

ORIGINAL ARTICLE



Structural collapse assessment of the access bridge to Hydroelectric Plant “Pacífico Mascarenhas”

Hermes Carvalho¹ | José Gomes Jr.^{1,2} | Pedro Montenegro³ | José Correia³ | Paula Vilela¹ | Túlio Bittencourt⁴ | Luiza Oliveira¹

Correspondence

Dr. Hermes Carvalho
Federal University of Minas Gerais
Department of Structural Engineering
Av. Antônio Carlos 6627
31270-901 Belo Horizonte
Email: hermes@dees.ufmg.br

¹ Federal University of Minas Gerais, Belo Horizonte, Brazil

² University of Coimbra, Coimbra, Portugal

³ University of Porto, Porto, Portugal

⁴ University of São Paulo, São Paulo, Brazil

1 Introduction

Heavy rains, floods, and rising river levels may cause impacts and destruction across urban, rural, and community areas and may be one of the factors that cause the collapses of bridge structures. To increase the discussion and exemplify a case of bridge failure, from a summary of a structural collapse case of a steel bridge, this paper presents the failure of the bridge known as “Ponte da Usina”, built-in the stretch of the dirt road that gives access to the “Pacífico Mascarenhas” Hydroelectric Power Plant. The bridge lies on the river “Parauninha” at the intersection with a dirt road that derives from the road and is located in the district of “Serra do Cipó”, municipality of Santana do Riacho, Minas Gerais, Brazil.

The bridge structure under study is 54 meters long and it is composed of 18 modules of 3 meters. It has 3,60 meters of internal width and 4,30 meters of counted width of the faces outside the pillars of the porticos [1].

The bridge consists of a metallic structural system with a thick wooden tabulated tray. It has porticos at each end, differentiated from the porticos of the central modules. The metallic porticos are crowned by lattice arches in 5 sections along the bridge. Also, the whole bridge is composed of basic metal shapes such as I-sections, T-sections, and angle sections as shown in Fig. 1, which represents an aerial image of the steel bridge before the collapse [1].

Abstract

The steel bridge popularly known as “Ponte da Usina”, is 54 meters long and is composed of 18 modules of 3 meters. Heavy rains that occurred on the night of 5 February 2013 at the top of the Serra do Cipó, caused an increase of the river level “Parauninha” of approximately 15 meters, causing destruction along its banks and the structural collapse of the bridge “Ponte da Usina”. This work describes the general bridge history and damages that have affected the structure in the past, the circumstances and the impacts of the collapse as well as the proposed alternatives for reconstruction of the collapsed bridge.

Keywords

Structural collapse, Steel Bridge



Figure 1 Bridge “Ponte da Usina” before the collapse [1].

The main modules in front of the elevation are constituted of two I-section pillars with a base of 14 x 35 cm that funnel in its superior end. These two main pillars are cross-braced by U-sections (14 x 7 cm) with a transition plate (57 x 70 cm) at the meeting of the two U-sections. The whole structure is bolted with hexagonal bolts and flat-head nuts or bolts, similar to rivets. At various points of the structure, reinforcement plates and also angles section are used, also bolted to the base structure [1].

The floor table is composed of wood with an average thickness of 5 cm as shown in Fig. 2. Boards are used in the

transverse direction and arranged in two strips in the longitudinal direction, where the wheels of the vehicles pass. Furthermore, the bridge is currently flattened on the banks by 1/2" diameter steel ropes to ensure better stability in times of extreme weather and during the transit of heavy vehicles.

The bridge has a reddish color, resulting from a texture mixed between the special painting for metals and the points that are in process corrosion. There are spots with graffiti in several colors, mainly on the sides of the vertical columns as shown in Fig. 2.



Figure 2 Inside part of the bridge [1].

At various points deformations are observed in the metal structure of the bridge from accidents with heavy vehicles or even from the fall it had suffered during a flood. After the fourth module, pillars of support on the southwest and northeast sides descend that rest on concrete blocks at the level of the lower bank of the river. These four pillars form two parallel porticos, structurally identical, and rest on the ground in four points, these being the massive blocks of reinforced concrete of the foundations.

At 6 February 2013, due to heavy rains that occurred on the night before at the top of the "Serra do Cipó", several streams that lead to the Parauninha River raised their level, causing destruction along its banks and the structural collapse of the steel bridge "Ponte da Usina". It is estimated that 130 people were directly impacted by the incident [2].

2 Bridge history

The steel bridge popularly known as "Ponte da Usina" was built in 1947 over the Parauninha River with the objective of allowing access to left riverside. The bridge was installed on the stretch of dirt road that gives access to the Hydroelectric Power Plant Pacífico Mascarenhas, inaugurated in 1928 in the municipality of Santana do Riacho. According to reports by plant employees, the superstructure of the bridge belonged to a larger structure, with about 600 meters, this bridge being only one of the parts of a bridge installed on the Dom Pedro II railroad (later Federal Railway Network S.A.) [1].

The installation of the bridge occurred due to the need to transport a generator to the hydroelectric power plant in

1949, since, until the construction of the bridge, the transit was made by the shallow river bed or improvised bridges, which would not support the weight of the generator.

The Pacífico Mascarenhas hydroelectric plant uses the water course of the Parauninha river, affluent of the Rio das Velhas River (São Francisco River basin) in the generation of energy for the company "Companhia de Fiação e Tecidos Cedro e Cachoeira" owned by the Mascarenhas family, pioneer in the textile industry in Minas Gerais.

The power plant Pacífico Mascarenhas is characterized as a small hydroelectric power station and currently the Power Plant operates with a power of 2944 kW and a new repowering is studied. The installation of Pacífico Mascarenhas marked the history of Serra do Cipó region, since it employed several local residents and promoted improvements in the region, such as the installation of "Ponte da Usina" bridge. The bridge serves the entire community and its use is associated with traffic in general, although its structure does not support very heavy vehicles, due to the damage that the bridge suffered during the years, mainly floods which damaged its frame [1].

In 1979, the bridge suffered with the rupture of the Vau da Lagoa dam, a reservoir owned by "Pacífico Mascarenhas" hydroelectric. The bridge was pulled out by the force of the water current, being crossed on the river bed. The bridge was rebuilt in 1981, so, at this time, the structure was dismantled and the pieces were catalogued for reassembly at the place of origin. However, the reassembling was carried out by a contractor who ignored the cataloguing of the parts, thus, during reassembly of the bridge, the technicians responsible could not install rightly the screws in the structure, compromising its stability [1].

In 1998, a new flood occurred in the region and contributed to further damage to the structure of "Ponte da Usina". The process of reforming the bridge was carried out, with the installation of steel cables in order to maintain the structure in its original place. At the same time, I-sections were implanted throughout its length, aiming to prevent the passage of coal trucks that have contributed to damage the bridge. Also, in 2003, another flood risked the stability of the bridge, however the steel ropes installed in 1998 kept the bridge in its original place.

In 2010, it was carried out on the Bridge renovation work, an initiative of Santana do Riacho City Hall in partnership with the fabric and spinning company "Companhia de Fiação e Tecidos Cedro e Cachoeira" [3].

3 Structural collapse of the bridge

Knowing the history of degradation suffered by the "Ponte da Usina" and the conservation status of the bridge, again, due to heavy rain on the night of 5 February 2013 on the top of the Serra do Cipó, several streams that flow into the "Parauninha" river raised its level by approximately 15 meters, destroying its shores and the collapse of the steel bridge. A general view of the collapsed structure is shown in Fig. 3 and a partial view of the damaged bridge may be seen in Fig. 4.



Figure 3 General view of the collapse structure [4].



Figure 4 Partial view of the damaged bridge [4].

With the collapse of the bridge, there was a complete interruption of vehicle traffic, which required moving or imposing a diversion of 40 km. One of the bridge entrances after the incident is shown in Fig. 5. It is estimated that about 130 people (students, residents and employees of the power plant) used the bridge daily to access rural communities and Serra do Cipó district and were directly affected by the incident. Also, is estimated that 70 students of a school bus route and tourists were affected as well, about 150 people weekly. According to representatives of the City Hall there were no records of people injured, displaced or homeless due to the incident [2].

In this context, the failure to reconstruct the bridge that collapsed led to the complete interruption of traffic along the road, directly impacting the access of residents to public equipment and the municipal headquarters. Due to the size of the project and the resources necessary for the reconstruction of the damaged bridge, the municipality did not have resources for the maintenance of the bridge.

Studies were initiated and it was proposed to maintain the temporary bridge located about 200 meters from the damaged bridge in March 2013, in response to requests from the surrounding population. These works were already carried out previously for temporary passage of light vehicles in the maintenance phases of "Ponte da Usina" [3].



Figure 5 Bridge entrance after the incident [5].

After surveys conducted by representatives of the City Hall, owners and technicians and the completion of the necessary procedures to obtain authorization by the Superintendency of the Regional Environmental Regularization - SUPRAM and the Chico Mendes Institute for Biodiversity Conservation - Icmbio, were granted the Dispensation Certificate nº 773584/2013 by SUPRAM and the Direct Authorization nº 001/2013 – Icmbio [3].

4 Alternatives for bridge reconstruction

As the non-recovery of the collapsed bridge interferes directly in the access of the residents to the municipal headquarters and various localities and given the social and historical importance of the bridge, since it is listed by the Municipal Council of Historical and Cultural Heritage, the City Hall of Santana do Riacho requested the coordination of the Curricular Internship Program of the School of Engineering of School of Engineering of Federal University of Minas Gerais - PIC/EEUFMG [4] at the end of November 2018 to carry out an evaluation and diagnosis of the current conditions of the structure of "Ponte da Usina". In addition, the municipality also requested the proposition of alternatives for a definitive solution for the bridge, to meet the demands of the local communities.

Thus, there was a technical visit by the PIC/EEUFMG team [4] to the site of the collapsed bridge on November 2018, to evaluate the local conditions and the situation of its damaged metal structure. Then, the team proposed 3 (three) possible solutions to its reconstruction:

- a) Hypothesis 1: Recovery of the original metal structure and reassembly of the bridge;
- b) Hypothesis 2: Elaboration of new metallic structure design for the bridge, keeping all elements and the geometric shape similar to the original structure;
- c) Hypothesis 3: New solution with design elaboration in mixed structure (concrete/metallic), with a geometric shape different from the original, with a capacity equal to 45 tons.

The School of Engineering of UFMG proposed to offer, for

the selected alternative, through the PIC/EEUFMG, technical support for the project and the necessary activities.

5 Final remarks

In this paper it was presented the collapse of a bridge structure in the city of Santana do Riacho / MG, Brazil. The heavy rains that occurred on the night 5 February 2013 lead to the Parauninha River to raised their level, causing destruction along its banks and the structural collapse of the steel bridge "Ponte da Usina".

It was described a succession of past damages occurred in the bridge due to heavy rains and floods over the years in which the bridge has been used by the people to access rural communities and the Serra do Cipó district. All the accidents occurred in the past contributed for damage the bridge structure, and not even a reform in 2010 was sufficient to prevent the further collapse of the structure that came to occur in February 2013.

After the incident, it was proposed the maintenance of the temporary bridge that is about 200 meters from the damaged bridge, which was previously used at the time of the maintenance of the steel bridge rather than the reconstruction of the bridge "Ponte da Usina", since the municipality did not have its own resources for the reconstruction of the collapsed bridge.

Finally, in 2018 the City Hall of Santana do Riacho requested PIC/EEUFMG [4] to carry out an evaluation of the current conditions of the bridge structure and the proposition of possible alternatives for recovery it. Therefore, considering the conditions of technical feasibility of execution and the implications of final construction costs, in view of the age and situation of the structural metal elements of the "Ponte da Usina", after approximately four (4) years and five months of its collapse, it has been proposed 3

(three) possible solutions for its reconstruction by the PIC/EEUFMG team [4].

Acknowledgements

The authors would like to acknowledge the Santana do Riacho City Hall (Prefeitura de Santana do Riacho) and UFMG (Universidade Federal de Minas Gerais).

References

- [1] Prefeitura Municipal de Santana do Riacho (2010). Dossiê de tombamento ponte da Usina Pacífico Mascarenhas, Santana do Riacho (in Portuguese). Internal document
- [2] Prefeitura Municipal de Santana do Riacho (2013). Plano de Trabalho de Reconstrução - Relatório de Diagnóstico, Santana do Riacho (in Portuguese). Internal document
- [3] Prefeitura Municipal de Santana do Riacho (2013). Relatório Técnico de Intervenção Realizada, Santana do Riacho (in Portuguese). Internal document
- [4] PIC/EEUFMG (2018). Proposta de alternativas para reconstrução da "Ponte da Usina" sobre o rio Parauninha no distrito de Serra do Cipó-MG, Belo Horizonte (in Portuguese). Internal document
- [5] Hoje em dia (2013). Portal Hoje em dia. Belo Horizonte, Brazil (in Portuguese). <https://www.hojeemdia.com.br/horizontes/chuva-destr%C3%B3i-ponte-hist%C3%B3rica-e-deixa-30-fam%C3%ADlias-ilhadas-na-serra-do-cip%C3%B3-1.102236> [accessed on 08 Jan. 2023]