General description and brief history (Pre-Treatment Station)

This report refers to the survey of structural anomalies carried out at the WWTP, PRE-TREATMENT STATION building, located in Bairro da Munhava, with a view to their diagnosis and correction, and it is part of the scope of the to carry out a Master Plan and Preliminary Design for Rehabilitation and Expansion of the Sanitation System of the City of Beira, assigned to the consortium PLANET SEURECA VEOLIA, currently in progress..

This building has evident rupture defects in various parts, such as floor slab which connects the foundation pile heads, and the superstructure with a greater incidence by the inlet of the feed pipe from EE4 pumping station. The photos below show some of the most affected parts of the building.





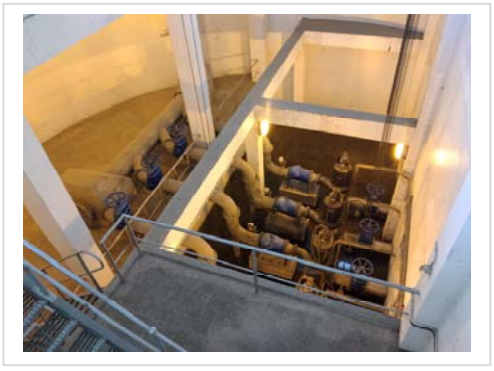




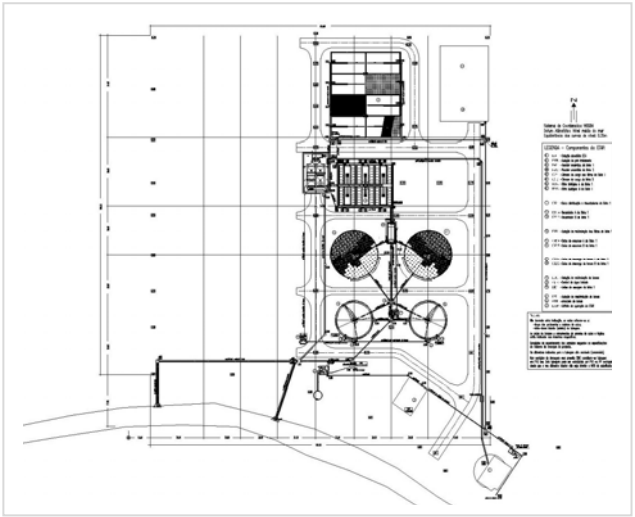




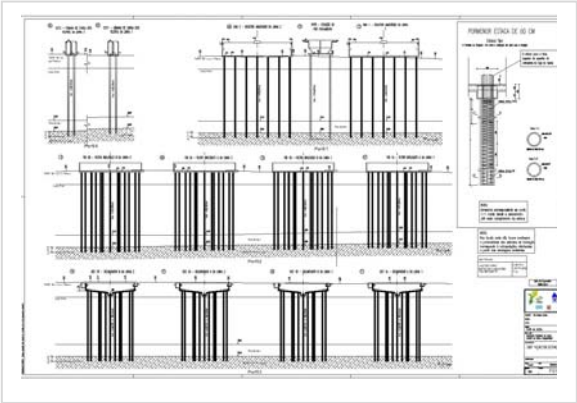
The WWTP started operating in 2010, having been operational until March 2019, when Cyclone IDAI destroyed several sanitation system infrastructures in general, including the EE4 Pumping Station (photo below), located inside the WWTP site, where there was a rupture of the inlet pipe that is at 6m depth , with the water table at about 1.5m deep, depending on the climatic season.

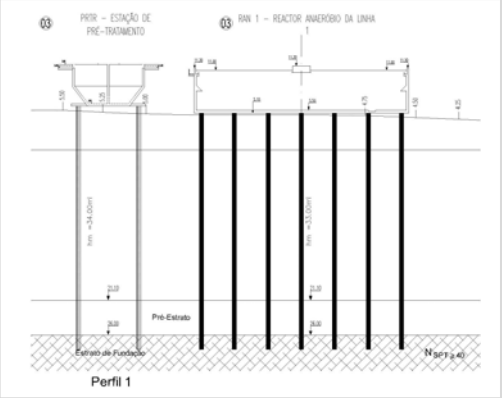


The WWTP was built in the estuary of the Pungue River, north of the industrial zone of the Beira Port, which had previously been used as the city´s main solid waste dumping site since the beginning of the 70s..



According to the tests and geotechnical studies that guided and preceded the construction, the subsoil layer with sufficient consistency and compaction state to support the WWTP structures, is about 25m deep, with the upper layers being composed of soft clays , coarse to medium sands mixed with silts and clay in small quantities.





A general landfill was carried out with imported selected soils, over the areas of implantation and circulation of the WWTP, estimated at about 1.0m-1.5m in thickness.

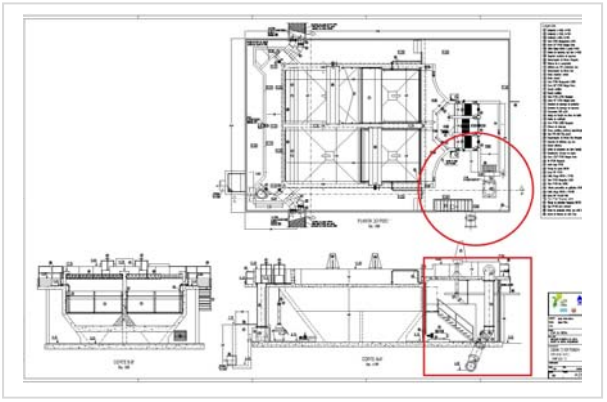
The fact that only the structures are supported by piles, and most of the pipes and connection pipes have been buried in ditches, and are based on a sub-base of the existing soils, with a layer of about 9 m of soft clays, added to the weight of the landfill, the vehicles movement, and the weight of the pipes that work in forced flow (section filled by pumping) contributed to the acceleration of the settlements in the circulation areas, as opposed to the structures supported on piles. This phenomenon is visible in the perimeter of most structures and valve chambers, as can be seen in the following photos:

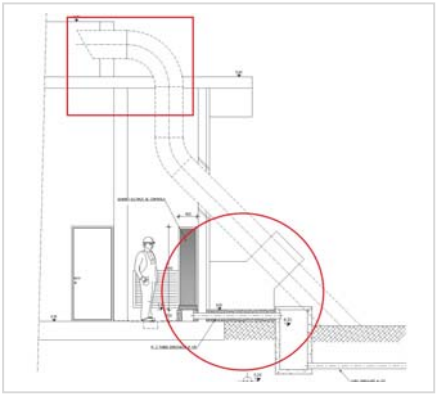
The settlement problems of the WWTP organ-buildings, with the same type of pile foundations, only occurred at the PRE-TREATMENT Station, with some visible signs appearing, albeit of lesser extent, in the Office building which is supported by a system of direct foundations.

According to reports from the personnel assigned to the WWTP services, the PRE-TREATMENT building suffered a rupture in the just before the official inauguration of the facilities, with a loud noise being heard that indicated the occurrence of the rupture, and which led the Contractor to make some repairs in cracks that had appeared at the time.

Also in that period, part of the slope of the floor slab, was compensated through the cement screed over the floor, which presents noticeable differences in thickness on the different sides and ends of the floor slab, which simultaneously has the function of interconnection and establishing balance between the different foundation pile cups.

An expedited measurement on site, during the survey carried out with the support of the personnel assigned to the WWTP, using a level hose, shows that the area of the building where the main pipe from EE4 is unloaded, on the side where the stairs are located, settled about 32 cm, in relation to the diagonally opposite area.



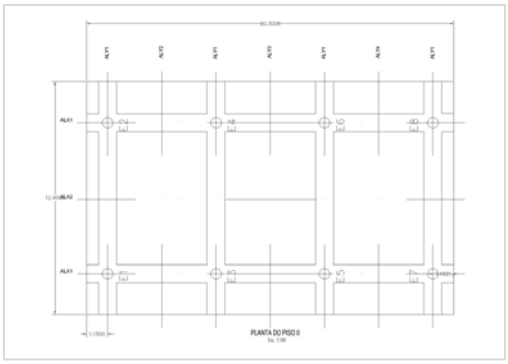


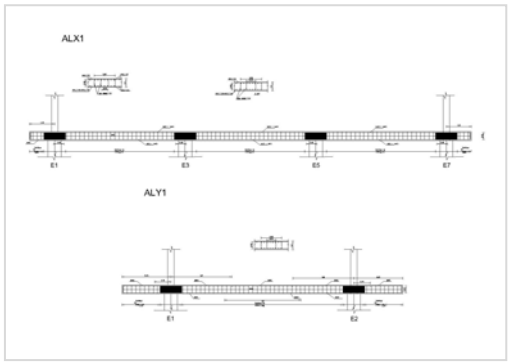
Despite the progression of the settlements, the Pre-Treatment function has been carried out for about 10 years, only interrupted due to the rupture of the pipe next to the building, as shown in the images.

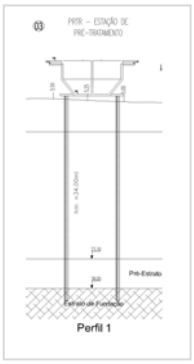
These ruptures frequently occurred as a result of the rigid pipe, without flexible joints, not being able to resist the efforts caused by the continuous and distinct settlements of the pipe and supports, as well as the building as a whole. The repairs to the pipeline carried out were aimed at restoring the existing situation, thus renewing the rupture-repair cycle.

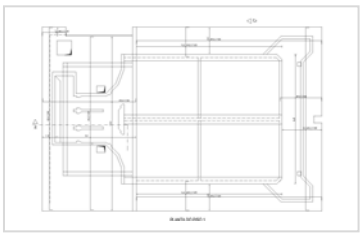
Building description and current situation

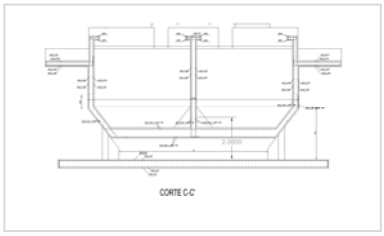
The Pre-Treatment building, rests on a set of 8 reinforced concrete piles with approximately 34.9m length and 0.60m diameter, interconnected by a pavement slab with an area of 20.30x12.90m2 and 0.40m thick, reinforced with beams embedded inside. The piles discharge (tip resistance) in a layer of medium and fine sand of low compactness. In the design, the lateral resistance of the pile was not considered due to the clayey nature of part of the lower strata, as classified after to the surveys and geological studies that preceded the design of construction works.

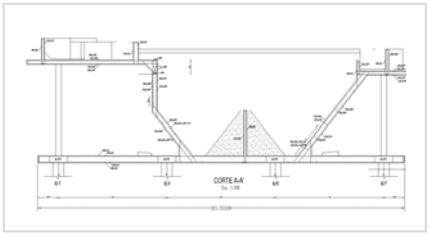




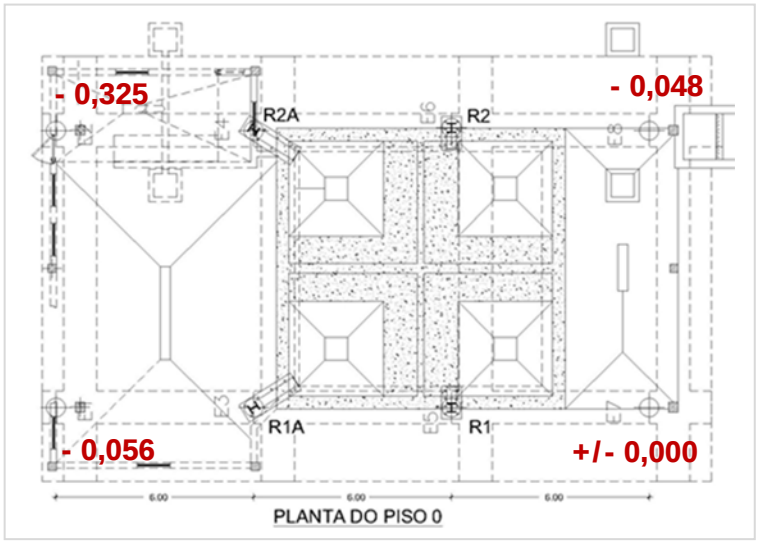








In order to assess the existing unevenness resulting from the differential settlements of the structure, with the support of the head of the WWTP, Mr. Cláudio and auxiliary staff, a survey was made of the levels of the pavement of Floor 0. As can be seen in the figure shown next, there is a visible slope in the direction of the corner of the pipe inlet. The unevenness occurs in the direction of the 3 corners of the pavement, being significantly more accentuated precisely in the corner where the aforementioned pipe is discharged, with a difference of 0.325 m in relation to the diagonally opposite corner, taking the reference point as +/- 0,00.



In a way, these movements of the structure can be considered as being a global rotation of the structure, having clearly set (-) in the area of the discharge corner of the pipe (-0.325), showing some signs of superelevation (+) in the area of the corner assumed as a reference (+/- 0.000), located diagonally in the opposite corner.

The aforementioned unevenness is due to the combination of two factors: the global settlement and rotation of the structure and cracks at different points of the pavement slab and the interconnection of foundation pile cups, as can be seen in the photos below.






The superstructure of the Pre-Treatment Station, namely, the walls of the tanks, present micro-cracks in some points, which can, however, be stopped by waterproofing, after the foundations have stabilized. In the first sample of photographs (page 1, last photo) one of the points with these characteristics is presented.

Preliminary conclusions

In summary, and based on our visual assessment, from the analysis of structural drawings and geotechnical studies, as well as from the reports of the personnel working at the WWTP, we now present the following preliminary conclusions on the causes and current situation of the Pre-Treatment Station:

> Note: the conclusions presented below, have as principle the combined action of the various effects simultaneously or alternately, however, concurrent to the worsening of the equilibrium status of the structure.

1. The occurrence of cracks on the pavement slab, at various points and at different periods, starting at the beginning of the activity and testing phase of the equipment seems likely, and according to witnesses it will have had occurred. With this weakened equilibrium element (slab), which should offer greater resistance to the reaction of the different piles, the probability of the occurrence of differential settlements is high, as it turns out to be the case.
   These points of cracks in the slab, with the acting of the self-weights and overloads, on the one hand, and on the other, the differential settlement of some of the most loaded piles, allowed the slab to rotate, resembling an inflection point, resulting in added unevenness.
   Assuming that the floor slab, together with the superstructure of the tanks, provide sufficient rigidity, for the structure to rotate slightly as a whole over time, due to the larger settlements.

2. With regards to other buried pipes of the WWTP, at the connection points with the buildings (based on piles), due to the general settlement of the landfill, roads, ditches and consequently of the pipe, and, being these connections rigid, the rupture of the pipes at these connection points is practically inevitable and widespread. Repairs to these piping rupture points were being improvised with the use of fiberglass, although with a limited duration.
   On the other hand, these pipes impose an additional load (before the rupture occurs) on the structures of adjacent buildings or boxes, such as access boxes and valves. This situation happened in the pipe main inlet to the Pre-Treatment building, having been aggravated by the volume of flow transported (large diameter), and by the fact that the flow is forced by the electro-pumps from the EE4 Pumping Station. Hydraulic phenomena, such as the “hydraulic shock” associated with starting and stopping of the electro-pumps, and the vibration induced by the flow, accelerate the densification and compacting process of the soils underlying the pipe, inducing additional forces to the supports and curves of the pipe adjacent to the Pre-treatment building.
   Therefore, there is a transfer of static and dynamic forces through the main duct, directly on the building, which is already weakened in terms of the balance of the pavement slab and pile Cups, as mentioned previously.

Recommendations

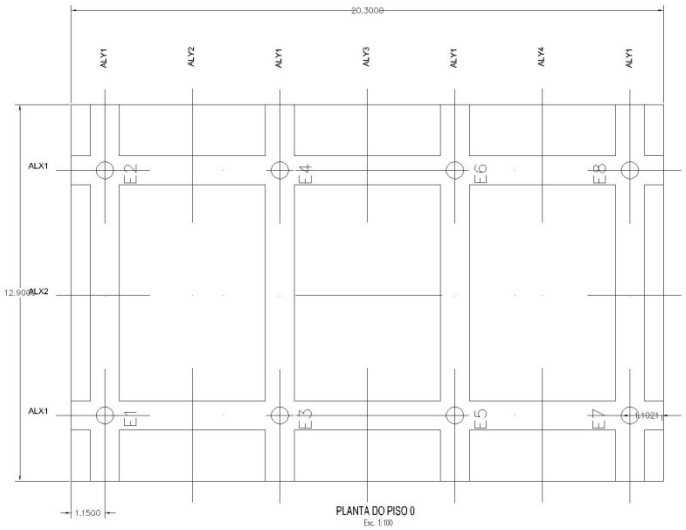
An internal inspection of all units (under empty condition – to be done concurrently) is recommended in order to ascertain whether the bottom and walls have been affected by the observed settlements.

The reinforcement of the foundations and the connecting elements of the piles, at the level of the pile cups, currently performed by the pavement slab, becomes essential, given the advanced status of collapse in which the structure is.

To reinforce the foundations, over the piles, different technological solutions can be studied, although due to the length (approx. 35m) and availability of specialized equipment in the Country, the use of piles identical to those previously used, molded in-situ, in principle, seems, suitable.

It is suggested to reinforce the existing piles (8 units), with the introduction of new intermediate piles (6 units), implanted outside the perimeter of the pavement slab between the 4 axes transversal axes ALY1, in the intermediate zones ALY2, ALY3 and ALY4.

These 6 new piles would be connected by equilibrium beams designed for this purpose, which would cross the pavement slab on the axes Y2, Y3 and Y4, and two other beams that would run on both sides in parallel with the axes ALX1, at a minimum distance of the slab ends, depending on the pile driver equipment to be used.



The operation of pre-leveling the structure as a whole, may be better decided later, depending on the costs involved in the operation, as well as the risks of introducing new loads in the structure, since it will be necessary to partially lifting (or lowering) the structure, with the help of large capacity hydraulic jacks.

However, levelling the structure by lifting it as a whole seems to be risky and an expensive operation. Providing the structure is previously repaired for any existing damages (fractures

and leakages), it will be possible to level the top of the walls and hydraulic weirs by using high resistance cement mortar.

This measure will only be justified, if the specialists of the equipment installed in the Pre-Treatment Station, consider it mandatory for the perfect functioning of this equipment or the pre-treatment process.

An economical solution for leveling the structure of the building as a whole, which can be considered, and better studied, would be the application of designed overloads specially placed on the opposite sides to the side with greater settlement / unevenness, in order to load the structure and precipitate eventual settlements, with measurement and control of displacements over time (displacement gauges), in order to minimize the unevenness currently existing.

In addition to the reinforcement of the structure, it is also recommended that the support for the discharge of the main pipe, with connection to the EE4, be disconnected (independent supports) from the building structure, and, that flexible supports are introduced to absorb the stress transmitted by the flow under pressure and hydraulic phenomena resulting from the interruption-start of the lifting pumps.

Independent support aimed to avoiding the transfer of loads to the building, caused by the gradual settlement of the pipeline, a situation that also occurs with the remaining pipeline reticulation within the WWTP.

1. Permanente works to be considered in the Master Plan, for a solution to be carried out by the contractor, in the contract model Design and Build"

The selected contractor – Design and Build – Yellow Book must follow the following methodology, among others to be proposed:

1.1 Survey and accurate measurement of all levels, including the lower area of the pavement slab, considering that the water table is between approximately 1.3 and 1.7m deep, depending on the season and rainfall.

1.2 Carry out of at least 2 (two) tests to identify the strata with sufficient capacity to be used as a tip reaction for the new **piles (6 units).**

1.3 Detailed design the reinforcement to the foundations and pavement slab, for approval by the Supervision Team and Owner, with presentation of the respective execution costs.

2. Immediate options for the operation of the WWTP in an emergency and transitory situation, until the execution of a definitive solution (previous)

2.1 According to information from the WWTP staff (to be confirmed by Luis), the WWTP will be able to operate at around 80% of its efficiency in the treatment of waste water, without the use of the Pre-Treatment Station, and with the introduction of a system of steel grid made locally in the City of Beira, for the reduction and selection of solid waste, and, the flow from EE4, to be discharged directly to the Anaerobic Reactor station.

2.2 The described structural conditions of the preliminary treatment units have certainly caused an uneven situation in the top of the walls resulting in misalignments of the mechanical equipment and consequent damage/malfunction of same.

In addition, the hydraulic operation of the units is affected as discharge weirs are not even and consequently "preferential currents" occur.