Observatory building design: a case study of DAG with infrastructure and facilities

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ABSTRACT

DAG (Eastern Anatolian Observatory in Turkish), will be built in one of the well-known mountain ridges of Erzurum, Turkey, at latitude of 39°46’50, longitude of 41°13’35 and an altitude of 3170 meters. As well as erecting the largest telescope of Turkey, the DAG project aims to establish an observatory complex both small in size and functional enough to give service to all astronomy community. In this paper, the challenge is explained in details: geological and geographical limitations, environmental and meteorological constraints, engineering and structural considerations, energy efficiency and sustainability.

Keywords: Observatory, Observatory Design, Design Criteria, Sustainable Solutions, Reverse Trombe Wall, Energy Efficient Building

1. INTRODUCTION

Several locations in Turkey have been identified as suitable locations for a scientific observatory after decades of painstaking research. One of these locations is Mount Karakaya in the Konaklı region of the city of Erzurum. After careful deliberations, it was decided that Doğu Anadolu Gözlemevi (Eastern Anatolian Observatory, in short DAG) will be built here, at a latitude of 39° 46’ 50”, longitude of 41° 13’ 35” and an altitude of 3170 meters. An area of 1.5 million square meters was subsequently granted to Ataturk University for the construction of the observatory. The area is easily accessible from the city center and is only 20 km to the airport. There are good transportation links to the area, including asphalt roads up to the popular ski resort nearby and a dirt road from the resort to the area of construction. Furthermore, there is a good water, electricity and communications network in the area necessary for living at and operating the facility.

The geographical structure of the area will allow the construction of a number of observatories thanks to its suitability for scientific observation. It is planned that the initial campus of the observatory will turn the area into a popular location for scientific research and help contribute to the growth of the Ataturk University as well as the economy, education and development of the region itself.

Once finished, DAG will house the largest infrared telescope of Turkey with a mirror diameter of 4 meters. Both the telescope and the dome are currently under construction. While the telescope and the dome are designed to be completely remotely controlled, a service building and relevant supporting infrastructure will be built to allow researchers to reside at the location.

Another important feature of DAG is that it will have a cleaning and coating plant for the 4-meter mirror. This plant, which will be the first in Turkey and the largest in Europe, will be located at the service building. It will be possible to dismount the mirror from the telescope and move it to the plant without the mirror having ever to go outside. The plant will also be able to service other telescopes in Turkey.

Following the completion of the master plan of the campus, excavation works and improvements to the access road have already begun.

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2. BUILDING PROGRAMME

The building program foresees the building with two parts and defines the requirements as given below:

Part One: The Telescope Building that will house the telescope and the relevant infrastructure

Part Two: The Service Building where the operations of the facility will be based.

Telescope Building: The telescope, with a 4-meter diameter mirror, will be placed on a reinforced concrete pillar. This telescope pillar will be completely separate from the remaining part of the enclosure building. The rotating enclosure (dome), will be placed on a reinforced concrete circular shear wall that is approximately 16 meters in diameter. The enclosure building will host all the accessories of the telescope as well as the AC units of the Azimuth floor and the telescope. The enclosure building is designed so that the mirror can easily be dismounted and transported to the cleaning and coating plant without being exposed to the outside. The designed structure will also provide access to people with disabilities to the Azimuth floor.

Service Building: This building will host the telescope control room, computer room, cleaning and coating plant, a garage for the snow plough trucks and 4WD vehicles, a mechanical and electrical facilities room, 6 suites with 2 beds each, study rooms, a library, a kitchenette, a common room, a fitness room and an observation deck above the roof level which will allow the visitors to view the telescope room as well as remote control observations without entering the Azimuth floor.

Due to adverse environmental and climatic factors and operational constraints, both buildings will be interconnected and fulfil the below mentioned design criteria. The designer will consider thermal, visual, acoustical, vibrational and energy performance of the building which may obstruct the observation process.

3. DESIGN CRITERIA

There are a number of criteria that needs to be considered in the site selection and design of an observatory and the service buildings.

Site selection criteria include, but are not limited to, the following:

- The location should be accessible and its geographic and climatic conditions should be conducive to human habitation.
- Annual clear skies percentage should be high and the humidity levels should be low enough to perform the observations without having any visual obstruction.
- Average wind speed should be low, especially during the observation periods.
- Atmospheric pollution and ambient light should be minimal.
- There should not be any heat or light source in the immediate environment that would negatively impact observation.

Along with the site selection criteria, there are numerous structural requirements too. These are:

- The telescope pillar, along with its foundation should not have any physical contact with any other structure.
- The telescope pillar should satisfy the stiffness level as required by the telescope manufacturer.
- Rotating Enclosure RC Shear wall should have the necessary stiffness and strength. The Rotating Enclosure should be able to withstand wind speeds (survival wind speed) up to 165 km/hr, which is the maximum observed wind speed in the region. The operational wind speed should be assumed to reach up to 36 km/hr. The enclosure building should carry the rotating enclosure with a mass of approximately 220 tons and resist the maximum 200 km/hr horizontal wind speed.

The location chosen for the project satisfies almost all the conditions delineated above, except for extremely cold temperatures during winter that fall as low as -35^{o}C that will have a negative impact on the occupants. While it is not planned to have physical occupancy during these extreme conditions, the equipment must still be protected against such adverse conditions. Therefore, the structure will have to include a heating system that will allow the continuation of its operations while not emitting any heat to the atmosphere.

4. FINAL DESIGN

The designer has made a proposal that encompasses all the requirements set out above. Approximately 110,000 m3 of excavation has been made and a massive basalt base has been reached in preparation for the construction. The required stiffness and strength levels have been achieved in all the reinforced concrete structures.

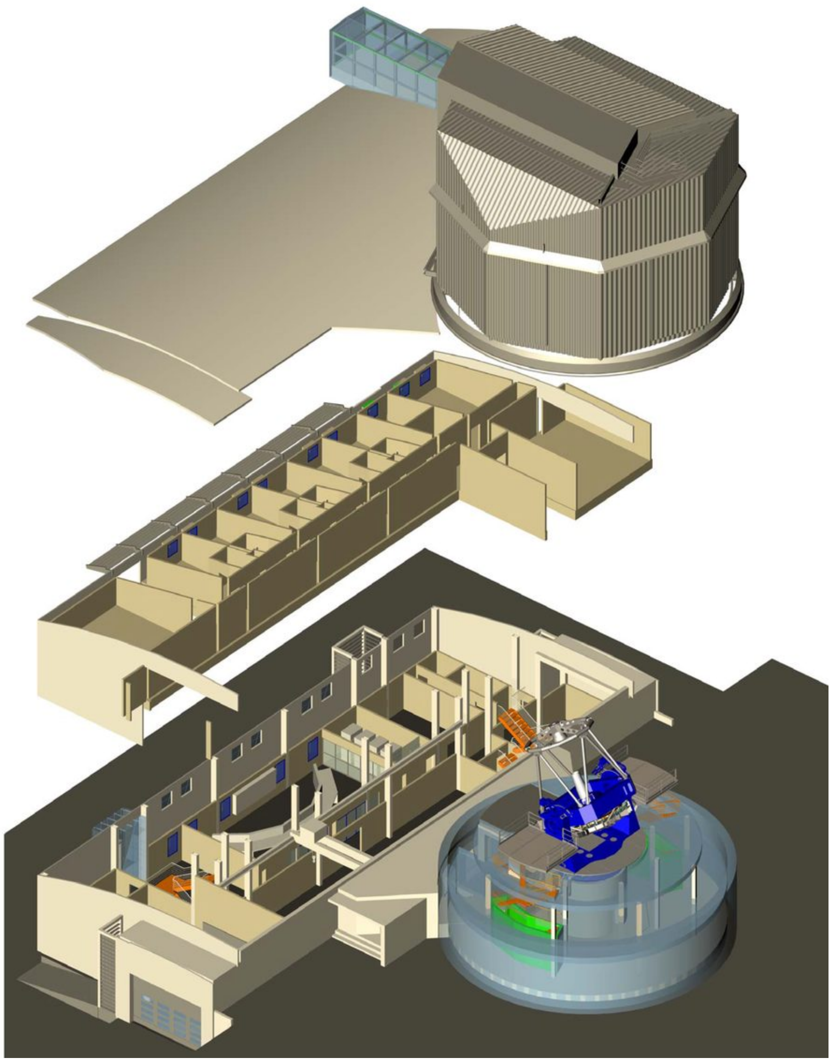

Figure 1. Exploded drawing of DAG

The telescope and service buildings have been placed at different levels but are interconnected, allowing the direct transportation of the mirror to the cleaning and coating plant when dismounted from the telescope. This level difference towards south between the telescope and the service building will also help to decrease any occurrences of turbulence. The roof of the service building is designed as a wing form so that the prevailing wind can flow smoothly (Figure 1).

To provide a sustainable source of energy the designer has provided a unique solution. Utilizing the high level of solar radiation in the high altitude and ultimate atmospheric conditions, the building will utilize passive solar energy for heating. Therefore, the service building will directly face south and its north façade will be buried halfway to the ground to decrease the heat losses. Electric heating will be used to provide heating in extreme weather conditions.

The first solution that comes to mind for passive solar heating is a Trombe Wall. In this system a wall is built on the winter sun side of a building with an external glass layer and a high heat capacity internal layer separated by a layer of air. Light close to UV in the electromagnetic spectrum passes through the glass almost unhindered then is absorbed by the wall then re-radiates in the far infrared spectrum which does not pass back through the glass easily, hence heating the inside of the building. Trombe Walls are commonly used to absorb heat during sunlit hours, and then slowly release the heat over night. The solution is not suitable because the system generates infrared back radiation from the external wall in to the air. Hence the designer made a change on the system and called it as "Reverse Trombe Wall". In this system a glass wall, forming a greenhouse, generates warm air by reflected long waved radiation sunlight from thin layer of insulated metal sheet and this warm air is trapped behind the glass wall. This warm air then moves up with increasing speed within the greenhouse aided by its triangular shape. This warm air is then immediately taken into the well-insulated rooms directly while the cool air within the room is taken into the green house by the positive pressure within the room generated by the warm air. In the sunlit hours, the warm air heats the rooms. Simultaneously, the glass wall with air gaps in between the glass sheets, provides fresh air inflow from outside to the greenhouse. Hence the air blowing into the rooms is both fresh and warm. In summer period the air flaps in the air blowers are closed to prevent overheating. In this system the cleaning and coating plant area will be used as a buffer zone for either warmed or chilled air to balance the temperature within the service building.

The building will have completely dry wall systems and insulated with rock wool. The heat transfer coefficients (K Values) are as follows:

External walls: 0.160 W/m2 K

Roof: 0.148 W/m2 K

Floor: 0.318 W/m2 K

Overall, winter period heating load of the building is estimated to be 21 kW, which will be fully covered by Reverse Trombe Wall solution. These values are much better than conventional solutions and also encourage the use of sustainable solutions with minimum energy consumption.

The service building will have 6 suites with 2 bed capacity and bath rooms, a fitness room for motivating the researchers, a common room to gather for dining and social meetings, a study room with a library. All the facilities are designed to minimize the loss of space and provide a compact building form.

The building will have closed waste water system. In this system all drained water will be collected in closed tanks and by bioprocessing the waste water will be treated and redistributed to the flushing reservoirs.

The summit has good natural spring water and fresh water can be obtained and stored in stainless steel water tanks. By using proper filtering system, the facility will have enough and good quality fresh tap water.

5. CONCLUSION

An observatory is technically an engineering structure. However, the seamless integration of an architectural and engineering approach to create a building that satisfies the intricate requirements of creating a sustainable structure that can survive in such adverse conditions is exemplary for a project of this size in Turkey.

The project satisfactorily meets all the expectations and has been approved for construction. The bidding process has been finalized and the construction will begin in July 2016. Upon the completion of the project, all necessary testing will be completed and compared against the predictions of the design. This will provide valuable insight to the process of designing and building a sustainable building of this size and will be an example for similar future projects.

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