevithick has the opportunity to try out his ideas on a little pumping engine, which he put up on Wheal Prosper mine at Gwithian. This was a single acting condensing engine with a cylinder 24 inches in diameter and a stroke of 6 feet. It was supplied with steam at 40 lbs per square inch by a cylindrical boiler 6 feet in diameter and 24 feet in length with an internal furnace tube running from end to end – a type of boiler, which became known as a 'Cornish' boiler. At first when the load was light, the steam was cut off at between one ninth and one tenth of the stroke. This was the first 'Cornish' engine, but its development was left to others, as Trevithick sailed for South America soon afterwards" [5].

Therefore, Trevithick proposed a modification of an invention of Boulton and Watt, although its development was later in time. This is the first example of Cornish's device.

Figure 1 shows a model of a Cornish pumping house, next to an existing boiler house in the Interpretation Centre of Mining Landscape Linares (Jaen).

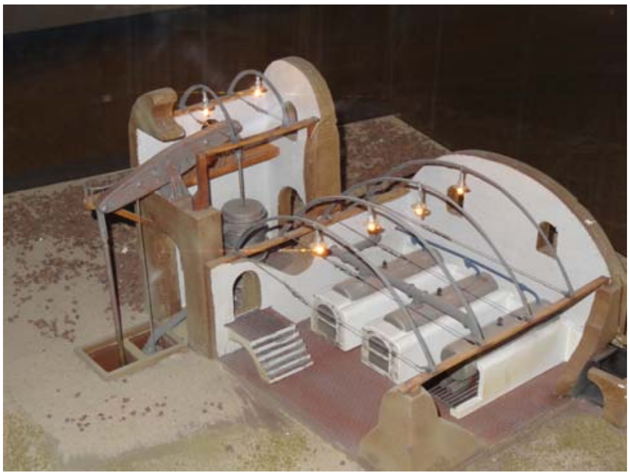

Fig.1 Photograph of the Cornish pumping house model of curved roof next to the boiler house in the Interpretation Centre Mining Landscape of Linares (Jaen).

Thus, the success of the steam engines designed by the engineer Richard Trevithick in Cornwall (United Kingdom), it contributes to the importation one of these kinds of machines in 1849 into the mining district, settling in Pozo Ancho Mine.

Afterwards, they were installed some dozen more, so that there were installed twelve in 1857, twenty in 1877 and forty-two in 1883.

In the other hand, Cornish boilers presenting an interior heater, large amount of fuel was needed (orujo, wood and coal) and they were the most commonly used.

2.1 The Cornish pumping engine house

The following quote reflects faithfully the operation of the Cornish pumping device.

The following description of the modern form of the Cornish pumping engine is chiefly taken from André's "A practical treatise on coal mining" [6]. The cylinder F, is 70 inches diameter, with a 10 feet piston stroke. It is provided with a cast-iron steam jacket, connected with the boilers by pipe H (fig. 2). The boilers are situated below the pipe H, so that the water of condensation returns by it. Where the boilers, from unavoidable circumstances, are above the cylinder, the supply pipe to the steam jacket cannot serve as a return condensed water pipe, and provision must be made for freeing the jacket from condensed water by means of a steam trap. The steam jacket is encases in wood; the annular space between the two is filled with some non-conducting medium, such as sawdust, and the whole is enclosed in brickwork, either in contact with the casing, or separated from it by a few inches, and is plastered on the outside, the plaster being covered with wood paneling. The cylinder cover is fitted with a false lid or cap, which encloses thick layer of sawdust, and is thus protected from the same influence by steam filling it from a branch of the pipe, H. C is the main beam, cast in two plates which are bolted together with distance blocks between them to keep them truly parallel [6].

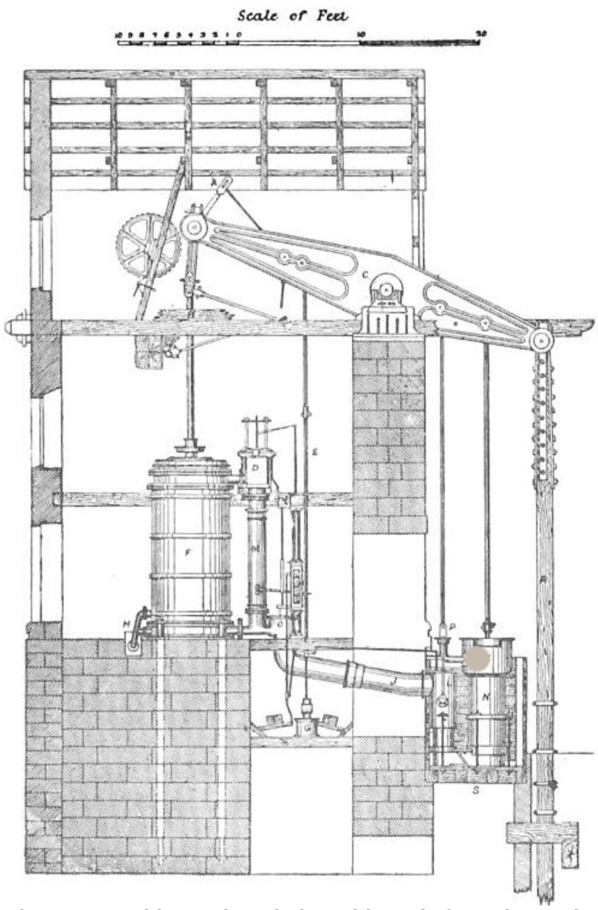

Fig. 2. Assembly sectioned plan with scale from the engine house of Cornish pumping [6].

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The Cornish pumping engine is a wonderfully elaborate and complicated specimen of ingenuity and skill, and it cost is about 8 pound per horse-power. A 90 inches, or 500 horse-power, therefore costs about 4,000 pounds; then the three-storied engine-house and pillars for such an engine, would require about 500 cubic yards of masonry, the price of which varies in different localities, according to the character and price of materials, such as stone, bricks, lime, etc. In Cornwall, where suitable stone abounds, it seldom exceeds 6s. 6d. per yard. Again the steam case must be covered with some non-conducting material, or else, having a greater surface area than the steam cylinder, it becomes a lager condenser.

Another objection to the Cornish engine is the large number of parts to maintain in an efficient state of repair and cleanliness. It has four double-beat valves with their sets of bright nozzle gear, consisting of pillars, levers, and guides, quadrants and catches on the ground floor, tapped rod carrying its adjustable blocks to work the four levers of double-beat valves and cataract governor in the basement; air-pump and condenser with foot and delivery valves, injection cock, and valve and lever attachments; also a large cast-iron beam, which for a 90 inches engine, weighs 50 tons, and the parallel motion with its many joints, all requiring a considerable amount of attention and care.

The method adopted in Cornwall has been to find out what weight of water has been lifted one foot high by the consumption of one bushel = 94 lb. of coal. Of late years the bushel has been exchanged for the hundredweight of 112 lb. In America the standard is 100 lb. of coal.

This found out, the ascertaining of the weight of water lifted out of a mine of a given depth is simple. Thus, if an *engine by the consumption of 112 lb. of coal lifts 60,000,000 lb. of water 1 foot high, the amount raised out of a shaft of 100 fathoms = 600 feet deep, would be 100,000 lb. This being the result of dividing the amount raised 1 foot by the depth of the pit.*

The engines at present working on the Cornish mines are all heavily loaded, pumping from great depths, in crooked, inclined shafts, entailing very considerable friction on the rods, and a late steam cut-off, which means less expansion in the cylinder and a low duty. From the best information obtainable, it would appear that the average duty of these engines is not at present in excess of 60 million.

The principle on which the Cornish pumping engine was designed, and which has just been described, met fully the conditions necessary for the economic drainage of the mines, and consequently no engine has heretofore held so high or meritorious a position [6].

3 Methodology

In this section, it is described the followed steps to obtain geometric documentation of the engine house of Cornish pumping under study, originally located in the San Vicente pit in the San Miguel mine of the town of Linares (Jaen). It was selected by its magnificent conservation condition of the masonry derrick.

3.1 Input data: Fieldwork

Due to the absence of physical remains of the Cornish pumping house during the visit to San Vicente well, related historical information was sought as old photographs (fig. 3) and sectioned assembly drawings with their graphic scales that they will show the size and disposition of its building elements (fig. 2). Furthermore, it has also been used diverse literature related to detailed information from the design of the Cornish houses [7-8].

With this historical information, it has been performing office work to understand its geometry and dimensions, finally obtaining the three-dimensional model.

***Fig. 3** Photograph of the original state from the engine house of Cornish pumping installed in the San Vicente well at the end of nineteenth century in the Interpretation Centre of Mining Landscape Linares (Jaen).*

3.2 Geometric documentation

From the viewpoint of engineering, reliably three-dimensional modeling is an optimal tool because it allows the precise study of each model elements and it provides an overview of how they are integrated between them.

The used software was AutoDesk AutoCAD 2012 [9]. Although this software is not parametric, which is recommended in the design processes due to it is redefining the geometry of the object as a result of successive evaluations about itself; the use of this program is justified for two reasons: first, its standardization because of the generated file (.dwg or. dxf file is a neutral exchange variant). It does not present exchange problems if the generated model is then used in another application where it can add textures, lights, computer animations, dynamic simulations or CAE applications for analysis of model behavior, and secondly, because of their easiness to use, since no 3D solid modeling requires the use of too many commands.

4 Results

Following are shown the results of three-dimensional modeling of an engine house of Cornish pumping (figs. 4 to 6).

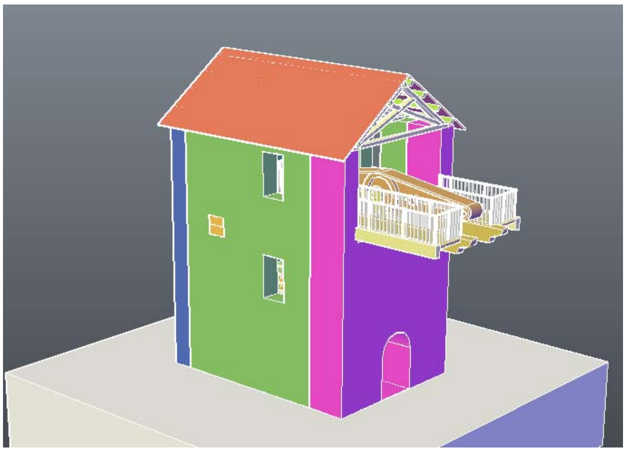

***Fig. 4** Anterior view of the Cornish house.*

***Fig. 5** Back view of the Cornish house.*

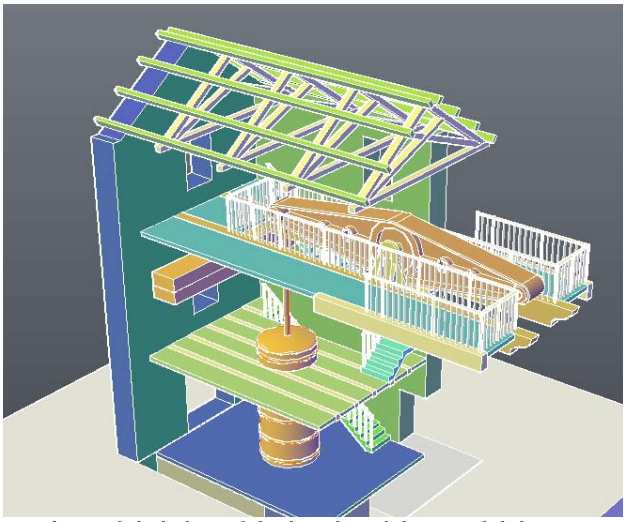

Fig. 6 Global view of the interior of the Cornish house.

Following it is shown the results of three-dimensional modeling of each element that makes up in the assembly of Cornish house.

4.1 Frontal wall

Its function is to support the weight the rocker arm and its support, being open at its upper part to allow the oscillating motion of the rocker. It also has a bow shaped hollow of half point for the cylinder for access.

It was constructed, in most of cases, based on ashlars of stone and its thickness was 1.85 m (fig. 7).

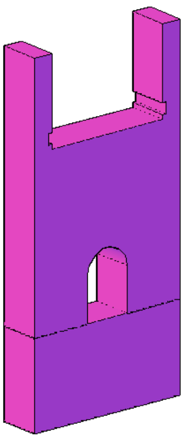

Fig. 7 Frontal wall.

4.2 Lateral wall

It was constructed, in most of cases, based on ashlars of stone and its thickness was 1.85 m.

Consisted of two square holes to embed the transverse beams which support in turn the longitudinal beams that provide support to the floor slab of the second floor and they were built with ashlars of stone of 0.90 m thick (fig. 8).

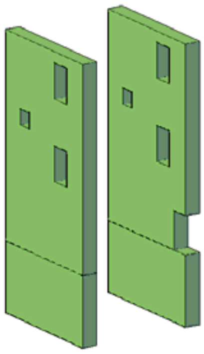

Fig. 8 Lateral walls.

4.3 Back wall

Its function is to support the weight of the roof and close the enclosure, having rectangular holes for the interior lighting as well as two square holes to embed longitudinal beams that support the floor of the second floor.

At the entry level, there is a hole, crowned by a semicircular arch of 2.4 m wide, which allows entry of the cylinder and their material, in the most of cases, are blocks of stone 0.95 m thick (fig. 9).

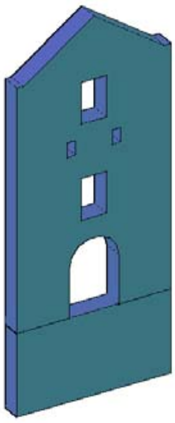

Fig. 9 Back wall.

4.4 Foundation and ground floor slab

Below the entry level, there is a basement depth of 4 m and over it, there is built a rectangular prism 5.64 x 5.00 m to support the cylinder.

The rest of the basement consists on holes to host pipes, condenser and switchgear, with a wooden slab of the decking ground floor of 15 cm thick (fig. 10).

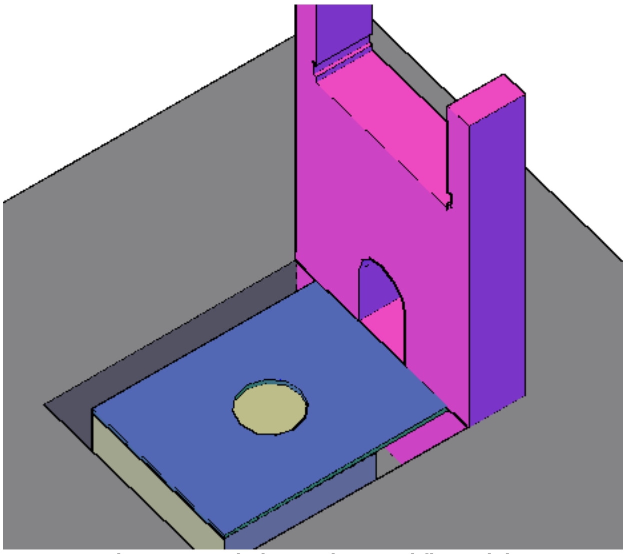

Fig. 10 Foundation and ground floor slab.

4.5 First floor slab

It is located at 3.80 m from the ground floor level and it consists on a wood decking of 15 cm thick, having wooden joists spaced 94 cm.

In its central part, it has a hole of 2 m diameter to allow placement of the cylinder (fig. 11).

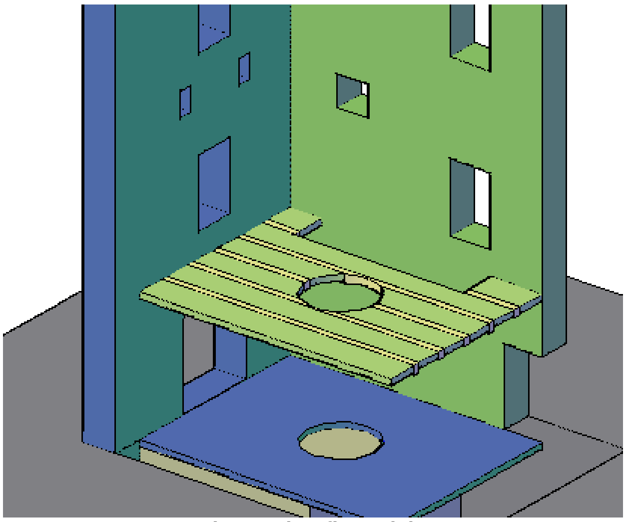

Fig. 11 First floor slab.

4.6 Transversal beams

Two wooden beams of rectangular section are arranged one above the other, and they are embedded in performed holes in the lateral walls.

The assembly section is 0.90 x 0.90 m, forming one element from the resistant structure from the second floor slab and being supported by the longitudinal beams which sits on that floor (fig. 12).

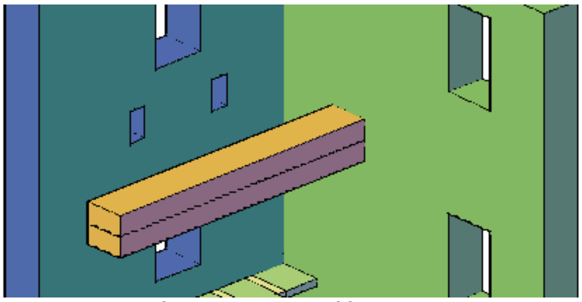

Fig. 12 Transversal beams.

4.7 Longitudinal beams

They are two wooden beams of rectangular section, 2.20 m separated, and they are embedded in the holes in from the back wall, making it one of the elements of the resistant structure of the second floor slab. They support the slab of this floor (fig. 13).

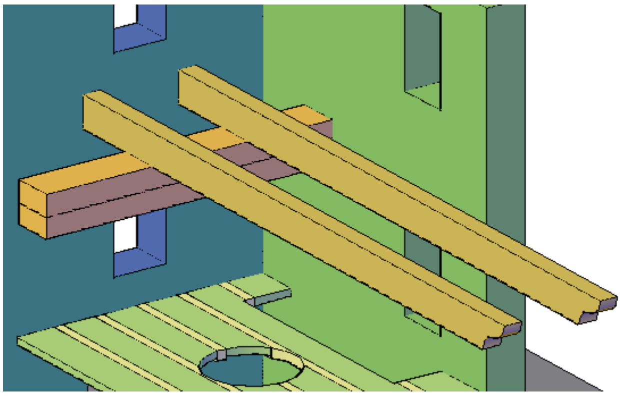

Fig. 13 Longitudinal beams.

4.8 Second floor slab

The slab of the second floor is located at 4.60 m from the level of the first floor, and is constituted by a wood decking of 15 cm thick, disposed both in the inside and outside zone. So, it lets step in the inspection of the rocker arm and pump.

It is supported at the ends on the lateral walls and in the middle of the longitudinal beams. Further, in its central part it has a hole of 1.80 m to allow movement of the rocker arm (fig. 14).

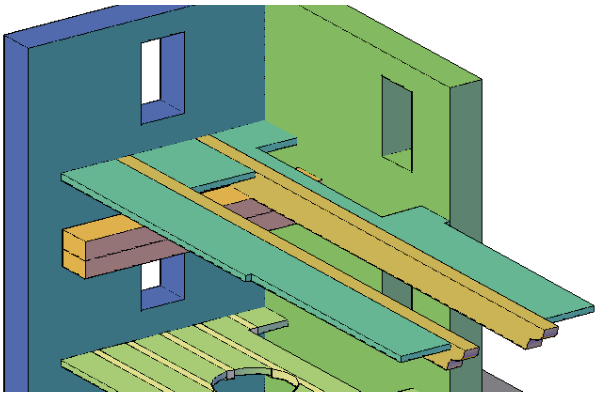

Fig. 14 Second floor slab.

4.9 First floor stairs

The stairs provide access from the entry level to the level of the first floor, saving a height of 3.80 m. It consists of a straight length of stairs with 20 steps, and each step providing footprint of 25 cm and 19 cm riser.

It also has a handrail with its height of 1.25 m along the entire length (fig. 15).

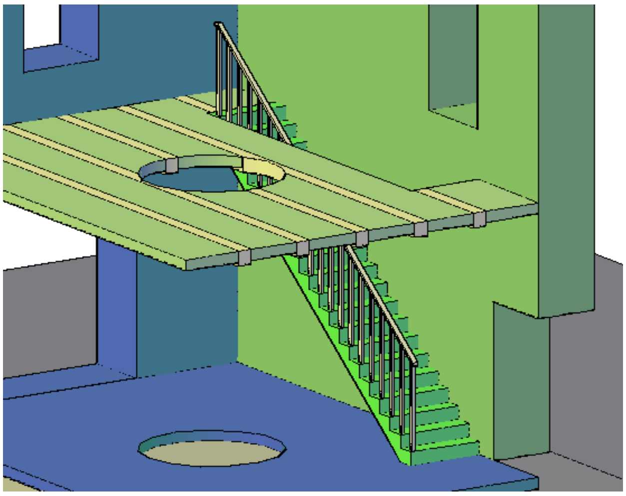

Fig. 15 First floor stairs.

4.10 Second floor stairs

These stairs provide access from the first floor level to the second, due to saving a height of 4.60 m, and it is formed by two straight stairs sections with an intermediate landing.

The lower section contains 4 steps and the upper section 20, showing each step a footprint of 25 cm and 19 cm riser, and it also has a handrail height of 1.25 m along the entire length (fig. 16).

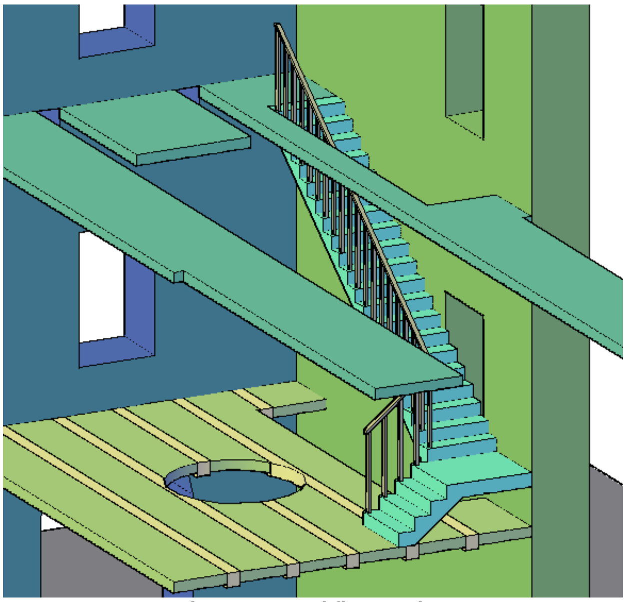

Fig. 16 Second floor stairs.

4.11 Cylinder

This element allows the movement of the rocker arm due to the force exerted by the steam, causing the interior movement of the piston.

It is composed of a hollow metal cylinder of diameter 2.00 m and 4.80 m of height, and it is embedded of its anchors over the foundation practiced in the basement (fig. 17).

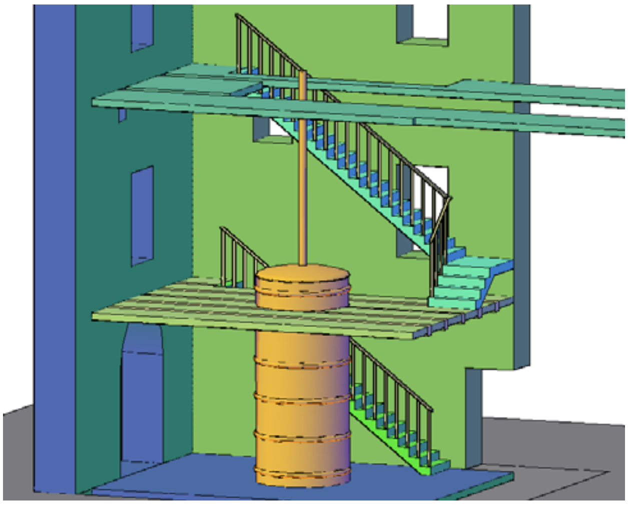

Fig. 17 Cylinder.

4.12 Rocker arm and support

This is the element that in its back-and-forth alternative movement allows subsequent aspiration and drainage of water that flooded the mine.

It consists of a steel beam symmetrical, with a length of 9.88 m and the diameter of the intermediate part of 2.00 m. Thus the rocker arm spins on an axis and it is sustained by a metallic support that is holding on the front wall (fig. 18).

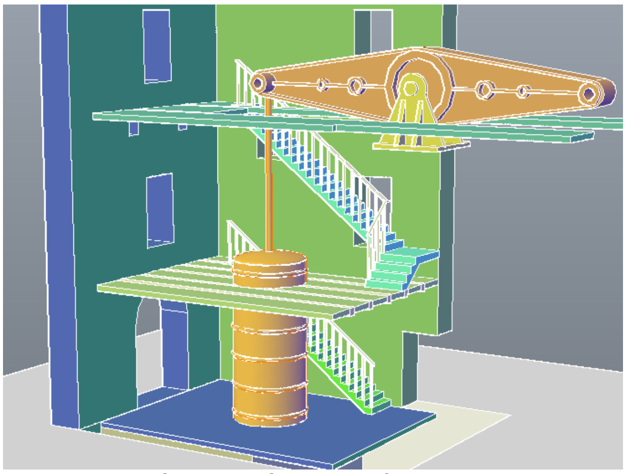

Fig. 18. Rocker arm and support.

4.13 Handrail of the rocker arm platform

The handrail is located on the second floor slab, both on the inside as on the outside part, forming a network of parallel metallic bars of 2 cm in diameter and 1.20 m in height, being crowned by a plate as handrails (fig. 19).

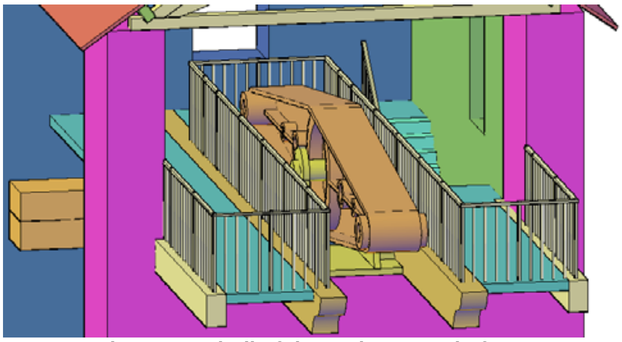

Fig. 19 Handrail of the rocker arm platform.

4.14 Roof trusses

They form a triangular structure bar. Furthermore, the lintel consists of two bars and two uprights crossbars.

They are supported over the front and lateral walls, with wooden square section 18 x 198 cm and with a span of 5.64 m (fig. 20).

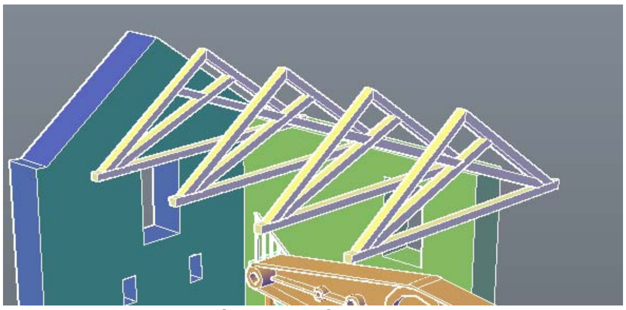

Fig. 20 Roof trusses.

4.15 Roof straps

Its role is to provide support for the roof sheeting deck, being supported above the trusses.

They are made of square section of 25 x 15 cm and they are spaced 1.20 m between them (fig. 21).

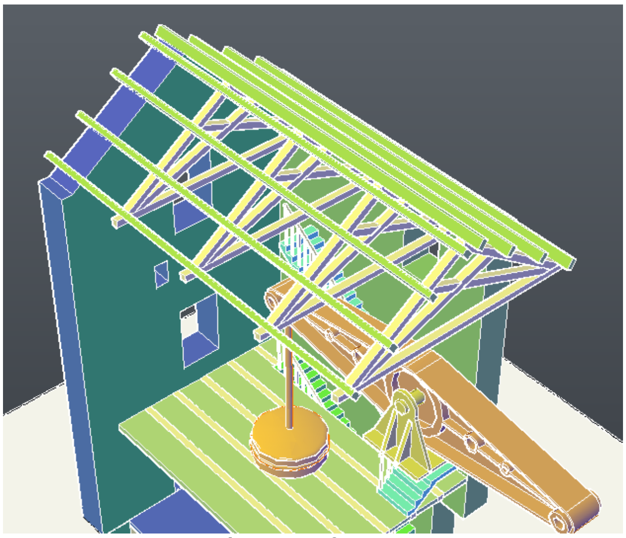

Fig. 21 Roof straps.

4.16 Roof

The roof is composed of a gable roof with each side formed by a sheet of 5 cm of thickness. They are supported directly above the straps (fig. 22).

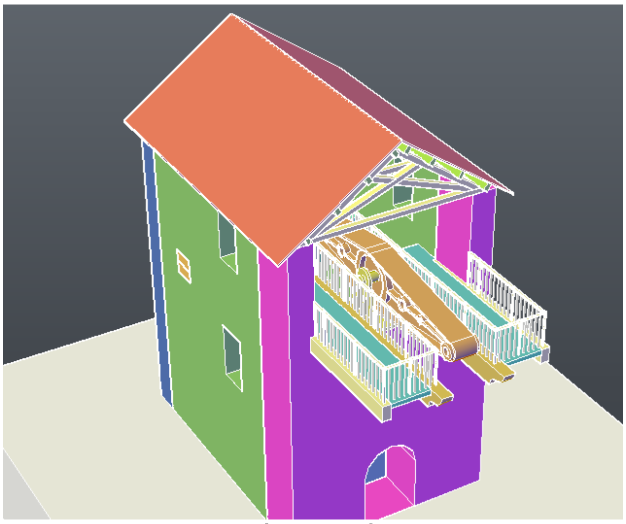

Fig. 22 Roof.

4.17 Sectioned and bounded views

Below, it is shown are two bounded and sectioned views which detail the interior arrangement of different elements (fig. 23).

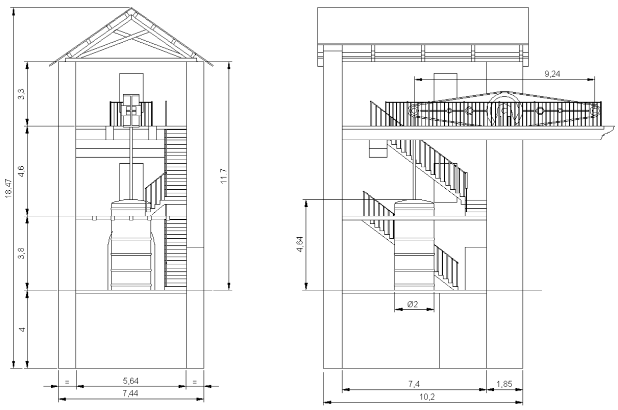

Fig. 23 Sectioned and bounded views.

5 Conclusion

It has been obtained the detailed three-dimensional model of the architecture of an engine house of Cornish pumping, through the employment of CAD techniques and from very low historical plan information type existing about them, making it possible to obtain a reliable model.

Also, this three-dimensional model obtained will be an important element in future proceedings as computer animation, since it will allow be located inside their respective dimensions, its functional elements such as vertical cylinder simple expansion, valves and rocker arm, in order to recreate the process of operating a key element in the mineral extraction phase.

Finally, the work done by the application of engineering techniques graphics, greatly contributes to the preservation and valorization of rich historical mining industry in our country, which is often neglected and suffer the plunder.

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