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Case Study of Pathological Manifestations of Neoprene Support Devices in Infrastructure

Felipe R. Gonçalves[1a], Lais A. Alves[2], Assed N. Haddad [1b] and Elaine G. Vazquez[1c]

[1] Escola Politécnica, Department of Civil Construction, Universidade Federal do Rio de Janeiro (UFRJ), Technology Center, Av. Athos da Silveira, 149 CT – Sector A, 2º floor, 21941-909 – Cidade Universitária, Rio de Janeiro, Brazil, felipe.rezende@poli.ufrj.br, assed@poli.ufrj.br, elainevazquez@poli.ufrj.br

[2] Department of Civil Construction, Federal Center of Technological Education Celso Suckow da Fonseca, Av. Maracanã, 229 Sector E, 2º floor, 20271-110 - Maracanã, Brazil, lais.alves@cefet-rj.br

Abstract. *The so-called works of special arts, are constructions of high complexities that allow the advancement of widening gaps and overcoming obstacles previously unthinkable. With the increase in magnitude of these structures, in addition to greater investments, the maintenance of these structures becomes an increasingly important factor for engineering. Among the elements of bridge structures, the support devices are components with important structural functions, being essential for their proper functioning and especially the durability of the entire structure. This paper aims to evaluate the pathological manifestations in support devices so, according to inspections performed and the diagnosis of causes, define their best practices and treatments for the maintenance and mitigation of the pathologies found. In the practical study the following steps were performed: survey and selection of the structures currently under maintenance of MetrôRio; selection of criteria for the evaluation of pathologies; carrying out inspections; comparative analysis between the viaducts to determine the priority order for negotiations; and definition of conduct. The results obtained were the result of evaluation of the field analysis, diagnosis and comparison with tests performed in support devices. Having as input the tests in the support devices, the best treatments and suggestions to avoid new pathologies were proposed.*

Keywords: *Support Device, Infrastructure, Pathological Manifestation, Maintenance.*

1 Introduction

Throughout history, bridges have been built to exemplify the engineering prowess of a civilization, many enduring longer than the empires that built them (Wilson, 2009).

Bridges and infrastructures systems, due to their inherent vulnerability, are at risk from ageing, fatigue and deterioration process due to aggressive chemical attacks and other physical damage mechanisms (Biondini, 2015). The preventive and corrective maintenance should be part of a comprehensive management process, including periodic surveys aimed at identifying any existing structural anomalies and failures, diagnosing them and then defining recovery and treatment actions, if necessary (Kainuma *et al.*, 2014).

The culture of inspection and maintenance of road bridges, railroads and viaducts in Brazil is recent, being from the 80's the first studies of pathologies in the structures (Araujoa, 2017).

There is a specific standard for the inspection work on bridges, viaducts and concrete walkways, ABNT / NBR 9452/2016 (ABNT NBR 9452, 2016).

Support devices are components with structural functions essential for the proper functioning and durability of the structure, but not just a sample of the entire structure, the support device alone can already represent a maintenance point of the structure, so its monitoring continuous inspections are considered very important in the bridge maintenance management process (Freire *et al.*, 2015).

It can be said that knowledge of the state of the bearing apparatus is a good sign and well represents the state of the bridges in their entirety in structural terms. Therefore, the analysis of their pathologies, causes and origins is of great importance in defining the treatment and maintenance of bridges, elevations and viaducts. (Freire *et al.*, 2014).

Metal and concrete support devices expose some problems that discourage their use, either in terms of maintenance difficulty, poor property of materials or even the built-in cost. Therefore, over time, it was searched for elements that could cover all the needs of a support device, this way arose the support devices in elastomer, based on polychloroprene, whose widespread trade name is neoprene which as a product industrialized, it presents greater uniformity of physical characteristics, as well as exceptional resistance to light and ozone, thus providing durability significantly superior to that of other types of elastomers (Cordeiro,2014).

This paper aims to present approaches towards improving some specific infrastructure maintenance principles, strategies, models and practices, based on a recent study to evaluate the pathological manifestations in neoprene support devices, of the structures currently under maintenance of *MetrôRio*.

The novelty of this work is in proposing a systematic approach to condition assessment, deterioration forecasting, and maintenance decision making over the life-cycle of the built asset. Given the importance of *MetrôRio* to society in Rio de Janeiro, it is essential that the entire system works continuously as there is no margin to support major service disruptions.

2 Methods

In the methodology the following steps were used: survey of the viaducts, elevations and bridges existing in the subway railway; selection of structures to be inspected; selection of criteria used in the evaluation of pathological manifestations; conducting visual inspections based on ABNT NBR 9452/2016; and suggestions for future interventions.

2.1 Inspection of Bridges and Support Equipment

Inspections are paramount to characterize the bridge's constituent elements and, therefore, their classification according to criteria established in ABNT NBR 9452 (2016). Each element is evaluated according to specific visual aspects defined in the standard. According to the same standard, the following types of inspections are considered: cadastral, routine, special and extraordinary.

ABNT NBR9452 (2016) provides in Annex A, a basic roadmap for tokens and cadastral inspections, the proposed initial documents are described such as project data, execution record and changes in the construction phase, previous inspections, among other elements that may provide more inputs for the definition of the causes and better dealings.

Inspection of assistive devices may not be limited to the space in which they are positioned and to the element. It is necessary to identify the general functioning of the studied artwork and to verify the compatibility with the current behavior of the support devices.

Because of their location, support devices are structural elements that are difficult to inspect, but their behavior must be monitored by inspectors according to the following general procedures in Table 1 (DNIT, 2004).

Table 1. Items to be inspected on assistive devices (DNIT, 2004).

Visually inspect the accessible faces of the appliance; After a few years of service, small cracks 2 to 3mm deep and 2 to 3mm long are tolerable;	Check that the support device has been correctly vulcanized and that there are visible and oxidized charter steel sheets;
If there is displacement of the structure, measure the angles between the surfaces of the structures in contact with the support apparatus;	Check for defective expansion joints on the superstructure, very close to the support device or directly above the device.
Measure distortions of the support apparatus;	Check that the support device has been moved from its original position;
Check for the presence of oils, greases or any other substance harmful to the elastomer;	Measure the heights of the support apparatus at the edges and center points;

According to ABNT NBR9452 (2016), Table 2 can be considered as a parameter for evaluating support equipment, given its condition and the scenario to which it is exposed.

Table 2. Device Classification (ABNT NBR9452, 2016).

Condition	Description
Critical	Support devices and / or their surroundings present breakdowns at risk of structural collapse requiring repair intervention and / or immediate device replacement.
Bad	Support devices and / or their surroundings present damage that compromises structural safety without risk of collapse, requiring repair intervention and / or short-term device replacement. All devices with breakage with charter exposure fall into this classification. Follow-up is recommended and interventions may be needed in the short term.
Regular	Support devices and / or their surroundings present malfunctions that may generate some structural deficiency, but there are no signs of deterioration of the devices, nor compromise of the stability of the work. Follow-up is recommended and interventions may be necessary in the medium term.
Good	Support devices and / or surroundings are not malfunctioning. Interventions may be necessary in the long run.
Excellent	Support devices and / or their surroundings are not damaged and the devices were manufactured from 1987 following the recommendations of ABNT NBR 9783 (1987).

2.2 Pathological Manifestation in Neoprene Support Devices

Although it has excellent performance compared to other types of support equipment, especially when not in need of maintenance, the neoprene device also requires some care. Table 3 shows recurrent pathological manifestations in neoprene supports.

Table 3. Pathological Manifestations in Neoprene Apparatus (Cordeiro, 2014).

Most Common Pathological Manifestations - Neoprene Apparatus
High Neoprene Distortion
Neoprene cracking or creep
Frame contact zone shutdown
High compression on neoprene
Loss of serviceability and distortion
Variations in rubber layer thickness
Unsticking of vulcanization of inner sheets
Degradation of sliding plates, guides or stops
Oxidation of steel elements

The causes for the deterioration of structures can be as diverse as the natural "aging" of the structure to the irresponsibility of some professionals who choose to use materials that are out of specification (Souza and Ripper, 1998).

The causes of pathologies in structures have their origins in two groups: intrinsic causes - referring to the processes of deterioration inherent in the structure itself, *i.e.* its origin is in execution, use, human failures, etc. and extrinsic causes - external to the material body, can be understood as factors that attack the structures from the outside inwards, throughout the process of conception, execution or the useful life. The most common causes of decreased service life in assistive devices are listed in the Table 4 (DNER, 2006).

Table 4. Causes of Pathological Manifestations in Support Devices (DNER, 2006).

Most common causes of pathological manifestations	
Intrinsic damage not detected during installation	Irregular seating causing additional localized overload
Displacements, rotations and loads in service much higher than estimated	Unintended aggressiveness of the environment
Attack by chemicals	Badly nesting in the crib

The treatment of a pathological manifestation should be done according to the inspection report, condition and definition of the causes of the given manifestation.

As it is a synthetic structure, of specific manufacture, it is more common that if it presents anomalies, it will be replaced by a new device. Except in the case of incorrect positioning of support devices or displacement of a Teflon sliding plate, for example.

Table 5 presents some common types of repair methods according to each pathology in neoprene support devices (Cordeiro, 2014).

Table 5. Neoprene Support Devices Treatments – adapted (Cordeiro, 2014).

Damage to Support Devices	Repair Dealer
Corrosion, presence of dust and moisture	Cleaning and use of protective paint.
Massive corrosion leading to section loss	Replacement
Offset or misalignment	Component replacement or total
Neoprene deterioration or wear	Replacement
Fissures	Crack sealing or replacement
Fragmentation of concrete in support	Removal and execution of new concrete

3 Results – Case Study of Pathological Manifestations, Their Causes and Treatments in Neoprene

All *MetrôRio's* assets are cataloged according to an asset tree ABNT NBR ISO 55000 (2014), which aims to give an overview, keep all history of interventions, corrective or preventive, and maintenance plans in force combined with each group of systems and equipment. Thus, the support devices studied in this work are under the structures system.

The object of case study was the support devices and their surroundings. The elevations between São Cristóvão and the *MetrôRio* Maintenance Center and between the Triagem and Maria da Graça stations are the oldest in the system, and their construction dates back to the late 1970s, or about 35 years of operation.

The recommendations of DNIT inspections were followed (DNIT,2004). Field information has been posted in a specific form for this service. A specific inspection campaign was carried out for the support devices of each structure. As an input for maintenance decision-making, 1228 neoprene support devices were performed along the entire railway structure. The inspections were performed by specialized technicians using the visual method, with the naked eye, and the access was made by stairs with a reach of 9.00 meters in height. The fieldwork was accompanied by a professional specialized in occupational safety, all safety procedures were complied with in accordance with current legislation. No device has been classified in the Excellent Class because it is over 30 years old and has not been manufactured (ABNT NBR 9783, 1987).

The CNV - SCR Elevated is located between the Maintenance Center - MC and the São Cristóvão station (later, there was also the connection of the elevated with Cidade Nova station). The old elevation has a total length of 970m and consists of 30 spans, 4 spans with 4 beams, 1 span with 3 beam and 25 spans with 2 beams. The trays are seated on 28 pillars and two staked joints at the longitudinal ends, constituting isostatic spans. In the beam x pillar and beam x encounter interface there are chartered neoprene support devices with regular dimensions of 700 x 250 x 40 mm. In this elevation, 30 pillars and 138 support devices were evaluated, two of which were not inspected for being covered. It was found that most of the assistive devices (79 units) inspected at this stage were classified as being in a regular state of conservation (57%). Supporting devices fitted with poor condition total 57 units (42%), as shown in Fig. 1.

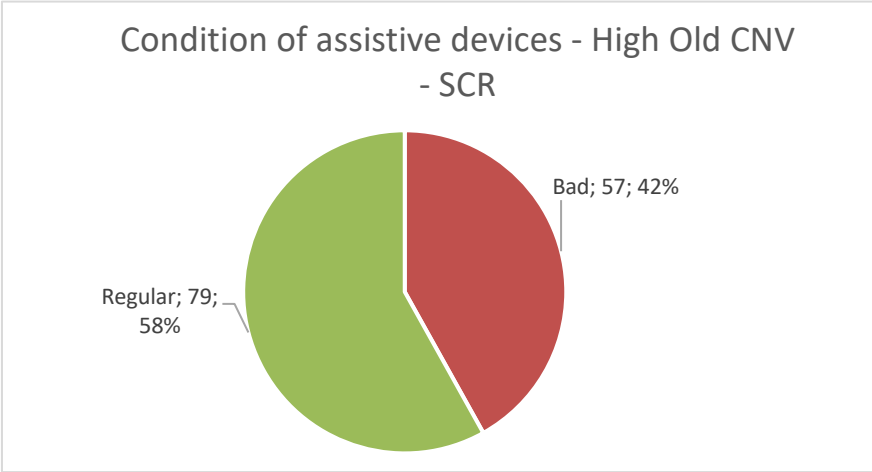

Figure 1. Support Device Conditions - CNV – SCR.

Elevated TRG -MGR is mostly located between the Triagem (TRG) and Maria da Graça (MGR) stations and starts after leaving the Bernold tunnel next to the Mangueira Olympic village. The Elevado has a total length of 2,925 meters and is formed by 84 spans, mostly with 4 precast beams each, with chartered neoprene appliances with dimensions 750 x 200 x 40 mm. In this elevation, 361 support devices were evaluated, and 37 pillars were not inspected because they were in a risk area where access could endanger the inspection team. It was found that most of the support devices (269 units) inspected at this stage were classified as being in a regular state of conservation (75%). Poorly classified support devices total 78 units (22%), 9 units (2%) were considered in good condition and 5 critical support devices (1%), as shown in Fig. 2.

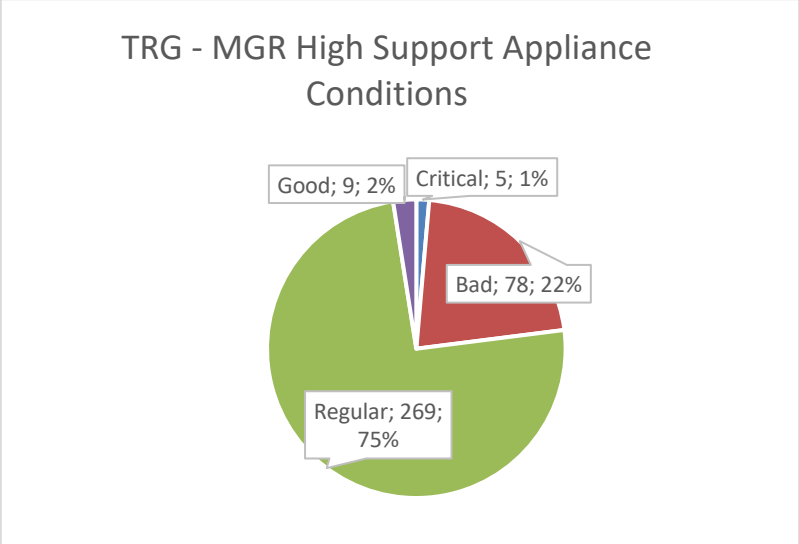

Figure 2. Support Device Conditions - TRG – MGR.

With the definition of the pillars that concentrated the largest number of critical devices, aiming at a better use of the operation, the decision was made to replace 12 units, from the perspective of urgent replacement. Tables 6 present this pathological manifestation, with the degree of risk, possible cause and the indicated treatment.

Table 6. Pathological manifestations in the devices and support.

Pathological Manifestation - Cradle Degradation (Plinth)	
Pathology	Anomaly around the support apparatus, but caused by malfunction of the element. 
Risk	Critical risk - severe pathological manifestation with compromised structural safety
Cause	From a malfunction of the supporting bond between the superstructure and the mesostructure of the elevation.
Treating	The treatment, in addition to the replacement of the support apparatus, should include reinforcement of the plinth with its recomposition at the bottom, called the cradle. As said, in neoprene support devices, it is not common to perform maintenance and treatment interventions on the element, but rather its immediate replacement.

4 Conclusions

The concern with the maintenance of structures such as those of special artworks was motivating for the work and allowed to relate the pathological manifestations in support devices with the pathological manifestations of the structures, the intrinsic and extrinsic causes as a whole, allowing an analysis, albeit superficial in the field of subject matter, sufficient for decision. The novelty was the proposal of a systematic approach to condition assessment, deterioration forecasting, and maintenance decision making over the life-cycle of the built asset.

Supporting devices are structural connecting elements which allow forces to be transmitted between the superstructure of the artwork and its support and are therefore essential elements for the proper functioning of the structure into which they are inserted.

The inspection processes took place exactly in accordance with all the literature found, allowing great inputs for subsequent decision making. Thus, the pathological manifestations were quite explicit.

As for the causes of the manifestations, it is a complex study and although there is literature, it is not trivial to understand the reason why two support devices, theoretically manufactured under the same process, of the same age, suppose stored in the same form, are adjacent to each other, exposed to very close loads and exhibit behaviors so distinct in terms of behavior in service.

Even with breakage and chartering exposed in the corrosion process, the devices can still perform satisfactorily without causing movement restriction of the part. But in these cases, annual monitoring is essential to follow up on a case-by-case basis to make sure that the performance and operation of the chartered neoprene parts is still adequate.

As for the process of negotiations, in cases where no substitution was considered, monitoring will take place in accordance with the first inspection. Thus, the big point of the issue of support devices is to understand their operation not individually but in conjunction with adjacent structures, as it is evident that despite some anomalies found, support devices, except those that had signs of degradation around them, they were still able to remain in service, provided they were well monitored.

ORCID

Lais Alves: https://orcid.org/0000-0003-0543-2374
Assed Haddad: https://orcid.org/0000-0002-4793-0905
Elaine Vazquez: https://orcid.org/0000-0002-7262-6753

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