ABSTRACT: The Italian Hospital “Umberto I” was finished in 1890. It was designed and supervised by Eng. Luigi Andreoni, was planned in the outskirts of the city, and it on lodge 200 patients, covering 2600 sq. meters in two levels.

The Hospital was designed in an eclectic style with a constant modulation of elegant arcs, framing, crossing vaults, and supported by Doric columns. Rooms are distributed around courtyards.

It was built with the traditional systems of those days, foundations in stone, masonry walls, and vaults in ceramic brick masonry. Columns in cast iron, ceilings with small vaults in ceramic brick supported by standard iron profiles. On the whole, the structure is in good condition, but there are fissures in vaults and profiles of the open gallery columns.

We propose reinforcing the vaults and columns of the gallery with non aggressive materials, based on the verification with FEA computer software.

1 HISTORY

1.1 Situation in the social and economic reality of that time

The Italian Hospital was built during a period characterized by large initiatives, only 50 years after the independence and the consolidation of the new republic. This is of great importance since it characterizes an epoch of large investments, considering the size of our country, and the hope of its inhabitants and the European migration who were attracted by the idea that in a young country there were much to be done with the powerful, booming and economically independent bourgeoisie. It is the moment of the second wave immigration, above all Italian, French, and central European, attracted by possibilities of work and investment. These people had a very good professional and cultural level. They brought new habits, refinement, and needs according to the uses of the fashion of the epoch. With a very optimistic future vision, they built many buildings with important investments, trying to imitate more developed societies, such as those of their own countries of origin. Some of these buildings still exist, while others were pulled down. If we reflect back to the country during this period, it represents an enormous quantitative and qualitative leap. The country is so young; it receives with open arms, a great influx of people with new ideas and initiatives, a young society whose hopes and sole criterion is a bright joyful future. Therefore, this brought about quick changes, buildings demolished and built without
regard of its colonial background. The Italian Hospital had already existed in a building located inside the walls of the city since 1853, but because of several occupations suffered during the military conflicts that continued after the independence, the building no longer presented adequate conditions for its function. It is for this reason that the Italian community, formed by families of merchants, industrialists, and labourers, decides to combine efforts in order to build a new larger building, with new technologies, on a property outside the city walls. Eng. Luigi Andreoni won the contest of projects, and Tosi won the contest of prices. Eng. Andreoni was born in Vercelli, Italy in 1853 and died in Montevideo, Uruguay in 1936. He graduated at the age of 21 years old in the "Reale Scuola di Applicazione di Napoli" in 1875, he arrived to Uruguay in August 25th, 1876. Shortly afterwards, already in contact with the higher class of the country, he received important assignments. Not only does he build the Italian Hospital, but also the Central Railway Station (where he ends up as General Manager), the Club Uruguay in front of the main square of the Old City, the Italian School, the Curia Episcopale, and many private residences, etc.

1.2 Location in the growing urban context
The building of the Italian Hospital, much as other buildings in the Old City, such as the Reus Building, the markets, the Central Railway Station, etc., are good examples of this period. All built by professionals and artisans who arrived from Europe with the new fashionable styles. The Central Railway Station is, currently being studied for a possible refurbishment for cultural purposes. Some of these buildings were new; other substituted inside the city walls, and other have been started to be demolished and only small sections still remained. This is a demonstration of the spirit of the epoch, that is to say, to grow, to expand, no longer being afraid of the enemy attacks. The walls are demolished to be prepared for a future of peace and welfare. The election of the site for the construction of the Italian Hospital, is as it can be appreciated in Figure 1, outside the walls and quite far away from the populated areas by then, just in the crossing of two avenues "18 de Julio" that continues as an exit towards the north as "Avda. 8 de Octubre" and another are still in project,
that would encircle the city “Cno. de Circunvalación”, today named “Blvrd. Gral. J.G. Artigas”. Between the city and the property, there were no constructions, only a small village grouping and small farms. The Hospital’s building site was flooded and marshy.

2 ARCHITECTURE

2.1 Project designed as a sanitary centre

The Italian Hospital building is an example of the idea, organization, and construction of a sanitary system in those days. It was built on a site located near the exit of the city toward the north and it could lodge 200 in two plants covering 2600 m². The first project was larger and its façade on the Cno. de Circunvalación was 270 m long, (Figs. 2–3), instead of 100 m as it was built (Fig. 5). It was planned placing all the rooms and services linked to open galleries and around three courtyards (Figs. 4–6). It has two levels, first floor or noble plan and ground floor. The façade that was finally built keeps a splendid perspective of the colonnade gallery and remarks two entrances. The open gallery of the first floor is covered by crossing masonry vaults lying on the bearing wall of the internal façade and toward the outside in a row of double columns of cast iron (Figs. 7–9). The lower floor is covered by small brick vaults supported by metallic profiles 140 mm large, placed every 60 to 70 cm. The inner courtyards were formerly planned for several services, but may suffered transformations during these years.

Problems arose from the beginning because of structural displacements, the eccentricities and because the hospital was built on a flood plain (Fig. 10). These problems were immediately conveyed to the designer, who tried to solve them, but misunderstandings between the building construction company, owners and engineer, did not allow him find a solution. These problems reappeared in 1936, when they maid new foundations in several points of the façade of the gallery. They were unable to make the re-foundation of the supporting walls of the internal façade, because of security and functional reasons, as the hospital could not be closed to the public.

2.2 Construction and structural scheme

It was built with linear foundations in stone or cement blocks with I beams (Fig. 10), at 3 m depth. The ceramic brick walls about 70 cm wide lay on these foundations, all the openings are half circle arches (Fig. 9). The ceilings on the ground floor are constructed whit small vaults of hollowed ceramic bricks.
(12 \times 4 \times 20 \text{ cm}), supported on steel profiles of 140 mm every approximately 70 cm, perpendicular to the façade. These vaults are arches of a very low hint, while the vaults that cover the corridors and large rooms of the first floor or noble floor, are constructed with crossing half circle vaults, or simple half circle vaults (Figs. 11–12). Meanwhile in those less important service rooms there are running vaults of ceramics as the ones we previously explained.

2.3 Structural problems

To a certain point, having analysed the whole building of the Italian Hospital and after finding several and different problems, we decided to focus specifically on the gallery of the façade to Blvrd. Gral J.G. Artigas, because it presents the greatest damages and pathologies. The initial problems in foundation, the sliding off the axis of the centre of the inertia of the surface of the blocks one from another instead of being aligned, was increased by the changes in the building surroundings suffered during all these years. Those changes altered the original characteristics of the soil, as it changed from being first a free land to being nowadays completely constructed and even worse, the existence of a nearby underground viaduct. The possibility of drainage or evaporation of the rainwater has been minimized not to say disappeared, remaining subject to abrupt contractions because of the dryness or enlargements in rainy periods, and vibrations caused by passing buses, trucks and cars. We could observe numerous fissure in the crossing vaults of the gallery, and in the floorings as a result of the differential subsidence of the walls along the gallery combined with horizontal displacements. It is clear that this area is one of the weakest points of the building. There are fissures in the balconies and in the supporting walls, that limit the gallery with the rooms and also in the columns of cast iron from the bottom to the top, these columns are filled with a mixture of lime and ceramics.

All these arguments carried us to formulate a hypothesis of structural behaviour to verify the present static conditions and the stability of this gallery, mainly the stability of the crossing vaults and the pillars. As there was no possibility of a destructive test, we arrived to the hypothesis after trying several model possibilities each one with different static and boundary conditions in a finite element analysis program. The final coherent hypothesis formulated was a sliding support with only the possibility of vertical displacement (because of the contribution of stiffness given by the half circle vaults) in the wall between the gallery and the rooms and a vertical support with horizontal sliding but no possibility of vertical displacement in the columns (Fig. 13).

Figure 11. Crossing vault.

Figure 12. Half circle arch.

Figure 13. Crossing vault displacement.

Figure 14. Tensor and displacement graphics.
3 STRUCTURAL VERIFICATION

3.1 Crossing vault

According to plans obtained from the head of maintenance, the façade of the gallery was supported by arches lying on pairs of columns, and it was re-founded in several points, in the 1930's, due to the descents produced. Verifying this information, we define the hypothesis for the analysis of the behaviour of the vaults, allowing certain displacements and on the other hand inflexible constraints. As we can see in Figure 13 all the line of pillars is displaced toward the outside, while the wall descends. While testing different hypothesis of boundary conditions and restraints, we found out that the lines of greater tensions coincide with the fissures observed and measured. This meant we were on the right way to obtain the causes of the damages without destructive tests on the building. This verified that these could be the causes of damages, according to the obtained information and the maintained hypothesis. Analysing a group of three vaults (Fig. 14), to which we have restrained the longitudinal possibility of deformation to simulate continuity, we can appreciate the same behaviour. In these graphics, the compression efforts are concentrated near the pillars, while the tensile stress, goes near the wall. In Figure 15, we show the complete real condition and location of the fissures in the whole gallery, where reinforcements or repairs had been done.

In Figures 16–18, the maximum tension and compression tensional stress can be appreciated, as it goes towards the wall having the same design as the cracks measured. These cracks present a development toward the transversal supports that separate the different vaults, it can be seen that these pathologies, which appeared long ago, were already repaired and they reappeared. In Figure 19, we can see cracks that were repaired and that did not appear again, maybe because of the re-foundation done in the past. This may indicate a tendency to stabilization and the possibility to confirm our hypothesis. In Figure 20 we can see the direct correspondence between the stress tensor obtained with a finite element analysis program and the picture of the fissures. We can observe that the cracks are in the area of concentration of maximum positive tensile forces or tractions. This shows that the vaults constructed with hollowed bricks and lime mortar are unable to resist this stress. While the supporting walls descended following the clay soil settlement, the façade, which after the initial displacement was re-founded to the rock 10 to 12 m deep, remains stable and gives stiffness. Consequently, the vaults tend to separate from the wall producing an articulation that allows them to act freely.

Step by step, we analysed and incorporated structure elements trying to prove our hypothesis. In a second loop of this program, we included the vault in the corner (Fig. 23). Then in a more extensive analysis we also included the wall, being able to confirm that it descends much less in the corner due to the stiffness given by the perpendicular group of vaults.
The behaviour is still the same, but in the corner there are variations. In the floor plan, we can see that adjacent to the vaults of the gallery of the main façade, there are large half-circle vaults, while in the perpendicular façade, adjacent to the vaults we find a less stiff structure, more deformable. This difference of rigidity exists in the upper floor as well as in the ceiling of the ground floor where the steel I beams are perpendicular to the vaults stopping possible displacements or parallel offering no resistance. In Figure 24 it is possible to observe the concentrations of shear stress in direction z-z around the columns.

3.2 Columns
In this stage of the investigation, we realised that the pillars are submitted to diverse and complex efforts, according to the diagrams of Figures 23–24, consequence of their location and of certain inflexibility where the maximum stress is concentrated. It is true then that the columns are submitted to effort of compression bending by the vertical loads and horizontal forces. The columns are tubes of cast iron of 30 cm diameter and 2.5 cm thick, filled with lime mortar and pieces of ceramics. When this mortar is dampened it produced deep damages, as corrosion, from the inside towards outside, generating the weakening of its walls, at the limit of not being able to resist the original efforts. This combination of efforts, added to the fact that the columns are weaker than in the beginning, does not allow them to submit the efforts that overcame due to the vertical and horizontal displacements. As it can be seen in Figures 25–28, we show how cracks starting at the bottom, where the maximum tensions are located, go up. The graphic of the horizontal displacements (Fig. 29) show the increasing values towards the outside, in a horizontal section of the crown, at the bottom of the columns. We demonstrate with Figures 30–31 the relation between the values of shear and displacement with an axial force. It can be clearly seen that the maximum displacements are produced where the maximum tensions are (generating a belly in the column).

3.3 Walls
The wall that divides the gallery from the rooms is the interior line of support of the vaults. This wall
suffered diverse movements such as differential settlements, produced by the problems of the foundations, the horizontal forces, originated by the vaults, etc., that generate complex efforts. It is clear that structures of this type where we find materials with very different rigidities, should be considered as a complex joint where all the efforts interact. Besides, this wall has important openings as doors and windows, in Figures 32–35 can be seen the cracks in the building and the resultant diagrams of the structural analysis of the same places. The cracks under the windows are produced logically where the concentration of the maximum tensions take place, which on the other hand are symmetrical with the axis of the gallery, in the left part of the gallery the cracks go towards the right and to the left on the right side. This damage can be reinforced by the fact that the gallery is 100 m long without any cut to allow dilatations.

4 PROJECT OF RECONSOLIDATION

4.1 Crossing vaults

With the results of the finite elements analysis, we verified our hypothesis and we were able to establish that the cracks in the walls, vaults and columns of the gallery are the consequence of horizontal displacements and differential descents that the whole construction suffered. The colonnade façade of the gallery stopped its descents due to the re-foundation carried out more than 70 years ago, but it still depends on the variations of moisture content of the soil. Nevertheless we propose the re-foundation places not yet re-founded places to keep them in good conditions of stability. We propose, also, to re-found step by step, the supporting wall behind, to stop the general movement. The vaults should be reinforced with a weave of fiberglass so as to enlarge its capacity to support efforts, repairing the cracks without modifying their capacity of deformation, allowing them to deform without surpassing the ceramics bricks capacity.

We propose to tie the line of the columns towards the back to the wall with tensors included in the ceiling of the first floor.
4.2 **Reinforcement of the walls**

The cracks will be filled with plastic mortars, to preserve the plaster and its protective properties.

4.3 **Reinforcement of the pillars**

They will be cleaned and protected against oxidation, as a way to stop the current damage. They will be surrounded with carbon fibre girdles to enlarge their capacity against the effort of axial forces and bending. The re-foundation of the places still without reinforcement is proposed with prefabricated steers.

5 **CONCLUSIONS**

The analysis methodology had satisfactory results, with computing technology it was recreated the structure function and prove the hypothesis and information obtained from the investigation process.

The verification with FEA computing software permitted analyzed the reality with a theory model without damaging the structure.

In other words, we pretended formulate a methodology which use the benefit of computing programs for studying the structure instead of damage it with aggressive essays.

Lastly, with results and understanding the problem, we used the technology to find materials and systems suitable to original building.

Scientific and social community must recover patrimonial architecture, we have to use modern resource for interpret how it works, for maintain it alive and for continue learning from it.