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Proposal of a new structural design normative for truss bridges for public networks in the Colombian cities

Propuesta para una nueva normativa para pasos en celosía de redes públicas en ciudades colombianas

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Abstract

This paper presents the results for four structural design applying CCP-14 (Colombian Bridges Code 2014) and AIS 180-13 (Seismic Requirements for structures different to buildings 2013). The designs correspond to truss bridges for two matrix network water, phone network and electrical network. In the first design for the four structures it applied the seismic spectrum recommended for Bogotá and the second designs used the seismic spectrum recommended for CCP-14. The third design apply all the aspects CCP-14.

The comparative analysis permits to establish a big difference between the three methodologies and permits to propose the writing of a new normative for this type of structures.

Differences between AASHTO code and AISC code for steel member design are presented and they are the base for the proposal.

Keywords: truss bridges, water viaduct, phone line viaduct, AASHTO, AISC, steel structures, steel bridges, NSR-10, AIS 180-13.

Resumen

Se presentan 4 diseños estructurales realizados con CCP-14 (Código Colombiano de diseño de puentes 2014) y con AIS 180-13 (Requisitos sísmicos para estructuras diferentes a edificios 2013). Los diseños corresponden a pasos elevados en celosía para soporte de redes matrices de agua, teléfono y energía. Se analizan 3 tipos de diseño para las 4 estructuras, uno empleando la microzonificación sísmica de Bogotá y AISC, otro aplicando el espectro del CCP-14 y AISC, el tercer diseño aplica CCP-14 y AASHTO.

El Análisis comparativo permite establecer diferencias significativas entre las tres metodologías y permite proponer la redacción de una nueva normativa para este tipo de estructuras.

Las diferencias encontradas entre los diseños y las especificaciones AASHTO, y AISC para elementos metálicos, se presentan y son la base de esta propuesta.

Palabras clave: Puentes en celosía; Viaductos para agua; Viaductos redes telefónicas; AASHTO; AISC; Estructuras de acero; Puentes de acero; NSR-10; AIS 180-13.

1. Introduction

In 2016 and 2017, were designed some structures in Juan Amarillo wetland in Bogotá. Four structures for public networks are presented in this article, where, it is possible to find many differences in your design.
The contractual documents had specified the use of Colombian standards in general. The Consultant decided the application of one standard or another according your expertise.

First, the Consultant decided to apply the AIS 180-13 (Seismic Requirements for structures different to buildings -2013), in this article the results of this design are named NSR-10.

The contractual supervisor not accepted this version and he requires a new design, where, the Consultant apply CCP-14 (Colombian Bridges Code-2014), in this

design, the structural calculations were done applying AISC 360-10. This design is named HIBRID.
At the end, the structures were designed with CCP-14 and the elements were designed with AASHTO standards.

2. The truss bridges

2.1. Structural Typology

All the solutions are a truss box. This box are conformed for simple or double angles en ASTM A572 Gr50. The figure 1 presents the transversal section, in the figure 2, shows the longitudinal section.

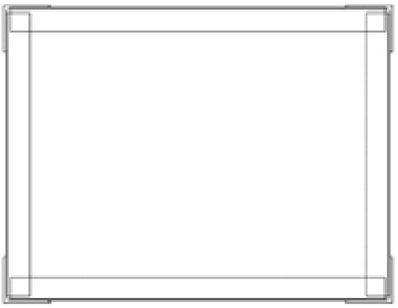

Figure 1. Transversal section
Source: Elaborated by Zulma S. Pardo V.

Figure 2. Longitudinal section
Source: Elaborated by Zulma S. Pardo V.

2.2. For electrical Network

The truss bridge for this solution has 18.00 meters and the transversal section of 1050mm*1050mm. The network passes between the truss. The abutments have piles of 24.00m.

2.3. For matrix network water

The truss bridge for this solution has 13.00 meters and the transversal section of 850mm*650mm. The network passes up the truss. The abutments have piles of 35.00m.

2.4. For secondary network water

The truss bridge for this solution has 13.00 meters and the transversal section of 850mm*650mm. The network passes up the truss. The abutments have piles of 35.00m.

2.5 For phone network

The truss bridge for this solution has 19.60 meters and the transversal section of 450mm*100mm. The network passes up the truss. The abutments have piles of 22.00m.

3. Standards or codes

3.1. NSR-10 [1]

It is the standard specification in Colombia and the for structures differente to buildings has a complementary document denomined AIS 180-13 (Seismic Requirements for structures different to buildings 2013).

3.2. CCP-14 [2]

It is the Colombian bridges code 2014 and is fundamented in AASHTO LRFD Bridge Design Specifiactions 2012.

3.3. AISC 360-10 [3]

It is the standard specification for steel buildings in USA. The NSR-10, in steel structures has a chapter named F. This title is fundamented in AISC 360-05 and the draft AISC 360-10.

4. Loads

4.1. Seismic Loads (EQ)

In the figure 3, two spectrums are presented. The black line is the spectrum corresponds with the seismic micro zoning of Bogotá, and the red line is the seismic spectrum of CCP-14.
For steel structures of this kind, the weight is low for this reason the importance in the final design is low for this load.

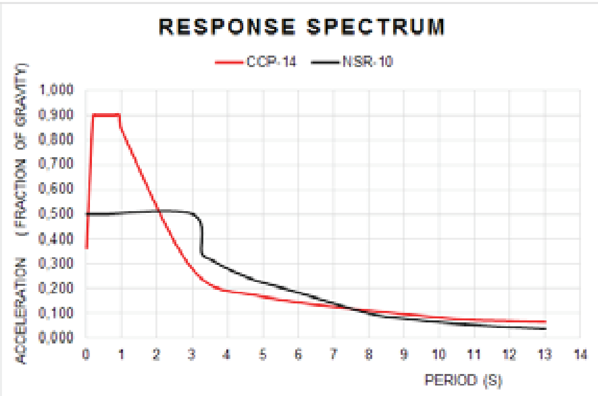

Figure 3. Response Spectrum
Source: Elaborated by Zulma S. Pardo V.

4.2. Wind Loads (W)

The AIS 180-13, specifies for this structures minimum pressures of 0.40 KN/m2 in Windward and Leeward, while, AASHTO (CCP-14) specifies 2.40 KN/m2 for windward and 1.20 KN/m2. The difference in Windward between both standards is 600% and for Leeward is 300%. For basic theory of structural engineering the steel structures are affected mainly for wind and is much different a design for AIS 180-13 or for CCP-14. The criteria of Designer and Supervisor are more different and produce much different solutions.

5. Design Philosophy

5.1. Load and Resistance Factors of Design (LRFD)

NSR-10, CCP-14, AASHTO are based in the methodology LRFD. The main difference is in the slenderness ratio for compression. AISC360-10, limits this ratio for compression to 200, AASHTO for principal elements limits uses maximum limit for slenderness 120 and for secondary elements 140.
In 1978, the AISC, [4], recommended to use 200 how maximum ratio for compression, this concept is empirical and the value guarantees, easy manipulation of element in the factory o in construction and reduce the second order effects. From 2005, this concept is mandatory for elements in compression [5].
The empirical recommendation of 200, some documents affirms is based in [6], who analyses different frames for second orders effects.

AASHTO, [2], recommends a value of 120 for principal elements of compression, in a graphic slenderness vs critical stress of compression (Figure 3), we can see the strength decreases very fast from 120 average, this explanation can be a support for the empirical concept AASHTO.

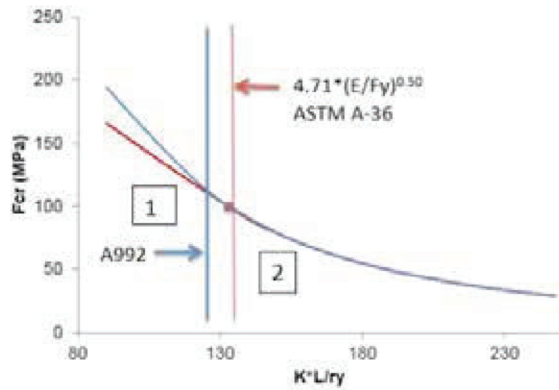

Figure 3. Reference [7]

For structures how the four analyzed the strength criteria is no govern, mainly govern the criteria for slenderness. These criteria generate more expensive structures if we consider the own weight.

6.Structural Design

6.1. Results analysis

Of the structural design and your drawings done for the author, the results can be resumed with the following figures.
If aspect ratio is the ratio between the base and the height of truss bridge in transversal section and density is ratio between weight of the structure and span, the figure 5 present that the changes of own weight of structure has not lineal ratio, although is possible observe the difference increases when the aspect ratio is near to 1. This figure permits recommend that square section is not efficient for this solutions.

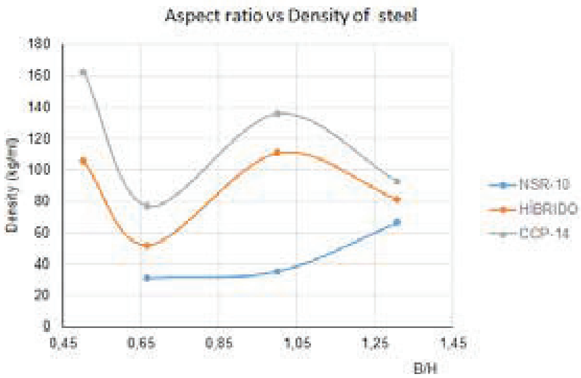

Figure 5. aspect ratio vs density of steel
Source: Elaborated by Zulma S. Pardo V.

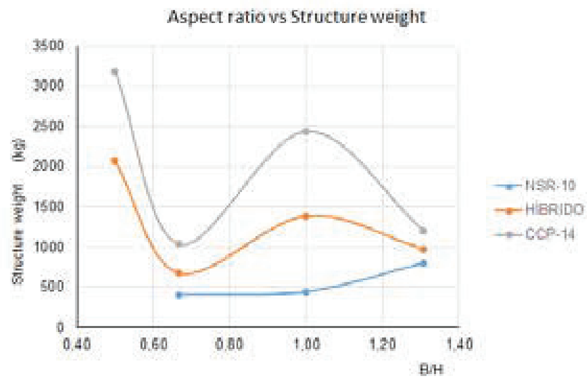

Figure 7. aspect ratio vs structure weight
Source: Elaborated by Zulma S. Pardo V.

If we analyze the figure 6, where the density is measured in kg/m2, for aspect ratio above 1.3, the difference between densities is reduced, while aspect ratio less than 0.60 the difference increase. For aspect ratios near to 1, the density is 200% if the design is done with CCP-14 respect to NSR-10.

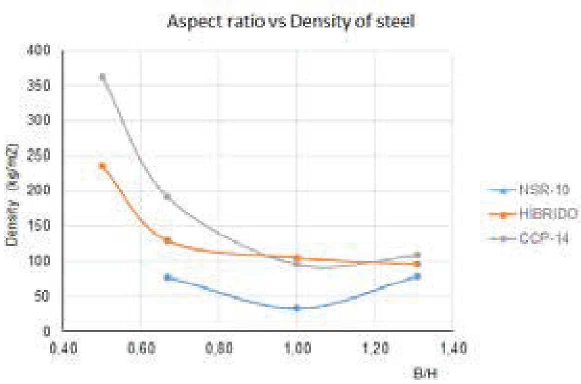

Figure 6. aspect ratio vs density of steel
Source: Elaborated by Zulma S. Pardo V.

For the figure 7, the differences of total weight of structure are low if the aspect ratio is near 0.60 or 1.30, while if the aspect ratio is 1.0, the difference between design for CCP-14 and NSR10 is approximated 500%.

If we study the figure 8, for longer spans the differences between design for CCP-14 or NSR-10 increase with the value of the span. While for spans near to 14m the difference is 256%, for spans near 18.00m, this value passes to 406%. For this reason, the difference of criteria of Consultant and Supervisor increased visibly the cost of project. And the cost grew of non-lineal form when the truss bridge for public networks had more span.

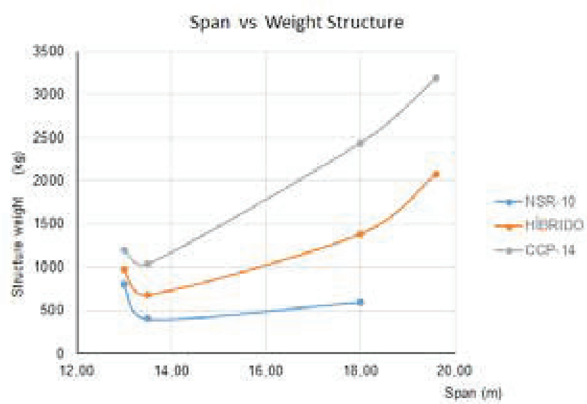

Figure 8. aspect ratio vs density of steel.
Source: Elaborated by Zulma S. Pardo V.

7. Conclusions

7.1. Summary

The objective of this work was to realize a comparison between different standard for design of truss bridges for public networks, where in Colombia there are much unknowledge and where the country has a vacuum in normative. This vacuum facilitates different interpretations and generates a high cost for this kind of projects in Colombia. It is necessary to create standards for this kind of structures that reduce the problems in the public contracts proper to this legal vacuum.

If the slenderness ratio is an empirical assumption and the truss bridges for public networks are not structures with cyclic loads and fatigue, ¿why to increase the weight and the cost for satisfy this requirement?

If Bogotá has not winds with velocities of 160 km/h, ¿why to demand a structural design for this conditions?

If the steel structure in this conditions is designed for wind, ¿why to demand a structural design with response spectrum of CCP14 that is not more detailed that seismic micro zoning of Bogotá?

7.2. Conclusions and Recommendations

This article will be presented the committee AIS 200 (Seismic bridges design and construction), requesting your study for create a new specification to truss bridges for public networks.

It is necessary more studies of structural engineers in more cities of Colombia that present comparisons for this kind of structures. These comparisons facilitate the development of a new specification for this topic.

It is necessary recommend to the government entities, study and specify in the terms of conditions of your tenders explicitly the standard for truss bridges for public networks. In this case, the author recommends apply the AIS 180-13, the seismic micro zoning of Bogotá, if the structure is in this city.

The aspect ratio for this kind of structure recommended for the author is 0.60 o 1.30, depend if the pipelines pass between or above the truss bridge.

The author not recommends square transversal section, for truss bridges for public networks.

For Bogotá, the author considers that apply AIS 180-13, is enough for design truss bridges for public networks. To apply CCP-14, increases the cost of construction unnecessarily.

7.3. Acknowledges

The author acknowledges to Consorcio Interpuentes 05, for the trust in the development of this structural design for this project and all the engineers de ZJ Ingenieros Estructurales Ltda that worked with much patience in the different versions of structural design that permit to realize this study.

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