Ferrocement Applied On Water And Sanitation

Ferrocemento Aplicado Al Tratamiento De Aguas Residuales

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ABSTRACT

The use of ferrocement on water and sanitation units had its higher application on Minas Gerais State of Brazil. The structure made by FRP together welded steel fabrics constituent the reinforced of cylindrical tanks. Since 1993 these tanks were arranged to serve communities in form of Potable Water Treatment Plants (ETA in Portuguese) and Wastewater Treatment Plants (ETE in Portuguese). A financial feasibility study carried out comparing the costs of units on ferrocement and reinforced concrete in a flow rate of 12 and 24 L/s and proved the saving from 50% to 60%, showed in the paper. An ETA have a classic hydraulic concept composed by flash mixing camera, flocculation, sedimentation and filtration. Since 1998 were developed wastewater treatment plants with a reactor UASB with volume until 400 m³ for flow up around to 30 L/s with efficient of 80% of removal of organic load. The construction is showed step to step on the paper. Finally, is showed a future project of a ferrocement rain water collector in form of hyperbolic paraboloids connect into a roof of a tank to reserve this precious water. The water supply service and sewage treatment on smaller villages and municipalities can take on ferrocement a promising material.

Keywords: *Ferrocement, Potable Water Treatment Plant, Wastewater Treatment Plant, Structural Analysis.*

RESUMEN

El uso de ferrocemento en unidades del agua y saneamiento tuvo su mayor aplicación identificada en el estado de Minas Gerais de Brasil. La estructura hecha por FRP híbrido con esqueleto de acero soldadas constituye el refuerzo de los tanques cilíndricos. Desde 1993, estos tanques fueron dispuestas para servir a las comunidades en forma de Estaciones de Tratamiento del Agua Potable (ETA) y Estaciones de Tratamiento de Aguas Residuales (ETE). Un estudio de factibilidad financiera realizado comparando los costos de las unidades sobre ferrocemento y hormigón armado en un caudal de 12 y 24 L/s y comprobó el ahorro del 50% al 60%, expuesto en el documento. Una ETA tiene un concepto hidráulico clásico compuesto por cámara de mezcla rápida, floculación, sedimentación y filtración. Desde 1998 se desarrollaron plantas de tratamiento de aguas residuales con reactor UASB con volumen hasta 400 m³ para caudales hasta 30 L/s con eficiencias del 80% de remoción de carga orgánica. La construcción se muestra paso a paso en el estudio. Finalmente, se muestra un proyecto futuro de un colector de agua de lluvia de ferrocemento en forma de paraboloides hiperbólicos conectados a un techo de un tanque para reservar esta preciosa agua. El servicio de abastecimiento de agua y tratamiento de aguas servidas en los pueblos y municipios menores puede asumir el ferrocemento como un material prometedor.

Palabras claves: *Ferrocemento, Tratamiento del Agua, Tratamiento de Aguas Residuales, análisis estructural.*

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1. INTRODUCCIÓN

This paper would like to contribute showing the experience of application of structures on ferrocement in the Company of Water and Sanitation of the State Minas Gerais – Brazil during three decades building hundreds of water treatment plants, wastewater treatment plants and water tanks with low costs and at all regions of the state [1].

The structure can be made by FRP or metal wire or both, mixing a welded metal wire and a tiny FRP web (see FIG. 1). The use of a metal wire in the middle and two layers on both sides it will higher the tractive module within minimum volume factor [2]. In these tanks the FRP have the advantage that the water doesn't corrosion. The geometry of all ferrocement tanks is cylindrical or hemispheres. Where FRP tiny mesh could be used with simplicity and to attended the ferrocement parameters of superficial specific. Included the project the tubes that connecting between all tanks are on PVC coated by ferrocement, whose protect the plastic for sun UV radiation and the PVC protect the cement for the gases of water in treatment. The valves used were normal in iron or plastic with compatible diameter.

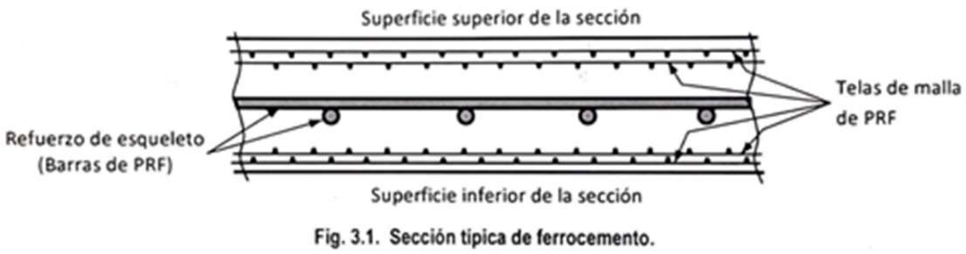

Figure 1 A typical ferrocement section using welded steel fabrics and FRP mesh fabrics

Source: Adapted from WAINSTOK RIVAS; HERNANDEZ CARNEIRO; DÍAZ PÉREZ, 2018 [2]. p.154.

The State Minas Gerais is known a hilly landscape who's the difficulty it's perfect for ferrocement treatment plants. That have different levels one to flocculation and decanter and other to filters and filtered water tank bellowed by a pump house to elevate the treated water to the necessary ground height to distribute to the city or village.

The same image you can mind for the wastewater treatment plant. The sewage net is project on gravity force in its end is on the low level near the river area. In this point a wastewater pump house to elevate to another place where be save to constructed the WWTP. Whose will Include a UASB reactor in modules with capacity 250 m³ or 400 m³ followed by rock filter and finally a surface flow like a third phase of treatment.

A special attention with the protection of the inside surface of wastewater treatment plants cover [3]. Above the water line are formed gases like hydrogen sulfide who's reacting highly and deeply with the cement and the iron making a powder of the structure. The solution is separate the gases from the structure by a polymer. Some materials were be testing like PRVF applied inside under face cover (Hight difficult process) and modified polyurethane applied with airless and other products will be testing.

2. FINANCIAL FEASIBILITY STUDY OF POTABLE WATER TREATMENT PLANT

A financial feasibility study carried out by Bonifácio, Sidney, Silva and Moreira (2018) [4], achieve the results showing a saving from 50% to 60% on the costs of potable water treatment plant on ferrocement comparative with reinforced concrete with a mean flow rate of 12 and 24 L/s (see FIGs. 2 and 3), sufficient to serve a population of 6,000 and 12,000 inhabitants, respectively.

Figure 2 Water Treatment Plant in Ferrocement (flow = 12,0L/s) Pingo d'Água-MG, 1993.

Figure 3 Water Treatment Plant in Ferrocement (flow = 24 L/S) Guimarânia-MG, 2017.

In Minas Gerais, Brazil, the first Potable Water treatment Plant (ETA acronyms in Portuguese) using ferrocement as constructive material dates from 1993 [5].

An ETA have a hydraulic concept on classical type (see FIG. 4), described below:

Flash mixing –
A cylindrical unit where can the raw water arrives divided by a flat vertical septum with a triangular weir that promote a measure of the inflow and a waterfall for the flash mixing. The coagulant/ flocculant aluminum sulfate or ferric chloride is injected at this point. Eventually it is necessary addiction of lime to adjust the incoming water.

Flocculation –
Hydraulic flocculation was used composed by cylindrical chambers interconnected with conductors terminated in 90-degree elbows which put up the water. The water moves from a chamber to another through passages located at the button of chamber that return the water making a continually mixing.

Sedimentation –
A cylindrical shaped with a depth 1.50 m only. The flocculated water is introduced into a center cylindrical chamber with circular holes which distributed to entire tank. The decanted water is collected through around all border circumference of the sedimentation tank.

Filtration –
They are four cylindrical units on ferrocement arranged in parallel which operate as a self-washed system. To washer one filter use the water filtered by the three remaining units. Their filtering bed is double-type consisting of anthracite layer coal installed over a sand layer which goes over a gravel layer. There are only two valves in each filter, one inlet and other wash water valve.

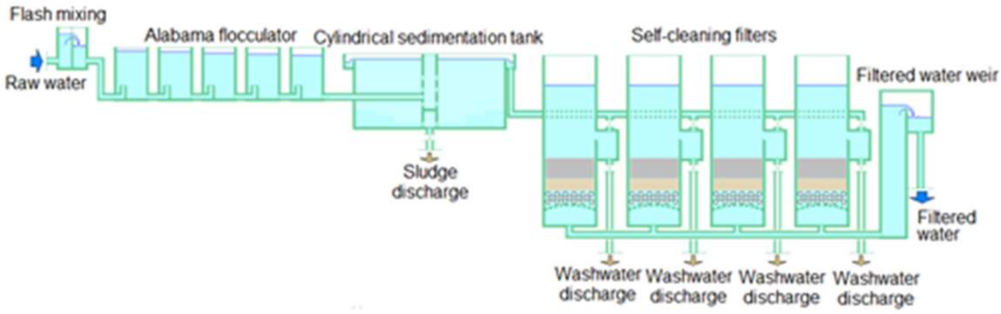

Figure 4 First conception of ETA on ferrocement.

Costs for construction processes

The comparation of use ferrocement structures and reinforced concrete (see FIG. 5) in the manufacture of a ETA with flow rate of 12 and 24 L/s will show for analysis and critical comparison.

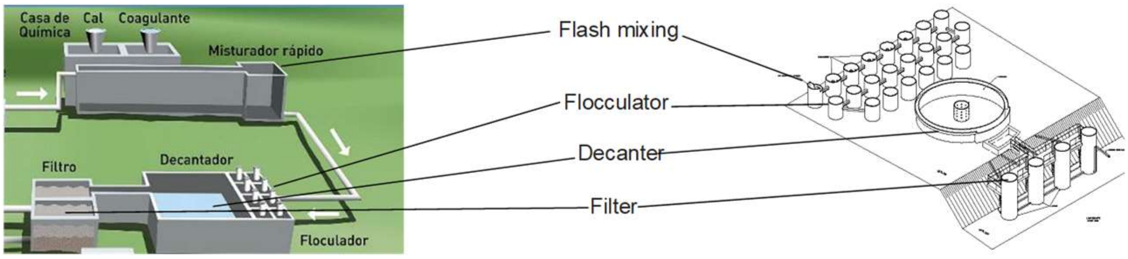

Figure 5 Comparation a Potable Water Treatment Plant in reinforced concrete and in ferrocement

Two budgets based on values of inputs and services generating the data described in table 1, below:

Table 1 - Service Description and Costs

Service Description	ETA 12 L/s		ETA 24 L/s	
	Ferrocement (US$)	Reinforced Concrete (US$)	Ferrocement (US$)	Reinforced Concrete (US$)
Earth Moving	561,11	2.954,74	1.121,87	3.115,55
Foundations and Structure (1)	37.824,45	47.202,97	47.411,89	66.482,84
Settlements	2.558,32	19.063,89	3.841,83	18.225,96
Miscellaneous Services (2)	26.535,58	21.512,08	31.602,17	56.081,29
Materials (3)	7.289,06	61.903,55	10.749,95	97.181,79
TOTAL (4)	**74.768,52**	**152.637,24**	**94.727,71**	**241.087,43**

Source: BONIFÁCIO; SIDNEY; SILVA; MOREIRA, 2018 [4].

(1) In the foundation item, it was considered a direct foundation in both projects.
(2) The building elements such as electricity, water and sewage, landline, cell phone, internet, office supplies and surveillance company during the execution period were considered within the miscellaneous services item.
(3) In the item "materials" are considered the elements such pipes and connections.
(4) The workforce was considered within each specific item because it deals with basic items of construction of the structures.

Is possible to verify that the use of ferrocement structure it is possible to obtain a saving of 50% to 60% in the value when compared to the use of reinforced concrete.

3. WASTEWATER TREATMENT PLANT

At Minas Gerais Brazil, since 1998, UASB reactors have been built for Wastewater Treatment Plant (ETE, acronym in Portuguese), in modules for flow rates of up to 30 L/s with efficiency of 80% of removal of the organic load BOD [6].

The anaerobic reactors of 400 m³, built in ferrocement, are in cylindrical form with 4.60 meters of external height and 10.00 meters of internal diameter. The walls have a thickness that varies from 3 to 8 cm.

The structural analyses are showed on Figures 6 and 7.

The steps of construction are carefully explained on Figures 8 to 15, below.

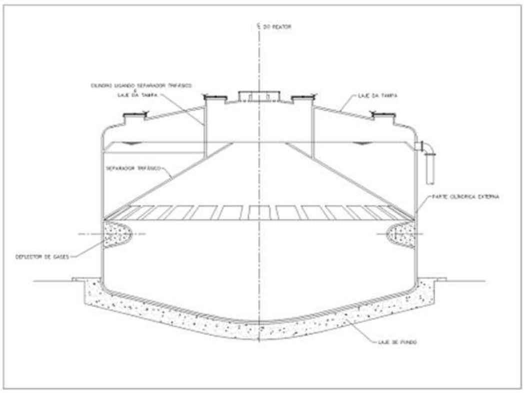

Figure 6 UASB Reactor - Typical Cross Section (2018) [7].

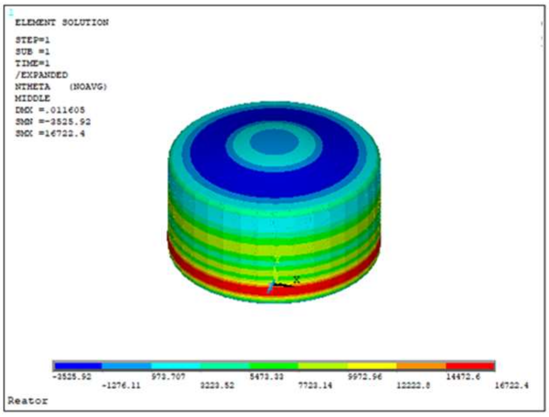

Figure 7 UASB reactor – Circumferential Membrane Force Nθ (2018) [7].

Figure 8 Execution of the reinforcement of bottom slab on ferrocement (2021).

Figure 9 Execution of the reinforcement for ferrocement (2021).

Figure 10 Application of mortar on the inner side of the wall (2021)

Figure 11 Application of the second layer of mortar on the external side of the wall (2021)

Figure 12 Cement curing water (2021)

Figure 13 Working inside the reactor tank (2021).

Figure 14 Application of FRP in the gas chamber (2022).

Figure 15 Installation of guardrails and access ladder to the reactor UASB (2022).

The internal surfaces received a crystallizing and waterproof cementitious mineral coating to protect surfaces in contact with wastewater. For the covering slab in contact with gases from anaerobic digestion, coatings were researched: high thickness with polyurea systems and polyurea / polyurethane hybrids; or based on polymeric silicate and for the ETE on this study, was chosen vinyl ester resin reinforced with fiberglass applied to the ferrocement substrate.

The construction cost of each UASB reactor in ferrocement for the ETE was US $ 126,765 in 2020 [6].

4. FUTURE PROJECTS – A FERROCEMENT RAIN WATER COLLECTOR

A project to building a rain water collector in ferrocement supported by the cover of an underground tank. The tank cover has a cone form and the roof slab is a combination by two hyperbolic paraboloids, “hypar” (see FIGs 16 and 17). The connect between the roof with the cone and the real behavior are being studied.

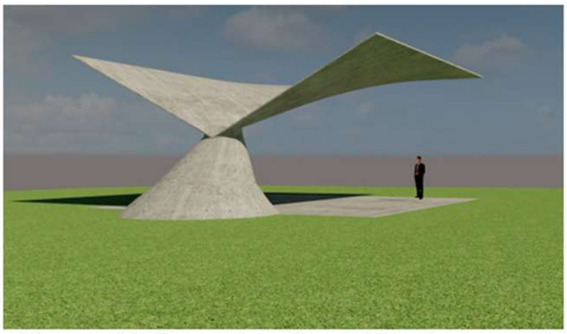

Figure 16 Computer view of the ferrocement rain water collector [8].

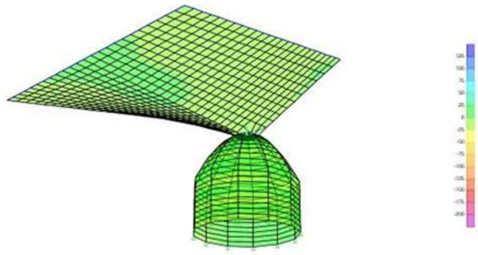

Figure 17 Study of structural analysis of the ferrocement rain water collector [8].

5. CONCLUSIONS

The largest deficits in developing countries of potable water supply services and sewage treatment persist in municipalities with smaller populations. According to the Brazilian Institute of Geography and Statistics - IBGE, in municipalities with a population of less than 20 thousand inhabitants, about 44% of the Total, located in urban and rural areas, are excluded from water supply services and 70% from collection of sewage.

Ferrocement is therefore a promising building material for sanitation managements as it is an appropriate technology for the construction of different sanitation units, like Sand Filters and other tanks. The efficiency of the applicability of these solutions can also be emphasized that the use of ferrocement technology promote the diffusion of information (how to construct) in a democratic way, thus contributing, to overcome difficulties of poor populations in the construction of Potable Water Treatment Plants – ETA, Wastewater Treatment Plants and Water Tanks, an equation to solve a social and environmental issues.

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