Revista ALCONPAT
www.revistaalconpat.org
eISSN 2007-6835
Revista de la Asociación Latinoamericana de Control de Calidad, Patología y Recuperación de la Construcción

Modification of a metal structure due to change of use

J. L. Gómez[1, 2]*, K. Klein[1,2], G. Montiel[2]
*Contact author: ccp.cons316@gmail.com
DOI: https://doi.org/10.21041/ra.v14i1.716

Received: 05/11/2023 | Received in revised form: 16/12/2023 | Accepted: 27/12/2023 | Published: 01/01/2024

ABSTRACT

The purpose of this work is to discuss the modifications made to a metal structure built in 1930, made up of triangular lattice beams supported on 60 cm thick walls and 14 interior metal columns to cover an area of 875 m^2 that housed the activities of the central market in the city of Deán Funes. In the 1980s the municipal management proposed its recovery for new sports uses, presenting the structural challenge of eliminating intermediate supports. The project and construction date from that time, and for this reason it is discussed the validity of the concepts and solutions adopted, as well as the importance of a maintenance plan to guarantee the degree of safety of the work.
Keywords: structural design; steel; patrimony recovery.

Cite as: Gómez, J. L., Klein, K., Montiel, G. (2024), *"Modification of a metal structure due to change of use"*, Revista ALCONPAT, 14 (1), pp. 70 – 81, DOI: https://doi.org/10.21041/ra.v14i1.716

[1] Facultad de Arquitectura Urbanismo y Diseño, Universidad Nacional de Córdoba, Córdoba, Argentina,
[2] Alconpat Argentina, Córdoba, Argentina.

Contribution of each author
In this work, the original idea and feasibility of the reinforcement - Ing. Gómez (100%); Pre-sizing of the reinforcement and development of the model - Eng. José Luis Gómez (40%) and Architect Karin Klein (60%); Data collection - Eng. José Luis Gómez (50%) and Architect Guillermo Montiel (50%); Writing of the Work - Eng. José Luis Gómez (20%) and Architect Karin Klein (80%); Discussion of the result and Conclusions - Engineer José Luis Gómez (33%), Architect Karin Klein (33%) and Architect Guillermo Montiel (33%).

Discussions and subsequent corrections to the publication
Any dispute, including the replies of the authors, will be published in the third issue of 2024 provided that the information is received before the closing of the second issue of 2024.

Modificación de una estructura metálica por cambio de uso

RESUMEN

El objetivo de este trabajo es discutir las modificaciones realizadas sobre una estructura metálica construida en 1930, conformada por vigas reticuladas triangulares apoyadas sobre muros perimetrales de 60 cm de espesor y 14 columnas metálicas interiores para cubrir una superficie de 875 m2 que albergaba las actividades del mercado central de la cuidad de Deán Funes. En la década del 80 la gestión municipal plantea su recuperación para nuevos usos deportivos presentándose el desafío estructural de la eliminación de los apoyos intermedios. El proyecto y la construcción datan de esa época, y por ello se discuten la vigencia de los conceptos y soluciones adoptadas, así como la importancia de un plan de mantenimiento para garantizar el grado de seguridad de la obra.

Palabras clave: diseño estructural; acero; recuperación patrimonial.

Modificação de estrutura metálica para troca de uso

RESUMO

O objetivo deste trabalho é discutir as modificações realizadas em uma estrutura metálica construída em 1930. Essa estrutura é composta por vigas reticuladas triangulares apoiadas em muros perimetrais de 60 cm de espessura e 14 colunas metálicas internas, projetada para cobrir uma superfície de 875 m2 destinada às atividades do mercado central da cidade de Deán Funes. Na década de 1980, a administração municipal propôs sua recuperação para novos usos esportivos, apresentando o desafio estrutural da eliminação dos apoios intermediários. O projeto e a construção datam dessa época, e, por isso, são discutidas a vigência dos conceitos e soluções adotadas, bem como a importância de um plano de manutenção para garantir o grau de segurança da obra.

Palavras-chave: projeto estrutural; aço; recuperação patrimonial.

Legal Information

Revista ALCONPAT is a quarterly publication by the Asociación Latinoamericana de Control de Calidad, Patología y Recuperación de la Construcción, Internacional, A.C., Km. 6 antigua carretera a Progreso, Mérida, Yucatán, 97310, Tel.5219997385893, alconpat.int@gmail.com, Website: www.alconpat.org

Reservation of rights for exclusive use No.04-2013-011717330300-203, and ISSN 2007-6835, both granted by the Instituto Nacional de Derecho de Autor. Responsible editor: Pedro Castro Borges, Ph.D. Responsible for the last update of this issue, ALCONPAT Informatics Unit, Elizabeth Sabido Maldonado.

The views of the authors do not necessarily reflect the position of the editor.

1. INTRODUCTION

Dean Funes, capital of the department Ischilín, is a city located in the north west of the province of Cordoba. Its origins match with the expansión of the railway back in 1875. During the first years of the twentieth century, its most significant constructions, such as the Central Market (1930), that has an Art Decó style and it is located in front of the Market Plaza (figure 1), were built. During the following years, comercial activities were moved to the outskirts of the city due to the growth of population making the building to fall on a state of abandonment. In 1982, under the government of José Naveira Ferrandes, the building is decided to be restored and a new space for sports to be placed instead. Below, the structural proyect that made posible this new use, which was designed and built back then, and at present continues to be used with that purpose, will be developed.

Figure 1. Ex Central Market of Deán Funes.

2. ORIGINAL STRUCTURAL IDEA

The original structural idea of the Market covered a surface of 875 m^2 which includes 26,05 m width x 33,50 m lenght. The plane on top consisted of a series of three triangular metallic lattice beams with a 8,7 m span, which made 7 axis separated by 4,19 m. A series of steel belts that made the three-section, sheet, pitched roof were standing over the unión of the angles with a distance of 2,15 m and 2,200 m. The main beams rested on14 metallic columns and on its perimeter over a 60 cm width stone wall (figure 2 and figure 3)

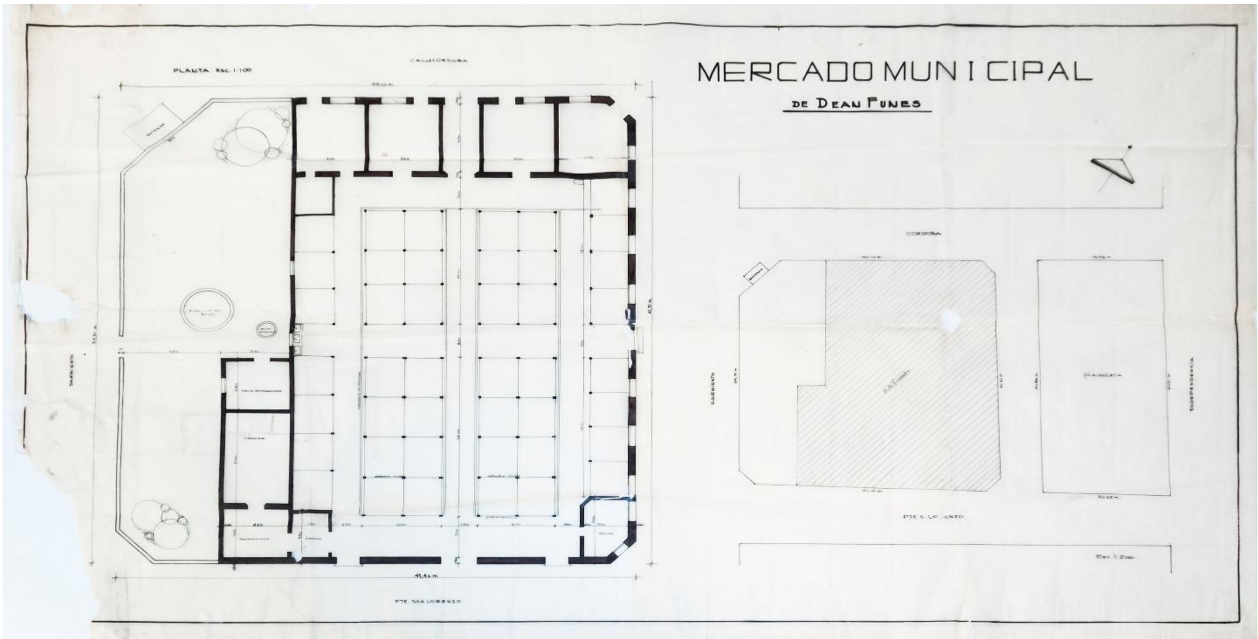

Figure 2.Original Municipal Drawing

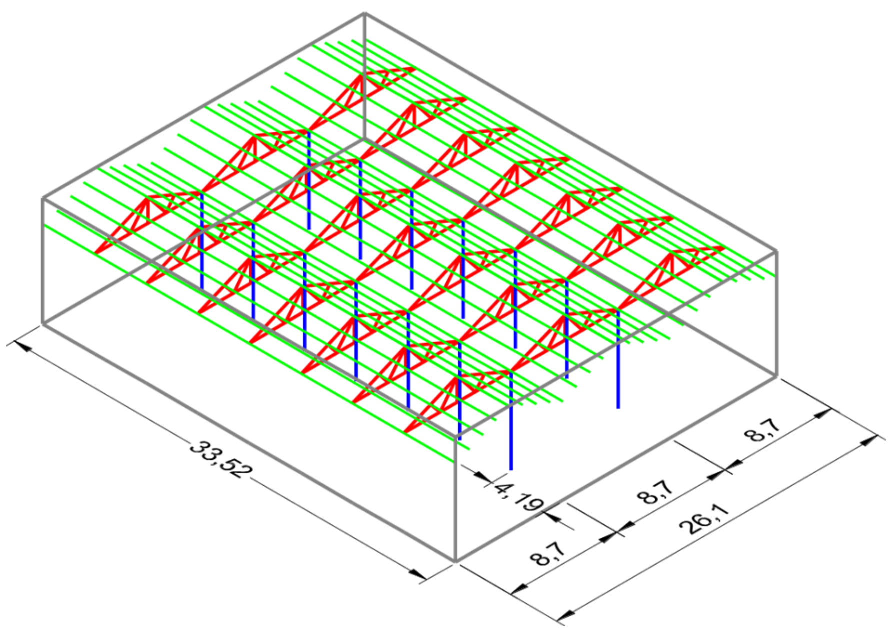

Figure 3.Original axionometric of the structure.

3. NEW STRUCTURAL IDEA

In order to have only one interior space free of bases, the new structure was proyected from one plain lattice beam of 1,80 m height, connecting the already existing ones, strengthening bars and adding new elements that allow the filling up of the 26,1 m of span.

To make the design of the new main beam it was necessary to build a new upper cord, which connected the metallic profiles of the existing bridgings, and two new posts matching the previous support that withstands the compression stresses and allows the lenght of the new cord's bending to be reduced (figure 4).

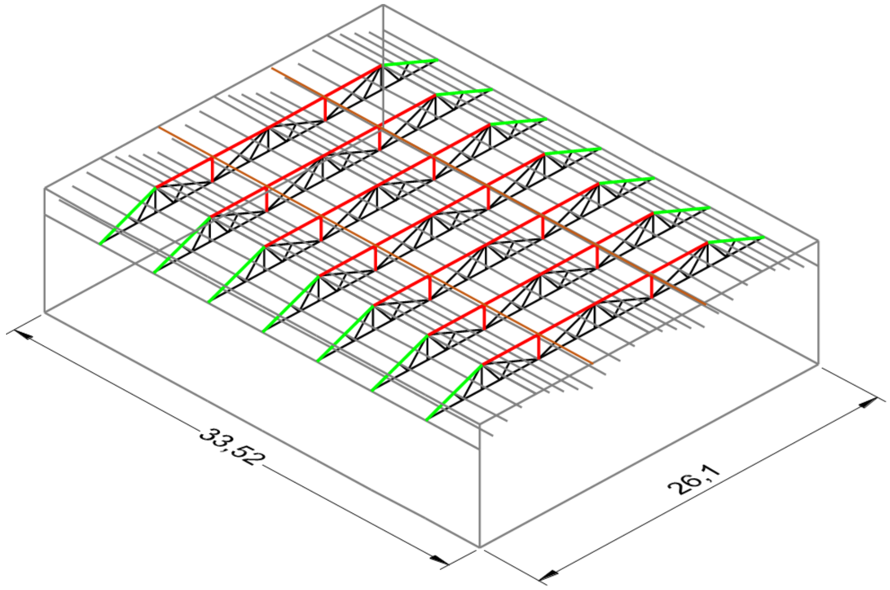

Figura 4. Axonometric of the structural idea.

Equally, upper brace beams with two profiles UPN 80 were set in order to reinforce that concept and to avoid the lateral bending perpendicularly to the beam's design (figure 5).

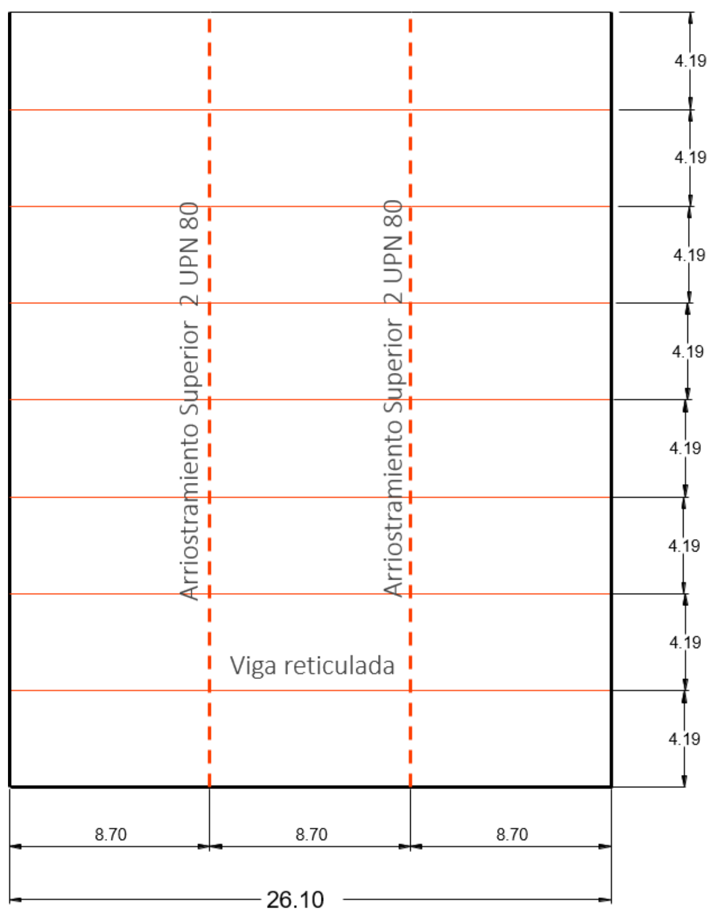

Figure 5. New exterior structure roof's plan

On the other hand, both the inferior cord and some requested existing diagonals were reinforced in order to withstand the internal stresses of traction and compression from the evaluation of the new structural behaviour,

4. METHOD OF CALCULATION

Next, it will be presented the method of calculation based on the regulations and available tools at that time, but which have validity at present.

4.1 Analysis of loads

At first, an analysis per square meter was conducted to determin the magnitude of the punctual actions over the new lattice beam's unión of its angles (figure 6).

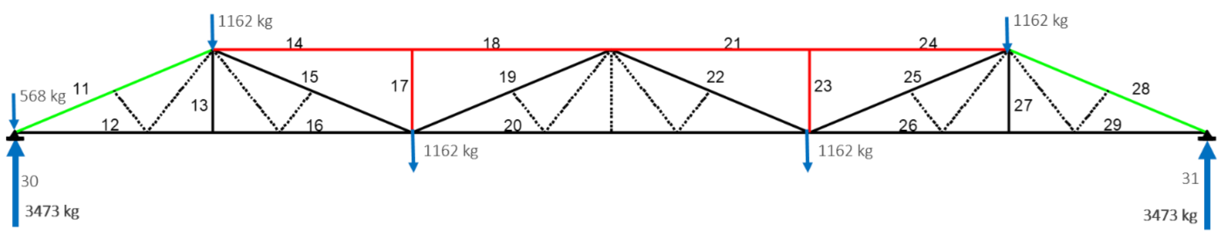

Figure 6. Lattice beam with numbered bars, (nudos), and loads.

4.1.1 Analysis of loads per square meters

- Corrugated sheet ------------------------------------ 10 kg/m^2
- Wooden beams --------------------------------------- 6 kg/m^2
- Lattice beam's dead load--------------------------- 22 kg/m^2
- Superimposed usage -------------------------------- 25 kg/m^2
- TOTAL --- 63 kg/m^2

4.1.2 Analysis of loads over girder's union of its angles

- Strut loads ----------63 kg/m^2 x area of influence (4,19 x 2,2 m x 2) = 1162 kg

4.2 Determination of requests

To calculate the normal stresses, a PPlan program from the Taller de Investigación de Diseño Estructural (TIDE) of the Faculty of Architecture of the National University of Cordoba was used. At that momento, the coordenates that defined the beam's geometry and the actions over itself were intriduced. As a result, the values of stresses in each unión of its angles which are summarized in the following table 1 were printed out.

Table 1. Requests and reactions.

Bar	Normal stress (kg)
11	-7.598 Compression
12	7.020 Tension
13	0
14	-11.233 Compression
15	4.559 Tension
16	7.020 Tension
17	-1.162 Compression
18	-11.233 Compression
19	-1.520 Compression
20	12.637 Tension
21	-11.234 Compression
22	-1.519 Compression
23	-1.162 Compression
24	-11.234 Compression
25	4.558 Tension
26	7.022 Tension
27	-1 Compression
28	-7.600 Compression
29	-7.022 Compression
30	3.474 Response
31	3.474 Response

4.3 Verification of general deformations

Considering the dimensions and analysis of the requests, the upper cord was premeasured with two profiles UPN 120 making a drawer-like section with an área of 27 cm^2, and the inferior cord was premeasured with two matched UNP 100 profiles with an area of 22 cm^2 (figure 7).
From the analysis of the parameters that intervene in the determination of the maximum arrow, there was established the following data:
-Moment of inertia of the group J =392.769 cm^4
- Load "q" 63 kg/m^2 x 4,19 m = 260 kg/m

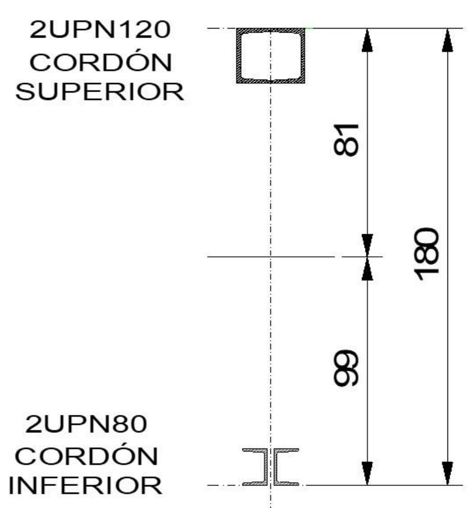

Figure 7. Compound section of the lattice beam.

4.3.1 Calculation of the maximum arrow

$$\text{fmáx} = \frac{5}{384}\frac{\text{qx l}^4}{\text{E J}} = \frac{5}{384}\,\frac{2{,}6\ ^{\text{kg}}/_{\text{cm}}\ \text{x}\ 2610\ \text{cm}^4}{2.100.000\ ^{\text{kg}}/_{\text{cm}^2}\ \text{x}\ 392.769\ \text{cm}^4} \quad (1)$$

$$\text{fmáx} = 1{,}9\ \text{cm} \quad (2)$$

4.3.2 Calculation of the admisible arrow

$$\text{fadm} = \frac{\text{L}}{200} = \frac{2610\ \text{cm}}{200} \quad (3)$$

$$\text{fadm} = 13{,}05\ \text{cm} \quad (4)$$

4.3.3 Comparison maximum arrow< admissible arrow

$$1{,}9\ \text{cm} < 13{,}05\ \text{cm}\ \ \text{Verifica} \quad (5)$$

4.4 Sectional verification and proposals of the structure's reinforces

After the control of deformations, a sectional verification was conducted. First, regarding the new structural elements of the upper cord and the uprights. Second, regarding the resistance of the existing elements subdued to new efforts such as the inferior cord and the diagonals (figure 8).

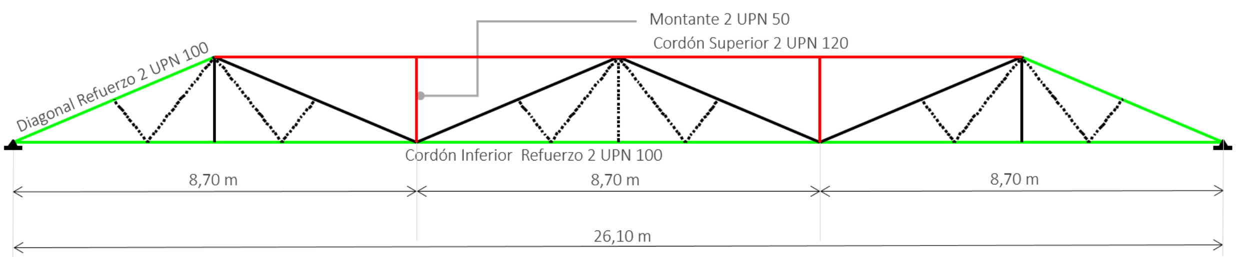

Figure 8. Section of the lattice girder.

4.4.1 Upper Cord

As previously stated, the upper cord was carried out by the drawer-like section made of two UPN 120. The necessary data to verify the resistance is shown in table 2.

Tabla 2. Datos del cordón superior

Bar 11	**2 UPN 120**
Normal stress	11.234 kg (compression)
Lenght	440 cm
Moment of inertia **Jx**	728 cm^4
Area of the group **A**	34 cm^2

Calculation of the minimun ratio turn

$$\text{i} = \sqrt[2]{\frac{\text{Jx}}{\text{A}}} = \sqrt{\frac{728\ \text{cm}}{34\ \text{cm}^2}} = 4{,}63\ \text{cm} \quad (6)$$

Calculation of the slenderness

$$\lambda = \frac{l}{i} = \frac{440\ cm}{4{,}63\ cm} = 95{,}03 \tag{7}$$

Rate of the bending for steel F24

$$\omega = 2{,}07$$

Calculation of the strain of work

$$\sigma = \frac{\omega \times N}{A} = \frac{2{,}07 \times 11.234\ kg}{34\ cm^2} = 683{,}95\ \frac{kg}{cm^2} < 1500\ \frac{kg}{cm^2} \quad \text{Verifies} \tag{8}$$

4.4.2 Studs

The studs were defined by a drawer-like section as well, but made by two UPN 50. The necessary data to verify the resistance is shown in table 3.

Tabla 3. Uprights Data

Bars 17/23	**2 UPN 50**
Normal stress	1.162 kg (compression)
Lenght	180 cm
Moment of inertia **Jx**	52,8 cm^4
Area of the group **A**	14,24 cm^2

Calculation of the minimun ratio turn

$$i = \sqrt[2]{\frac{Jx}{A}} = \sqrt[2]{\frac{52{,}8\ cm}{14{,}24\ cm}} = 1{,}92\ cm \tag{9}$$

Calculation of the slenderness

$$\lambda = \frac{l}{i} = \frac{180\ cm}{1{,}92} = 93{,}75 \tag{10}$$

Rate of the bending for steel F24

$$\omega = 2{,}05$$

Calculation of the strain of work

$$\sigma = \frac{\omega \times N}{A} = \frac{2{,}05 \times 1162\ kg}{14{,}24\ cm^2} = 167{,}28\ \frac{kg}{cm^2} < 1500\ \frac{kg}{cm^2} \quad \text{Verifies} \tag{11}$$

During the executive proyect, the studs were resolved to be made with two elements with the shape of an inverted “V” to fix the rainwater drainage system over the valley rafters (figure 9).

Figure 9. Picture of the external structure

4.4.3 *Inferior Cord*

A sole inferior cord was design to join the existing cords and to resist a máximum traction effort of 12.637 kg with 2 UPN 80 (table 4). To determine the use of the existing structural elements, it was used a tension of 1500 kg/cm² and, from there, to compare necessary section with the 22 cm^2 area (figure 10).

Figure 10. Picture of the inferior cord.

Table 4. Data of the inferior cord.

Bar 20	**2 UPN 80**
Normal stress	12.637 kg (Tension)
Area of the group **A**	22 cm^2

Calculation of the necessary area

$$A = \frac{N}{\sigma} = \frac{12.637\ kg}{1500\ kg/\ cm^2} = 8{,}43\ cm^2 < 22 cm^2 \quad \text{Verifies} \tag{12}$$

4.4.4 Extreme Compressed Diagonals

The exterior diagonals which work with an effort of compression of 7600 kg were reinforced with two normal profiles UPN 100 (table 5).

Tabla 5. Diagonales comprimidas

Bars 17/23	**2 UPN 100**
Normal stress	7600 kg (compression)
Lenght	470 cm
Moment of inertia **Jx**	412 cm^4
Area of the group **A**	27 cm^2

Calculation of the minimun ratio turn

$$i = \sqrt[2]{\frac{Jx}{A}} = \sqrt[2]{\frac{412\ cm}{27\ cm}} = 3{,}90\ cm \tag{13}$$

Calculation of the slenderness

$$\lambda = \frac{l}{i} = \frac{470\ cm}{3{,}9} = 120{,}5 \tag{14}$$

Rate of the bending for steel F24

$$\omega = 2{,}83$$

Calculation of the strain of work

$$\sigma = \frac{\omega\ x\ N}{A} = \frac{2{,}83\ x\ 7600\ kg}{27\ cm^2} = 796{,}6\ \frac{kg}{cm^2} < 1500\ \frac{kg}{cm^2} \quad \text{Verifies} \tag{15}$$

5. RESULTING SPACE

The structural intervention freed the interior space from supports by using the preexisting elements, which made possible reuse of the building for the new activities and reverse the abandonment of the it (figure 11).

Figure 11. Picture of the interior.

6. TO SUM UP

In this unprecedented work, here there are some important considerations:

- It has been accomplished a relatively simple itervention by modifying radically the interior with creativity and solid estability concepts
- It is important to keep in mind the durability of steel with mínimum maintenance and the date the Central Market was built. In addition, it has been benefited by the zone's weather.
- It is necessary to warn about the need of a maintenance plan, especially on the structural elements on the outside, as its continuous touch with the environment can accelerate its corrosión. It is necessary to have an aceptable level of security for this building.
- It should always be promoted the reuse of "apparently obsolete" buildings by the people in charge, and the councelling from the structural calculation, in continuing the construction's life cyrcle, so as to minimize the impact of the carbón footprint from its recycle.

7. APPRECIATION

In memory of José Navarro Ferrandes, former mayor of Deán Funes. His concern allowed the transformation of the abandoned Central Market into a beautiful roofed sports centre.

8. REFERENCES

Nonnast, R., (1993), "*El proyectista de estructuras metálicas*". PARANINFO, Madrid, España,
Instituto Argentino de Siderurgia (1991) "El Acero y sus usos, ejemplo de cálculo de estructuras de acero", Buenos Aires, Argentina.