CONCRETE STRUCTURE DESIGN AND CONSTRUCTION AT 4,000 METERS ABOVE SEA LEVEL

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ABSTRACT. In the state of Puebla is located a hill called "La Negra" and it is the place chosen to construct a Millimeter Radio-Telescope, the biggest one in the world. The hill corresponds to a volcano system 4,000 meters above sea level and it takes part of the "Faja Volcánica Trans-Mexicana" that goes through the central part of the country from east to west. This place was chosen because it attends to the equipment operation needs, which are defined according to the location and atmospheric conditions of the installation. The final selection was decided after analyzing more than one hundred different places around the world. The millimeter radio telescope has a concrete base that houses an operations building and a dish aerial with a maximum diameter of 50 meters. The equipment base was built over a reinforced concrete structure that is placed "in situ" with an altitude of 4000 meters above sea level. The atmospheric conditions have different temperatures from –5 to 25 °C, cycles of humidity and drying with relative humidity over 60%, wind velocity between 5 and 10 m/s, maximum 14 m/s. The mix was designed reviewing the specific mechanical requirements and the conditions of the place where the mix was to be produced, with a controlled temperature no lower than 10 °C to accomplish the specified properties. To satisfy the concrete rules it was necessary to modify the production plant of concrete to guarantee total control over the mix temperature when fresh and obtain the required hardened properties.

Keywords: Radio-telescope, Placing, Production, Extreme conditions, f'c, Control mix, Temperature.

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INTRODUCTION

In the state of Puebla, México, is located the highest hill of the country with a maximum altitude of 4600 meters over the sea level and also placed in the central part of the Mexican territory belonged to the "Faja Volcánica Trans-Mexicana" fisiographic province, it contains the biggest Millimeter Radio-Telescope (MRT) in the world with a receiver frequency plate with 50 meters diameter. The selection of the place included to analyze and review of 160 different places in all over the Mexican country, also this place was chose among hundred different places, from these different places was very important to find good conditions to have more hours of viewing without any interference of the waves that sometimes appear in this kind of equipment; the important conditions to take decisions are: environmental humidity, wind velocity, Clear days, variety of temperature, etc. This place does not have any infrastructure, so it is necessary to develop all processes to manufacture concrete in an industrial way.

The MRT corresponds to an international project with the participation of different countries like: The United States Of America, Germany and Mexico, it develops new technologies in the manufacturing of this kind of operative systems; as a prove, it is necessary to mention a building industry with the finality to manufacture different pieces and after being assembled the telescope is ready; for this structure was necessary to assure that the specifications were done with exactitude rules and dimensions were established for each piece that take part of the plate, even though does not exist any commercial instrument with the measurement required to accomplish with the exactitude the assemble.

The installation considers as an important task of the project, the construction of a concrete base, also the base for the telescope and other accessories to make the equipment work. All these structures will be built over an altitude upper 4000 meters over the sea level where the placing conditions are qualified less common, in other cases adverse for the concrete manufacture.

OBJECTIVE

To develop concrete specifications and technical propose to design and manufacture a concrete structure under extreme conditions; all these have to satisfy the structural and durability requirements that allow to assure the good performance of the material under different conditions, all this established by the place of the MRT.

SPECIFICATIONS

The concrete advertises for the project include the following requirements:

Template f'c 15 N/mm², 5 cm thick, maximum aggregate size 19 mm, Volumetric Weight 2200 kg/m^3 Cement Type IP (ASTM C 595) or type II cement with low alkali 8ASTM C 150;in bulk with a quality certificate of the producer; in another cases it is possible manage cement bags.

Aggregates: brittle particles <3% elongated and flat <15% as crushed dust, the percentage that goes by the mesh 200 has to be less than 2%, lose by washed sand <3% and grave <1%.

Note: there is a confusion in regard to the crushed material, the specific gravity <2.5, modulus of refinement from 2.5 to 2.9.

Water; there is a consume higher than 0.19 m^3 in each m^3 of concrete, it is very important to use water reducer and initial set retarded admixtures in the set (type D o G according to ASTM C 494).

As we can see, these advertises include the selection of components and also the grade of the same ones, it assumes that it is very important to elect and review the raw material and wait if the final combination gives as a result a mix with the correct characteristics. It is important to mention that these can accept the mix after evaluating fresh concrete, for its consistence and when the compressed resistance becomes hard, according to ASTM.

This task will specify the analysis of the structural concrete uses, although the other type mentioned is also considered basic with the specific criterion that at the same time are defined according with the used row material in the material production.

Technical Suggestion

With the finality to attend to all the requirements to this project, it was done a technical suggestion that are added to the specifications, all this represented a general guide to define the necessary activities to accomplish, the concrete manufacture process. In this suggestion [1], there were concepts no included in the original advertises as the selection of the special aggregates that allow to accomplish with specified elastic modulus and it was not considered as a part of the original property of the product. The use and management of the alternative cement, the inclusion of system pores in the concrete who will help to prevent the repetitive action of the freeze cycles, the definition of the minimum temperatures in the fresh mix (13 and 16 °C) for each element based in particular characteristics [3], the established requirements for the minimum conditions [4] (minimum temperature 4 °C and the appearance of rain and fog) to stop the production and to place the concrete finally the schedule for the set, established according to atmospheric conditions that are being review at the moment.

EXPOSURE AND SERVICE CONDITION

The faceable atmospheric conditions [5] for the structures set:

- Temperatures between –5 °C and 25 °C, it means that there is an unfavorable risk during the concrete manufacture resulting from the low temperatures.
- Relative humidity upper than 60%.
- Wind velocity between 5 and 10 m/s, with a maximum of 1m/s in certain moments.
- Exposure and service conditions during the operation.
- Minimal temperatures from –5 °C.
- Freezing and defrosting cycles.
- Exposure to a moist environment.
- There are no presence or abrasive actions.

- There is no risk of any chemical attack with the direct contact between the material and the aggressive.
- There is no possibility to get any chemical reaction between the cement alkali and the employment in the concrete manufacture, also this elements have been evaluated, also have been proved their inoffensive behavior.

According with the exposure and service conditions defined by MRT structures, the main big risks of the problem are the following:

When the concrete is fresh or in process of becoming stiff it is necessary to pay special attention on the concrete temperature to assure the cement hydration.

In another way, when the concrete is stiff it is important to take care of the internal structure capable to support the degrading action resulted from exposure to the current action from freezing and defrosting cycles; also, concrete has to be manufactured with a permeability level that closes the possibility of any corrosive process over the steel reinforcement, since the natural environment is very wet and the rainy periods are common.

MANUFACTURING AND CONSTRUCTION PROCEDURES RECOMMENDED

Taking in consideration the placement of the project there is no any infrastructure for the materials transportation and processes done for the project construction are not the best quality, even, some traces have a pendant in around 10%.

To put in practice MRT, it was necessary to implement a plant (Figure 1) in the place to avoid any problem when the concrete was provided. To perform this task it was necessary to divide the concrete production plant in different parts and after that it was replaced along 1 km from the chosen place for the construction, as a plant support was included a truck mixer as a base and in different periods, if would be more demand there is an extra equipment to accomplish a correct delivery of concrete.

Material delivery: for a deficient infrastructure during a construction, the delivery where the cement and aggregates are, it is necessary to transport them in 2 stages: first of all, take the cement and aggregates to the nearest town and place them in a warehouse and second, to take them through the production plan; in the case of the cement only 15 tons can be transport and the aggregates only charges of 4 m^3; the delivery time between the warehouse and the plant is around 4 hours.

Concrete production: to make a production it is necessary to modify the plant and include:

A water heater system that has the blank to search a minimum temperature of 70°C, to accomplish this task was necessary to install at water tank and withaheater like, also used in petroleum asphalt plants.

To get the specified temperatures in the project the production system existent, the tube circuit, the cement silo, the additive tank and water were recovered totally with polyurethane being apart from the low environmental temperatures; in another way the aggregates warehouses are covered with canvas to maintain the temperature apart of outdoor conditions; in all the equipment's the oil was substituted by oil that do not get freeze.

Figure 1 Concrete production plant

Before starting the current delivery, there were manufacture concrete proves with the finality of verifying the specific characteristics and authorize the project mixes; when the set is starting, are prepared 2 mixes with low volume (3 m^3) to make valid results, when it is proved starts the total delivery made in trucks of 7 m^3 and at the same time they delivery volumes no more than 6m^3; the material delivery schedule were always favorable for the concrete to get a high environmental temperature in the set, 90% of the sets were done after 13 hours.

The sets are programmed at least 24 hours and the total volume has to be assured.

Concrete set: the concrete set area, at the beginning of the set is covered with canvas, the same is injected with steam to avoid contrast temperatures, this task is done after 2 or 4 hours after the set is finished and at the end is recovered with canvas in the case of a frustum of a cone that is the main support of the observation plate there were specific steeps, for example the placement of a thermal cover in the (forms) at the same time it is cured with water steam.

RESULTS

Fresh and Hydrating Concrete

In the following are presented the results after the concrete [6] is placed in a 95% that correspond to a MRT base structure and support.

The results of the fresh mix are presented on Table 1 and it shows the good management of the concrete temperature before the setting, the same one was placed in all cases under specification.

The Figure 2 shows the environmental temperature conditions and the main characteristics of the elements, all cases presented the minimum temperature for the concrete mix, where the task under analysis establishes 2 ranks.

Table 1 Results of the fresh mixes

CONCEPT	SAMPLE NUMBER	X	S	C.V. (%)	MINIMUM VALUE	MAXIMUM VALUE
Slump (cm)	44	20.00	2	8	15	22.00
Concrete Temperature (°C)	44	21.00	3	13	16	26.00
Environmental Temperature (°C)	44	9.00	3	30	3	16.00
Air Content (%)	44	4.62	2	22	22	6.98
Fresh Volumetric Weight (kg/m^3)	44	2242.00	45	45	2187	2292.00

In the Figure 3 is demonstrated what: independently of the environmental temperature conditions and the particular characteristics of the elements, the minimum temperature specified is fulfilled in every case, were in the analysis case is established two acceptation ranges.

Note: In the figures, the temperature does not show all the measured results but we can consider as a representative samples the obtained results from the MRT construction.

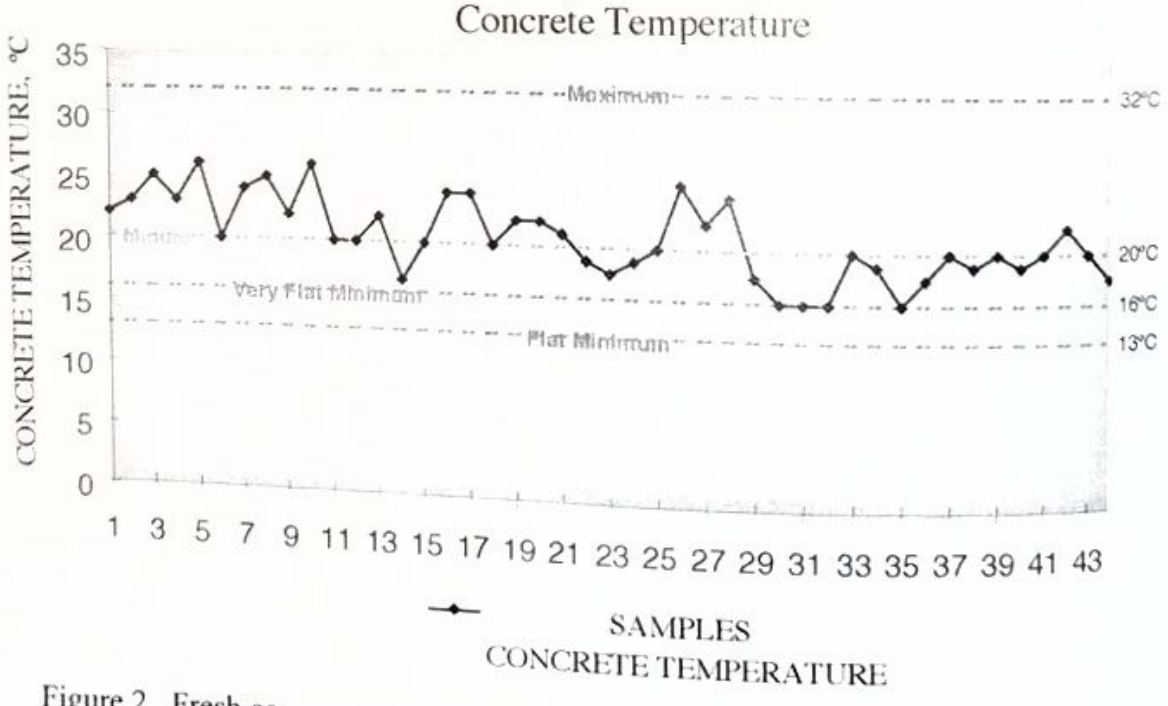

Figure 2 Fresh concrete temperature during the placement in centigrade degrees

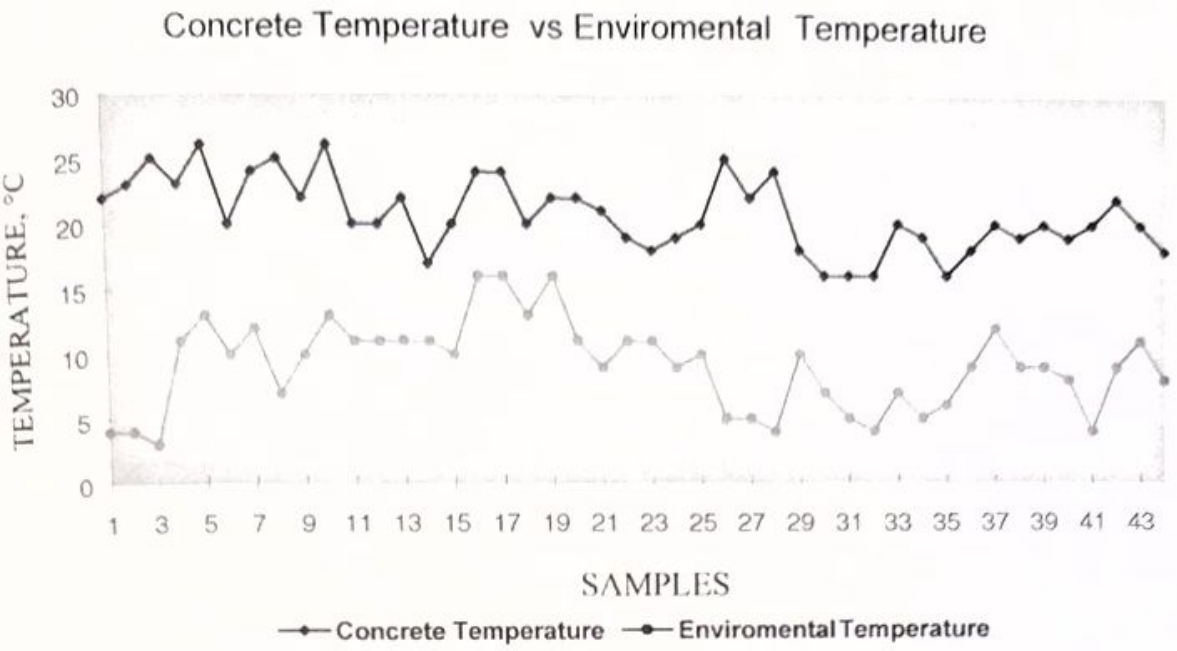

Figure 3 Comparision between the fresh concrete temperature and the enviremental temperature in centigrade degrees

Hardened concrete

The compression strength results are shown in the Table 2, these show what the admixture have a light excess performance in relation to the original acceptance approach what suggest a f'c of 35 N/mm², in the basis of that it's possible to comment the following points.

Table 2 Compressive strength results of the concrete

f'c (N/mm²)	AGE (days)	SLUMP (cm)	SAMPLE NUMBER	S (N/mm²)	X (N/mm²)	C.V.	MINIMUM VALUE	MAXIMUM VALUE	% f'c	CEMENT CONTENT (kg/m³)
35	3	18	29	4.4	25.3	18	149	329	101	350
35	7	18	34	4.1	35.8	11	287	441	143	350
35	28	18	37	2.2	43.8	5	388	471	175	350

According with the project owner was necessary to define the minimum cement amount for each m3 of concrete (350 kg/m^3) to satisfy the durability conditions for the same structure. To obtain efficiency during the use of the forms in the project, the owner asked to deliver the concrete accomplishes the 80% of performance in 3 days.

The group of these variants with a low a/c relationship (0.45) establishes an increase in the natural develop of the compression performance of the product. It is important to mention that the 2 specified compression performances, only one maintains itself (35 N/mm²) according with the owner project interests.

The static modulus of elasticity results can be checked in the Table 3, we can see that the aggregate inclusion with calcareous composition has an excellent quality, the obtain values over the minimum specified by design, where the minimum was 221 35.9 N/mm², this value mentioned before was not accepted at all.

Table 3 Static modulus of elasticity results of the concrete

AGE (days)	SLUMP (cm)	SAMPLE NUMBER	S (N/mm²)	X (N/mm²)	C.V.	MINIMUM VALUE	MAXIMUM VALUE	% Ec
7	18	6	2537.6	30022.2	9	270806	348117	136
28	18	15	3589.9	33259.5	11	284082	397455	175

CONCLUSIONS

Related with the original project specifications it is considered the structural needs of the product that are less important to the exposure and service conditions of the elements.

The final opinions are consider for the concrete production and set, for example to unify owners interest, designers, masonries, supervisors, and project producers, in this way, everybody stay with the same position to get the collective goal.

The good obtain results of the fresh concrete properties in fresh state, becoming stiff prove the measurements effectiveness taking in programming, production and concrete placement. In particular, the temperature control was effective to assure the material production in regard to a minimum value defined by a temperature placement.

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