Museum of Tomorrow. The possibilities of the future of construction

Get to know the details of the architectonic project of Santiago Calatrava, an astonishing futuristic building.

EDITORIAL

Hello, dear reader!

This edition has a little historic taste for us.

We can be proud to be a part of one of the most astonishing global architectural constructions, projected by the creative hands of the *catalão* Santiago Calatrava, the Museum of Tomorrow.

The use of a high performance concrete in the project consecrated the most advanced technology of this moment for projects that demand high sustainability and resistance levels: the Active Silica.

For us this is a new breath in the development of products that transform the entire concrete chain and reduce the environmental impact in the civil construction sector, diminishing costs and aggregating durability.

I am sure that you will be impressed with the project and with the efficiency of the materials used. You can invest a few minutes in our reading and you won't regret.

And don't forget: if you want more details on Tecnosil solutions, we are pleased to receive your contact information. It's easy: access www.silicon.ind.br and www.tecnosilbr.com.br

Have a nice reading and a big hug.

JOÃO PAULO F. GUIMARÃES
President of Tecnosil Group

Museum of Tomorrow.

One of the most modern Brazilian constructions, with the Tecnosil brand.

Launched in 2015, in Rio de Janeiro, the Museum of Tomorrow was designed along with the urban remodeling around Praça Mauá Square and with the re-qualification of the city's harbor area. All of its surroundings benefited with free spaces and unobstructed views thanks to the Perimetral demolition.

A project that parts from a sculptural assumption, in conformity with the character language of its collection of works: the museum is surrounded by water mirrors, traffic paths for cyclists and pedestrians, and even a green area with typical species of the Atlantic forest.

Superb dimensions with an exceptional architectural language.

The Museum of Tomorrow is already considered a new icon of the Brazilian architecture and it explores the possibilities of the future of construction. Its concept embraces the stringency of science and the expressive language of the arts, having technology as a support, in immersive environments, audiovisual installations and games.

It is an experiential museum in which the content is shown sensorially. The establishment examines the past, shows the trends of the present, and explores the possibilities of the upcoming 50 years in regard to sustainability and cohabitation.

Virtuous and asymmetrical curves among themselves combined with automated sophisticated mechanisms.

Another feature is the mobile coverage of the building,in which large steel structures serve as base for the plates that capture solar energy. Throughout the day, they move themselves like wings to follow the sun's position. The project also values the entry of natural light.

The program

Under general direction of the Roberto Marinho Foundation, the museum has Luiz Alberto Oliveira as the curator of the Physics and Doctor in Cosmology, artistic direction of Andrés Clerici, and museological concept of Ralph Appelbaum.

The future and present interlinked into only one structure, in which Tecnosil had the privilege to contribute.

>Find out more about Santiago Calatrava.

Born in 1951 in Valencia (Spain), Santiago Calatrava graduated as an architect at the Polytechnic University of Valencia and as an engineer in Zurich, in Switzerland. Worldly known and awarded, he is the author of the

Olympic Stadium of Athens, where the 2004 Olympic Games were disputed, and of a lot of other famous works.

Project of the Spanish architect Santiago Calatrava in partnership with the Ruy Rezende Architecture office.

Brazilian technology in a global visibility project.

>Brazilian technology in a global visibility project.

The configuring principle of the Museum of Tomorrow, which features its dual scale, is a great enclosure that contains a linear sequence of small exposed nucleus in the central ship of the second construction pavement.

Since it is partly implemented over the sea and partly over the land, thus in porous land, its construction demanded the reinforcement of the pier's foundation, by inserting metallic piles with special anti-corrosive treatment and root-piles, capable of reaching great depths.

Structurally, the project is composed by two interconnected sets, of symmetric geometry, the metallic coverage and the concrete enclosure that sustains and seals the museum. They're both designed and measured with high level of complexity.

Sustainability is one of the guidelines here.
The water from the Guanabara Bay is captured to supply the water mirrors and for the cooling system. After being used for air conditioning, the water is returned to the ocean and it is cleaner.

A bold project that counted with high performance products.
Meeting the demands of the creation of the Museum of Tomorrow was quite a challenge. An engineering boldness that Tecnosil was proud to be a part of, providing a high performance concrete (CAD) with the addition of the Active Silica, which a less permeable solution, and thus, more resistant to several chemical attacks. The application of the extremely thin particles of the Active Silica densifies the cement paste and reduces the porosity of the concrete even more, thus increasing its lifespan and improving the physical properties of the concrete.

Active Silica: great ally that increases the durability of concrete structures.

The more factors that can facilitate in the input of aggressive agents in the concrete mass, the greater will be the deterioration of the material. Thus, the Active Silica technology was the most recommended in the Museum of Tomorrow, because it reduces porosity and brings improvements in the concrete's ability to support the destructive effect of aggressive agents (water, oxygen, carbon dioxide, chlorides and gas solutions).

Check all of the advantages with the use of Tecnosil Active Silica:

>Power and CO_2 consumption reduction.
>Natural resources savings.
>Increase of concrete's lifespan.

>Better performance of abrasion and erosion;
>Low permeability, porosity, and absorption.

There were 55 thousand tons of structural concrete that counted with the Tecnosil innovation by giving way to one of the largest architectural works of the Americas and by offering to the world a new look on the future.

Know more about Active Silica *It is a thin pulverized powder derived from the manufacturing process of the metallic silicon or silicon iron. Its particles are spherical, glassy, and has an average diameter lower than 1 µm, with extremely high specific surface and an apparently low specific mass. The high content of SiO_2 in the amorphous shape, together with high fineness, provides very high reactivity with products derived from cement hydration, giving better performance in concretes and mortar.*

Technical File

Constructed area 15,000 m^2
Architecture Santiago Calatrava
Foundation Roberto Marinho - Hugo Barreto and Lúcia Basto (general management)
Curator Luiz Alberto Oliveira
Concrete consultancy WG Corrêa
Museum Plan Expomus
Construction Porto Novo Dealership

MUSEUM OF TOMORROW

TECHNOLOGY OF CONCRETE APPLIED TO THE MUSEUM'S PROJECT.

SPECIAL CONDITIONS OF THE CONSTRUCTION

1. FOUNDATIONS

The building of the Museum of Tomorrow was build at Mauá Pier, which advances into the offshore and was projected and built by the Danish company Christiani Nielsen, in the 50s.

Due to existing issues in the pier's structure, a construction of new foundational blocks was necessary over the existing reinforced concrete slab, buried approximately 1.5 m beneath the pier's floor level.

For such, a substrate treatment was specified for the solidarization of the old concrete with the new concrete of the new blocks that were built over the crimped metallic piles, resulting in the building structures of the Museum being seated over these new foundations, totally independent from the current pier.

In order to assure the durability of this foundation, the concrete of the blocks and buried pieces were considered as being subject to an aggressiveness mean of class IV (very strong), according to the classification of the NBR 6118 norm, limiting the minimum thickness of the armor's coverage to 45 mm.

The guidelines for the composition of this concrete were in order to specify the use of the Portland cement type RS, fck of 40 MPa, maximum water-cement relationship of 0.45 and minimum cement consumption of 360 kg/m³, with the addition of 8% of active silica, in relation to the cement's weight.

The treatment of the old existing concrete in the buried slab of the pier, prior to the release of the new concrete of the piles crowning blocks, the increase of superficial roughness of the concrete was constituted, through a water jet, cleaning of detritus, saturation of the old concrete and application of trace 1:3 mortar of cement and sand, with 8% of micro silica and a/c < 0.5 relation by the whole surface.

2. WATER MIRROR

In the project of the Water Mirror structure, the employment of a concrete with high impermeability level was specified, as well as an armor against the crack deriving from coercion traction tensions and the execution of impermeable construction joints.

In order to obtain a greater impermeability level in the concrete of the walls and at the bottom of the Water Mirror, it was suggested that the concrete mix was done in a differentiated manner, resulting in a concrete in which the cement mixed with the coarse aggregate would be more perfect, producing better resistance to traction and a greater impermeability level.

Besides, other requirements for this concrete was the use of the active silica and the total water consumption limitation in the 180 t/m³ concrete.

3. SUPERSTRUCTURE

In the superstructure concretes a concrete was specified which would present a homogeneous aspect with an excellent aesthetics quality and final tonality which would be the brightest possible, without the use of white cement.

Preliminary technical studies and analyses were performed from tests results executed over testing bodies and prototype parts, for the performance evaluation of all concrete features of the superstructure regarding the conditions listed above, parts which were selected according to the orientation and suggestion of those responsible for the structural project and for the architecture of the Museum of Tomorrow.

Examples of the parts are shown in the figures below.

In the definition of the concrete features, in view that the superstructure would have had direct contact with the ocean water, it was admitted for these structures that the environment's action would have an aggressive class of type III in the Brazilian norm NBR 12655.

In the specified features, the employment of the Portland cement type RS was established, having the fck of 40 MPa of wall slab concrete and beams, while the fck columns was of 50 MPa, limiting the maximum water-cement relation to 0.55 for the armored structures and 0.50 for the pres tressed beams, with minimum cement consumption of 320 kg/m³, with the 8% addition of active silica, in relation to the cement's weight.

Besides, concrete plans were established to avoid concrete joint marks of being spotted, segregation spots, bubbles, stains and tonality changes of the concrete in the apparent structure surfaces.

4. CONCRETE OBTENTION WITH HIGH IMPERMEABILITY LEVEL

A very important aspect taken into consideration in the project of the Museum of Tomorrow, due to its location and with a foundation immersed in a groundwater of very aggressive features, was the specification of concretes with high impermeability level, specially pertaining to the construction joints and the absence of cracking.

For this, the production of concretes that met the following conditions was needed:

- a special composition (dosage), toward a careful dosage of the materials composed in the concrete, with the addition of products that would increase its impermeability, such as, the active silica;
- concrete mix was done in differentiated conditions;
- care in the execution of the structures to reduce the retractions of hydraulic and thermal origin.
- measurement of an armor to combat the coercion tensions deriving from volumetric deformities of the concrete, which are restricted by the foundation or by an already toughened structure.

Regarding structures subject to these conditions, it is crucial to avoid the concrete cracking of the structures that will be in touch with the water under pressure, due to the restricted volumetric deformities, which aren't usually made, thus in this case it is necessary that the opening of cracks is limited into 0.1 mm at most.

The Brazilian norm NBR 6118, regarding the cracking of the structures, considers that the cracks with opening of up to 0.2 mm do not have the least importance for the safety and durability of the structures.

This consideration is not applicable to structures for which any water percolation and other fluids are inconvenient, specially when these fluids are harmful to the concrete.

Taking into account that there are countless cases of wall structures that show generalized cracking, a measurement criteria has been adopted by countless structural projectionists for the horizontal armors, which minimize or even avoid this cracking.

5. IMPERMEABLE CONSTRUCTION JOINTS

It is pointless for the structures to be executed with high impermeability level concrete if the construction joints necessary for the execution of these structures permit the water percolation through them.

There are currently several devices to make the construction joints impermeable, the hydrophilic tape being the most used device diffused in our constructions.

6. FINAL OBSERVATIONS

This grand project, whose construction was recently finalized, can thus be considered a construction example in which all of the technical details were appreciated with proper care, by the technology consulting company of concrete WGCorrêa Consultoria de Engenharia Civil Ltda, as with how a structure of this type must be done.

The operation and specification of products and adequate constructive techniques, all the way from the project phase, had the objective to obtain a structural concrete which could present the best aesthetic and durability qualities within the mean in which the construction is inserted.

W.G.CORRÊA CONSULTORIA DE ENGENHARIA CIVIL LTDA.
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Active Silica: the best prevention against the Aggregated Alkali Reaction (RAA).

The aggregated-alkali reaction affects a big number of civil construction projects. In case of moderate damage, the periodic monitoring and the maintenance of the concrete structures favor the pathology control. In the most severe cases, the replacement of affected elements is needed due to the compromise of mechanical properties of the concrete.

And what makes concrete more durable? It depends on the concrete's ability to resist the chemical, physical, mechanical, and environment's biological aggressions for which it was projected or the internal mechanisms of the actual concrete.

Among the chemical aggressions there are the ion attacks by chloride and sulfate, carbon dioxide, acid attacks, and the alkali-aggregated reactions (RAA). This last one only occurs when there is the sum of three factors: the presence of reactive phases in the aggregate, enough humidity, and, at last, the concentration of alkaline hydroxide ($K+$, $Na+$, OH^-) in the solution of the concrete pores sufficient to react with the reactive phases of the aggregates.

(include RAA photo attacking the concrete)

Of all preventive measures for the employment of reaction aggregates in civil construction projects, the use of active silica is one the most efficient because it significantly reduces and controls the deleterious expansion related to the alkali-aggregate reaction in the concrete.

(include graphics and cite source: "Eng. Flávio André da Cunha Munhoz. Efeito da adições ativas na mitigação das reações sílica e álcali-silicato, tese de mestrado, São Paulo, 2007.")

The addition of contents between 5 and 8% - of the Tecnosil Active Silica in relation to the cement's weight - improves the features of concrete and mortars, either in the fresh state as well as when hardened, providing:

- Cement consumption reduction;
- Better performance, inhibiting chemical aggressions, chloride ions penetration, RAA;
- Low permeability, porosity, absorption;
- Greater mechanical resistance;
- Better paste/armor and paste/aggregates adherence;
- High resistance to aggressive environments;
- Lower reflection index in projected concretes;
- Larger application thickness on projected concrete;
- Increases cohesion;
- Reduces exudation;
- Better performance against abrasion and erosion.

(subtitle)
The benefits of the Active Silica in the improvement of rheology.

The good quality active silicas, such as Tecnosil's - when about 3% to 10% over the trace's cement weight is used - decrease the porosity and permeability, and favor the increase of mechanical resistance against the compression, the elasticity module, and the resistance to the decay or abrasion of concrete surfaces that exposed in these efforts.

In the specific case of the Museum of Tomorrow, the employment of Tecnosil Active Silica was the ideal solution. For being located at an area subject to strong action of the sea air, which harms the durability and resistance of the concrete, the Active Silica actively acts with the alkaline hydroxides dissolved in water, thus neutralizing the alkali-aggregate (RAA) reaction and ensuring greater lifespan of the concrete.

According to Eng. Ronaldo Tartuce, we can just know the features of the cements and study the amounts of necessary Active Silica for us to execute a correct RAA mitigation.

TECNOSIL HAS THE SOLUTION THAT YOU SEEK.
JUST TALK TO US.

A partnership which is helping transform all of the concrete chain to technically and economically adapt to the new norm of the NBR-6118 which values the durability and mechanical resistance as one of the most important requests. Our work is focused in the supply of high aggregated valued products for the feasibility of the High Performance Concrete (CAD), actively participating in the technological development with their partners and clients.

TO REQUEST AN EVALUATION VISITATION OF YOUR PROJECT AND THOROUGH BUDGET ACCORDING TO YOUR NEEDS, PLEASE TALK TO US.

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TECHNICAL FILE