# GREATER DURABILITY FOR HYDRAULIC WORKS IN GABIONS

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The gabions began to be used more than 2000 years ago. Traces of similar structures were found in the ruins of the city of Caral, in Peru, dated approximately 2627 BC. C. (Figure 1a) and there is news of similar works used at the same time in Egypt in the Upper Nile. In both cases, vegetable meshes were used to contain the stones, in the first case they were made of a braided net and in the second intertwined wickerwork. During the Middle Ages and the Renaissance similar structures were used as foundations and in the 19th century they were used in the Napoleonic wars and in the American Civil War to build bastions (Figure 1b).

**Fig. 1 First applications of the gabions: a) Caral "gabions of braided vegetal mesh"; b) American Civil War)**

The metallic gabion, similar to the one we know today, appeared for the first time shortly after, in 1892 when it was used in the Reno River to rebuild a dike that had been destroyed during a flood (Figure 2).

**Figura 2. First work in wire gabions**

The gabion, at that time, was very different from the one we know today, since it was produced with a crawling mesh and not double twisting. The coating of the wire, which initially was of very low grammage, was increasing until it reached, in the 50s, the values still used today of a few hundred grams per square meter. In the 90s of last century, then came the zinc / aluminum that is used today.
Even so, unlike retaining works, the use of Reno gabions and mattresses have serious restrictions on hydraulic works due to the corrosion and abrasion they may suffer.

In the 40's of last century began to be used an additional plastic sheath, the Poly vinyl chloride, better known as PVC that, even if fulfilling its protective action in many aggressive environments, had and has some limitations that are:

- contain in its composition chemical elements such as halogens (chlorine) and toxic (DOP's, plasticizers, phthalates, etc.) that, even if in small quantity, can be contaminants to the environment;
- it is not very resistant to some acids (sulfuric, formic, acetic), to potassium hydroxide, to caustic soda and to liquid ammonium, which may be present in the water due to industrial discharges;
- be little resistant to ultraviolet rays;
- be little resistant to abrasion.

By way of comparison, we show, in Table 1, the expected design life according to the EN 10223-3: 2013 Standard depending on the coating used.

**Table 1.**

| **Type of exposure (combinations of extreme conditions will reduce design life)** | **Degree of aggressiveness of the environment** | | | |
|---|---|---|---|---|
| | Very low | Low | Medium | High |
| Presence of water | Dry | Dry | Frequent | Frequent |
| Presence of salinity | Not | Not | Occasional | Frequent |
| Abrasion caused by wind / water | Not | Very little | Occasional | Frequent |
| Exposure to pollutants | Not | Very little | Occasional | Frequent |
| Soil resistivity | Very low | Low | Low | High |
| **Type of coating** | **Expected design life** | | | |
| Zn* | 60 | 25 | 10 | Not recommended |
| Zn/Al | 120 | > 50 | 25 | 10 |
| Zn/Al +PVC | > 120 | > 120 | > 120 | 120 |
| Zn/Al +PMC | > 120 | > 120 | > 120 | 120 |

* The zinc coating referred to in the EN standard is the one required by the INVIAS standard

As it is possible to observe in the table in the conditions frequently found in a river (the last column on the right), according to the European norm, the use of gabions whose wires are only coated with zinc is not recommended. Only the use of an additional plastic material sheath allows to reach an acceptable useful life above 50 years, naturally depending on the particular conditions of the river under examination.
Due to the restrictions of the PVC in the presence of some chemicals often present in the water of the rivers, the company Maccaferri studied other polymeric materials with greater area of action and is currently available a new material, which was called PoliMac, for the coating of the wires that increases the useful life of these structures in more critical situations not only in chemically aggressive environments, but also in rivers with high solid transport and consequently high abrasion.
The **New Gabion** presents properties that differs it mechanically and chemically from the gabion coated with zinc / aluminum and coated with PVC, especially in aggressive environments. Figure 3 shows the durability of the **New Gabion** liner compared to that of PVC coated in various environments.

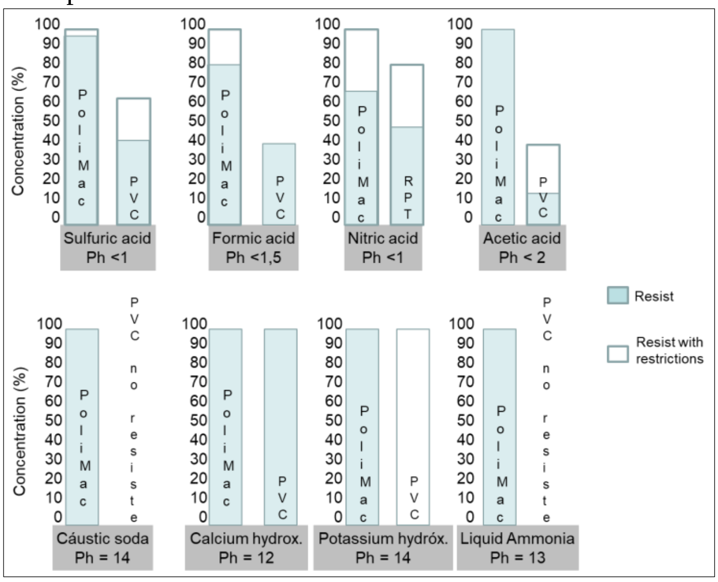


**Figura 3. Behavior of PVC and PoliMac exposed to different environments.**

The behavior of the New Gabion net exposed to ultraviolet radiation was also verified in the accelerated aging test according to EN 10223-3 and ISO 4892-3 standards (Fig. 4).

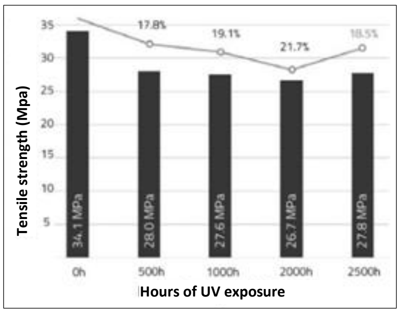


**Figura 4. Accelerated aging test - Tensile strength of the mesh.**

In the same way, the different behavior of this polymer in relation to abrasion was verified. Due to the absence of specific standards to verify the resistance to abrasion of the wire used in the manufacture of gabions, existing standards for other materials were adapted and a third was invented.

- The first test was carried out by adapting it to the Brazilian standard NBR 7577 " Fios e Cabos eléctricos" for electric cables, in which the friction between a steel tip and the plastic coating is caused by a pneumatic piston. The tip, perpendicular to the surface of the sample, slides longitudinally on the upper part of the wire. The test bodies are Ø 600mm and the test speed is 300mm / s. The end of the test is given when, after the complete loss of the plastic protection layer at some point in the sample, the tip and the metallic wire come into contact, closing the circuit (Fig. 5). With the PVC coating the test was interrupted after 12,811 cycles, with the PolyMac coating after 140,000 cycles (approximately eleven times more).
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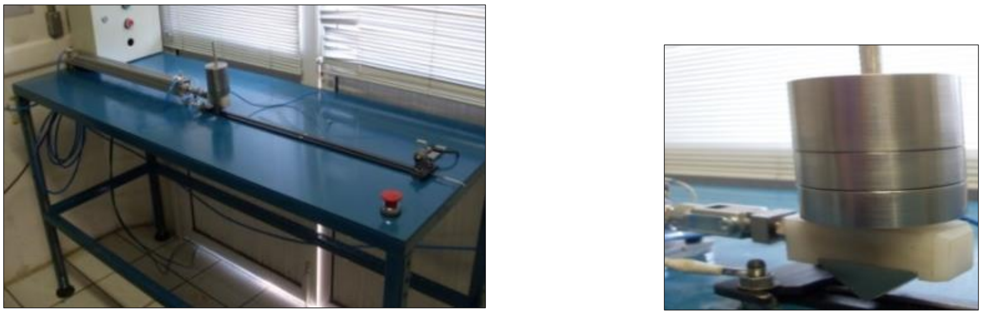

**Figura 5. Abrasion test according to NBR 7577**

- The second test, developed by Maccaferri, consisted of supporting a test body in an abrasive stone linked to a motor / bench grinder, with a controlled speed of 300 RPM; the time was timed and every minute a verification of the wear of the coating in the contact region was made (Fig. 6). With the PVC sheath the test was interrupted due to the total wear of the coating after eight minutes, with the PolyMac sheath the test was interrupted due to the total wear of the coating after one hundred thirty minutes (approximately sixteen times more).

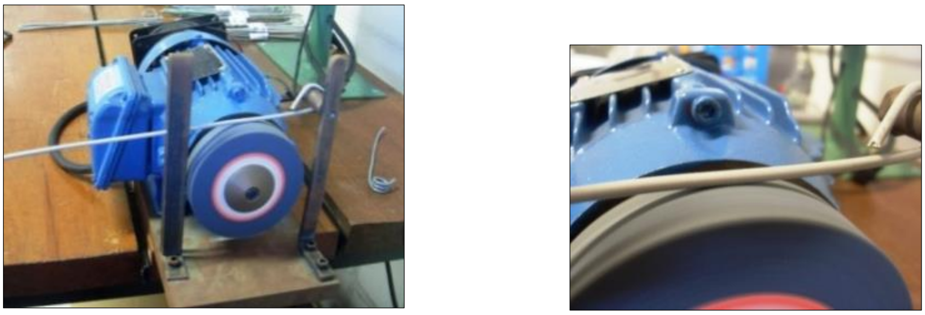

**Figura 6. Abrasion test on abrasive stone**

The results of the tests are reported in the graphs of Fig. 7.

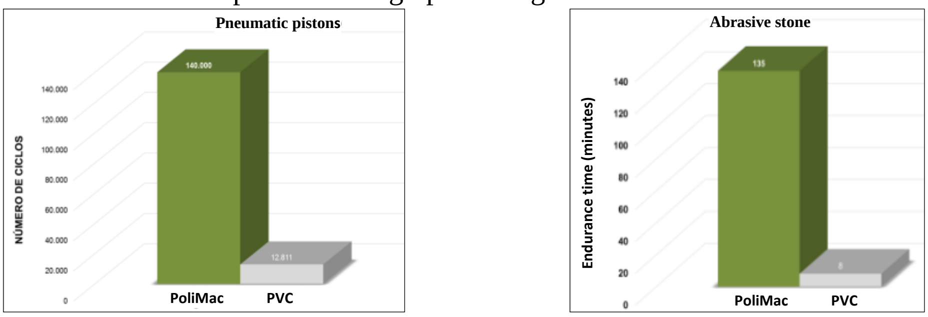


**Figura 7. Results of the tests of the pneumatic piston and abrasive stone**

To verify if the behavior was conditioned by the medium in which the material is used, the samples were divided and immersed in controlled aqueous solutions of pH 2, 4, 6, 8, 10 and 12; after 500, 1000, 2000, 3000 and 5000 hours of exposure, each sample was submitted to abrasion stone abrasion

test.
The results for pH 2 and 12 are illustrated in the graphs of Fig. 8.

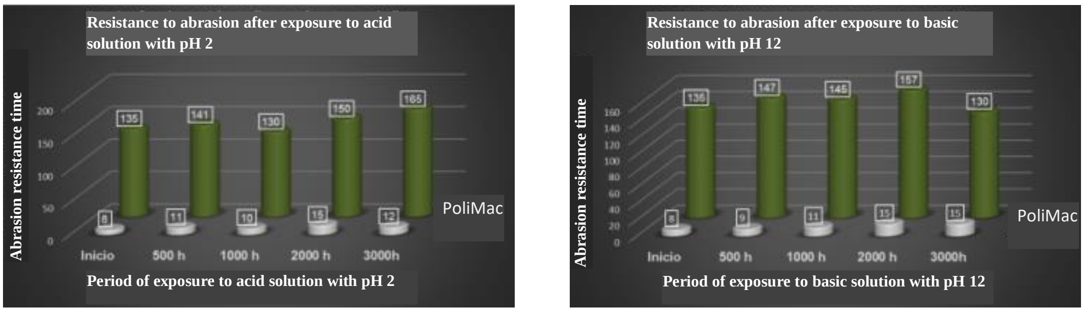


**Figura 8. Difference of behavior of the samples submerged in extreme solutions with pH 2 and 12.**

- For the third test, whose purpose was to compare the abrasion resistance of the two polymer coatings (PVC and PoliMac) to that of the metal coating (zinc / aluminum), which in some countries is still traditionally used in rivers, was The Los Angeles test (Fig. 9a), appropriately modified, was used. The test bodies of the different materials were introduced into the equipment together with quarry stones, sand and water (Fig. 9b); in this way the friction between the different materials during the rotations of the equipment caused the wear of the different samples.
  All the samples before the test were 6 mm thick and 16 mm in diameter (Fig. 9b) and were weighed before the test; at the end of the test they were dried and weighed again to measure the mass loss that occurred. Unlike the traditional trial, the duration was extended to 5,500 rotations to achieve more reliable results.

a) b) c)

**Figura 9. a) Los Angeles equipment, b) wear material used in the test and c) test bodies tested.**

From the results listed in Table 1 it is possible to verify that the mass loss of the PolyMac is of the same order of magnitude as the zinc/aluminum alloy, while the abrasion resistance of the PVC is much lower than both.
Comparing the behavior only of zinc/aluminum and PolyMac and obviously taking into account the difference in specific weight and thickness of the two coatings that are:

- the specific weight of the Polimac is approximately 950 kg / m3, while that of the Galfan is approximately 7,200 kg / m3 (the Galfan is 7.3 times heavier than the PoliMac).
- the thickness of the Polimac is 0.5 mm while the Galfan coating is 0.035 mm (35 μm) (the plastic coating is 14 times thicker than the metallic one).

considering that below the polymer sheath the metallic wire is also coated with zinc / aluminum alloy and therefore the total durability is the sum of that of the two materials in sequence, consequently the time necessary to wear the PoliMac is more than double the zinc / aluminum alloy and, defining as the end of the useful life of the gabion the appearance of red oxide (rust) in the wire, it is possible to reach the conclusion that:

**in hydraulic works the useful life of the New Gabion, when subjected to abrasion, is approximately three times greater than that of a gabion with only the metallic coating,**

that is to say that, under equal conditions, today it is possible to triple the durability of a fluvial structure exposed to the abrasive action of the material carried by the current.

**Tabla 1. Results of the Los Angeles test.**

| Material of the sample | | | Gabion | | |
|---|---|---|---|---|---|
| | | | Metallic | PoliMac | PVC |
| Total mass of soil = 10 kg | Rotations | Initial mass | 44.19 | 7.85 | 9.46 |
| | 500 | Mass [g] | 44.18 | 7.85 | 9.46 |
| | | Δ mass [%] | -0.02 | 0.00 | 0.00 |
| | 1,000 | Mass [g] | 44.12 | 7.86 | 9.45 |
| | | Δ mass [%] | -0.16 | 0.13 | -0.11 |
| | 1,500 | Mass [g] | 44.13 | 7.88 | 9.45 |
| | | Δ mass [%] | -0.04 | 0.38 | -0.11 |
| | 2,000 | Mass [g] | 44.10 | 7.86 | 9.42 |
| | | Δ mass [%] | -0.20 | 0.13 | -0.11 |
| | 2,500 | Mass [g] | 44.08 | 7.85 | 9.41 |
| | | Δ mass [%] | -0.25 | 0.00 | -0.53 |
| | 3,500 | Mass [g] | 44.085 | 7.838 | 9.399 |
| | | Δ mass [%] | -0.24 | -0.15 | -0.65 |
| | 4,500 | Mass [g] | 44.073 | 7.829 | 9.392 |
| | | Δ mass [%] | -0.27 | -0.27 | -0.72 |
| | 5,500 | Mass [g] | 44.071 | 7.824 | 9.389 |
| | | Δ mass [%] | -0.27 | -0.32 | -0.75 |

Recalling that in the cost of a structure in gabions the element in double twist mesh is approximately one third of the total cost of the work, the increase in cost of gabions with polymeric coating is then more than justified in hydraulic works in consideration of the increase of the useful life of the structure.

To further increase the useful life of the gabions, after further studies, the company Maccaferri is studying a new polymer whose tests will be extended throughout 2018. The results are very encouraging and, only in the case of the piston test (Norma NBR 7577) the resistance surpassed the 440,000 cycles, almost tripling the resistance of the current PoliMac. This new coating will be available in the market probably in the course of the year 2019.