A380 AIRCRAFT HANGAR WITH A CLEAR SPAN OF 96M AND THE NEW AMIRY TERMINAL IN KUWAIT AIRPORT

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ABSTRACT

This document describes design, production and assembly works of "The Space Frame of A380 Aircraft Hangar" having a clear span of 96m and "The New Amiry Terminal Building" in Kuwait International Airport. These two buildings were in the same contract and they were constructed in Kuwait.

Keywords: A380-Planes, Design, Hangar, Large-Span, Space Frame, Terminal-Building

INTRODUCTION

The Kuwait International Airport is located in Farwaniya, Kuwait. It can currently handle six million passengers per year after a massive renovation and expansion project. In 2007, a new aircraft hangar for Airbus A380 planes and a new terminal building for VIP passengers were planned to build. Starting date for Ahmediah Trading and Constructing Co, Main Contractor, was 15th of September 2007. Airbus A380 Aircraft Hangar and The New Amiry Terminal Building were built in the same contract. Both structures are made of prefabricated steel USKON space frame system and all materials of the space frame have been supplied from Turkey.

SPACE FRAME OF A380 HANGAR HAVING A CLEAR SPAN OF 96m

The outer dimensions of The A380 Aircraft Hangar are 86.50m x 177.00m. The Hangar is divided into two bays for different types of planes. The larger bay has a dimension of 96.00m x 86.50m and it has been designed for Airbus A380 plane which is one of the largest planes in the world. The second area adjacent to the larger one has a dimension of 81.00m x 86.50m. This part is designed to lodge smaller planes comparing to A380, like a B747 or equivalent. There are two large doors in front of the hangar. The clear spans of the bays along these doors are 96.00m and 81.00m, respectively. The height of the Hangar from ground level to the bottom chord of the space frame is 28.20 m. Grid size of the space frame is 5.053mx5.125m.

A slope of 2% was provided from front side towards the rear side of the hangar. Depending on this slope, construction height of the space frame is variable. Minimum height of the space frame in aggregate of two layers is 7.50m on the rear side and the max. height is 9.04m on the door's side.

There are 8163 no's of pipe members, 1823 no's of nodes and 65 no's of supports in the space frame system. The self weight of the space frame except the purlins is only 62.7 kg/m^2 despite such a clear span of 96m.

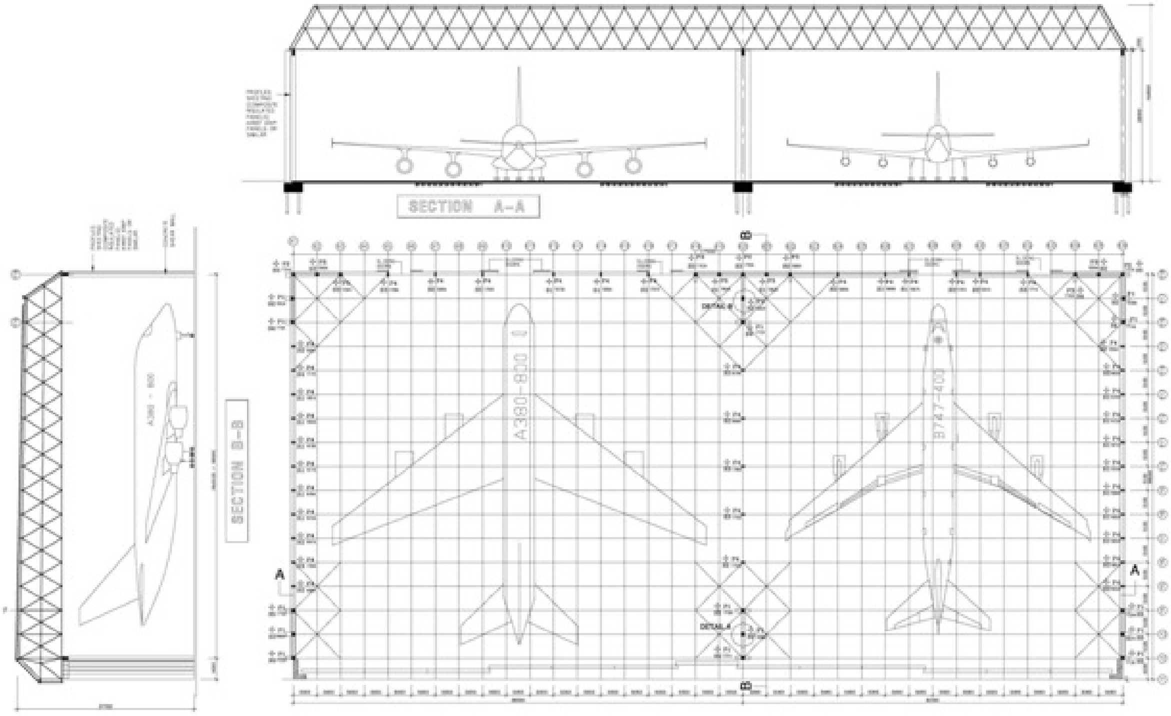

Figure 1. Plan View and Sections of The A380 Hangar

GENERAL INFORMATION ABOUT THE PARTICIPANTS OF THE PROJECT

Employer : Ministry of Public Works , Special Projects Administration
Contractor : Ahmadiah Contracting & Trading Company - Kuwait
Architectural Design Concept : Meinhardt UK Ltd. - England
Consultant / Supervisor : Ministry of Public Works
Structural Design Consultant : Farooqi Engineering Consultants - Kuwait
Designer and Supplier of Steel Roof Structure : Uskon Space Frames - Turkey
Supplier of Composite Roof Cladding System : Arabian Profiles-UAE & Kalzip Roofing Sys.-UAE
Supplier of Wall Cladding and Framing : Arabian Profiles - UAE
Supplier of Steel Sub-Structure : Khalid Kharafi - Kuwait
Supplier of Main Hangar Doors : Jewers and Sons - U.K.
Heavy Lift Contractor : VSL – Switzerland

DESIGN PROPERTIES OF THE PROJECT

Design calculations are as per Eurocode1 and Eurocode3 using Load and Resistance Factor Design Method. In all phases of structural design, the most unfavorable conditions have been taken into account including erection phases and open or closed door combinations. 212 numbers of loading combinations have been used in design calculations to satisfy the requirements of open or closed door conditions. The loading criteria in the project are as follows:

- Space Frame Self Weight = 62.7 kg/m^2
- Cladding + Purlins = 25.0 kg/m^2
- Service Load = 18.0 kg/m^2
- Live Load on Roof = 60.0 kg/m^2
- Wind Load = 168.0 kg/m^2 (V=80 m/h)

- Temperature Differences = $\Delta t = \pm 35°C$
- Seismic Loads = as per UBC'97 (Zone=I , Importance Factor=1.5 , R=4.5)

The Hangar is a steel structure as a whole but also there are 6 no's of reinforced concrete shear walls in the structure. There are 65 supports on the sub-structure. 26 of these supports are on reinforced concrete shear walls. Remaining 39 supports are on steel columns braced by steel elements along the perimeter. SAP2000 software has been used in structural design.

Some information about the space frame structure is as given below:

- Area of Space Frame = 15310 m^2
- Number of Members = 8163 no's
- Number of Nodes = 1823 no's
- Number of Supports = 65 no's
- Span of the Space Frame = 96.0 m.
- Minimum Diameter of Pipes : D = 88.9 mm , t = 3.0 mm (S235)
- Maximum Diameter of Pipes : D = 323.9 mm , t = 10.0 mm (S355)
- Minimum Bolt Diameter = M20 - 10.9
- Maximum Bolt Diameter = M72 - 10.9
- Minimum Node Diameter : D = ϕ 110 mm
- Maximum Node Diameter : D = ϕ 380 mm

ASSEMBLY WORKS OF THE SPACE FRAME AND LIFTING OPERATIONS

Assembly work is a part of the design of the structure. First, whole system except for a few nodes and members which prevent lifting of system has been assembled on the ground level including purlins and other required equipments on the system. There are 8 no's of openings in the space frame for Lifting Towers. 8 no's of temporary Lifting Towers were constructed passing through the space frame. These towers have been used to lift up the space frame onto its original position.

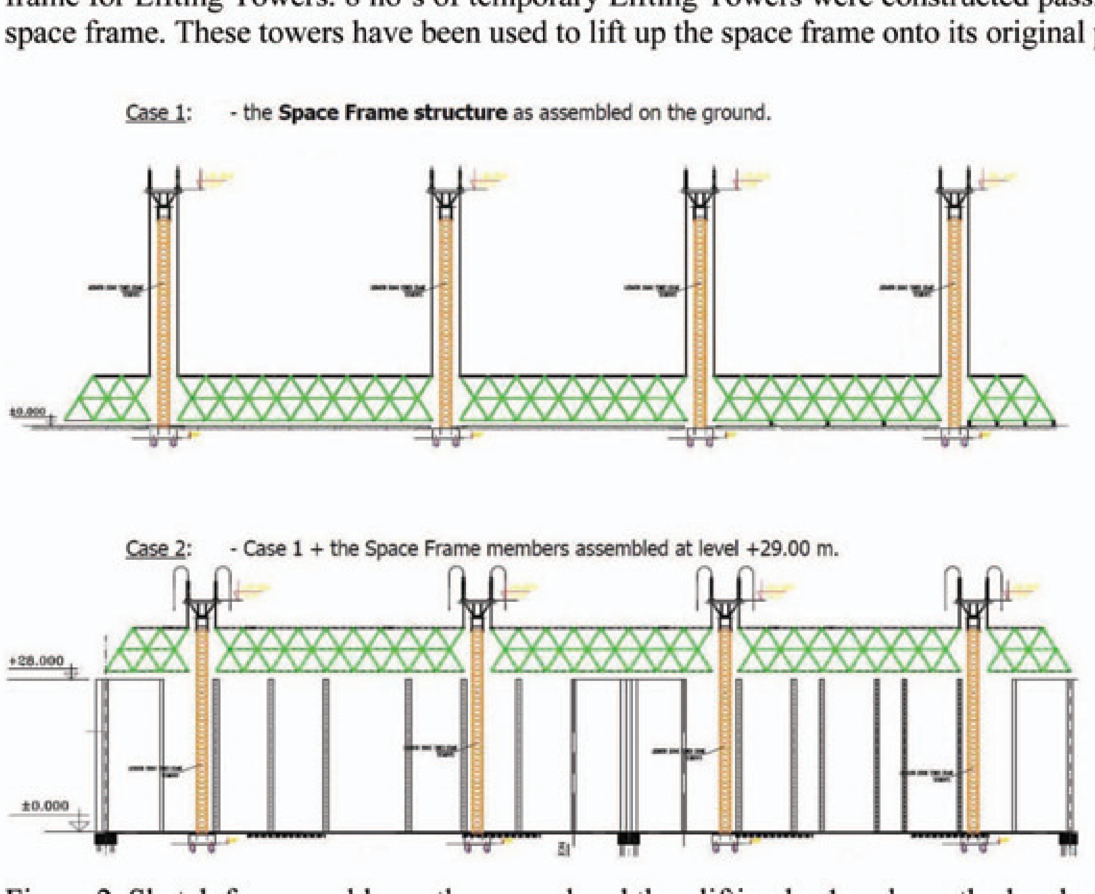

Figure 2. Sketch for assembly on the ground and then lifting by 1m above the level of supports

The lifting of the space frame was carried out by VSL, Switzerland. The roof is assembled at 40cm above of ground level on temporary soldier supports without camber and be lifted simultaneously using 16 no's of VSL strand lifting jacks on these 8 no's of temporary Lifting Towers. Elevation of the original supports is 28.00m. Total lifting height from ground to bottom chord member's level is approximately 29m. The VSL strand lifting jacks are installed on temporary lifting towers inside the roof frame (openings).

Lifting principle and sequence of the job were planned and coordinated by VSL and USKON. For lifting operations, reactions as per 16 no's of holding nodes and displacements of some critical nodes were calculated from computer model. They were measured on site and compared with the ones in the model results for a safe lifting. Wind and other meteorological conditions were defined for planned lifting days. The emergency conditions like displacements, reactions, wind velocities etc. have defined for unwanted cases. The lifting from ground level to the final level was divided into the following distinct operations:

- Stage A: Erection of temporary lifting structure (During roof assembly)
- Stage B: Erection and commissioning of strand lifting equipment
- Stage C: Lift-off operation and controls.
- Stage D: Main lifting operation to the final height.
- Stage E: Lifting the roof structure 1m above the final height.
- Stage F: Interruption for connection after completing of missing side space frame members and insertion of definitive columns.
- Stage G: Lowering of the whole roof to final level
- Stage H: Load-transfer from the lifting jacks to the definitive columns and connection.

For the lift-off, lifting and load transfer operations, forces (lifting pressures) and vertical displacements on these 8 jacking groups have been constantly monitored and compared with the theoretical values provided by the structural analysis.

Figure 3. Lifting connection elements

Figure 4. Lifted space frame with hydraulic jacks

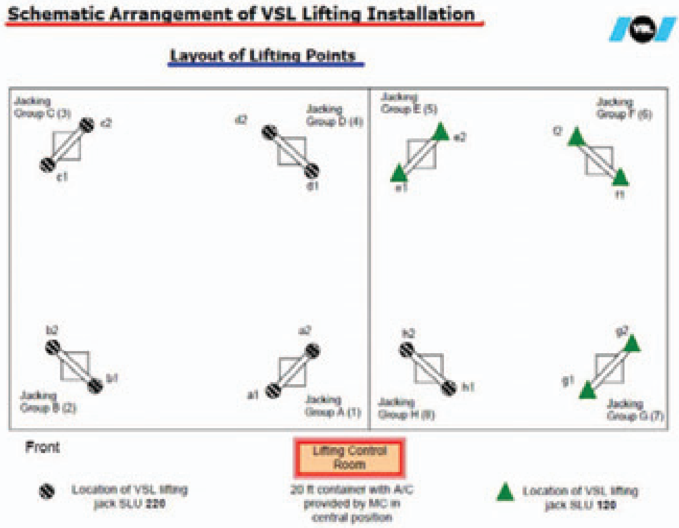

Figure 5. Layout of lifting connection points

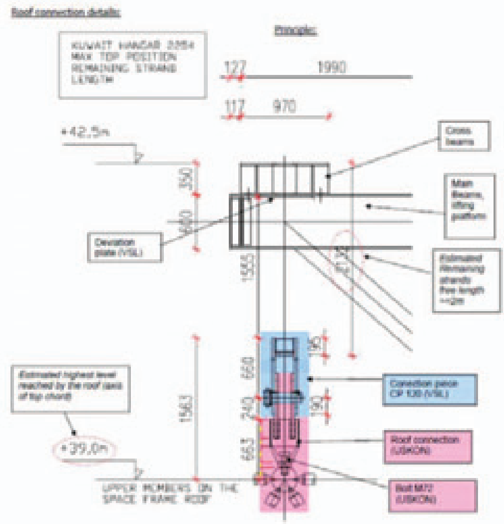

Figure 6. Connection detail of system

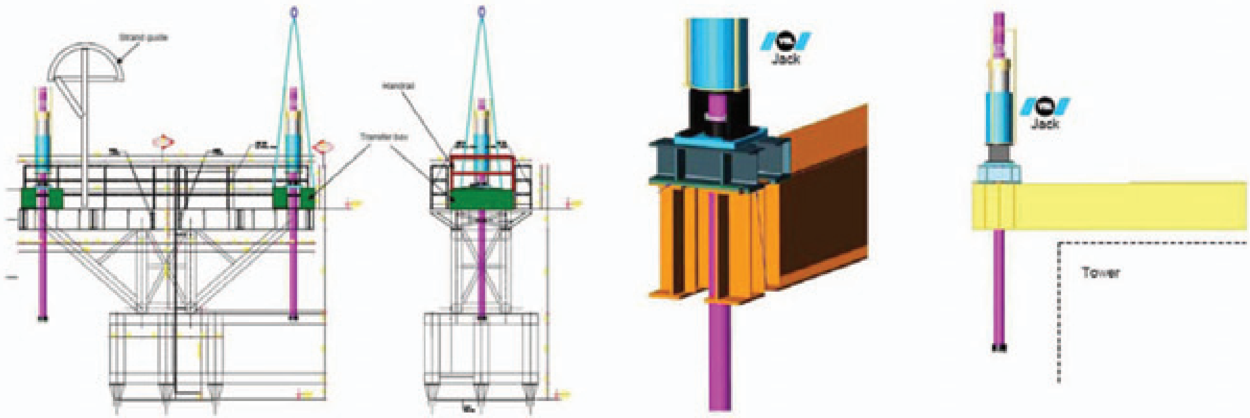

Figure 7. Detail of top platform with transfer beams and connection details of jacks

Figure 8. View of the airbus a380 hangar during installation after lifting process

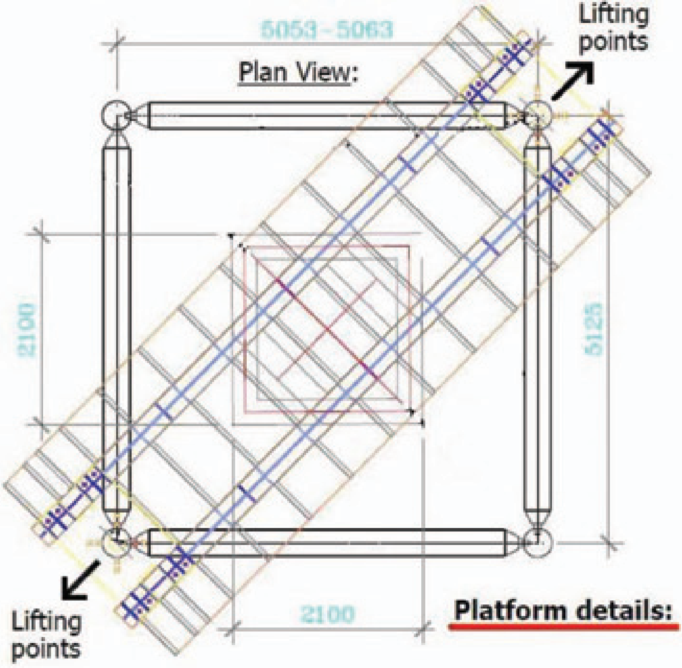

Figure 9. Plan view of platform and lifting points

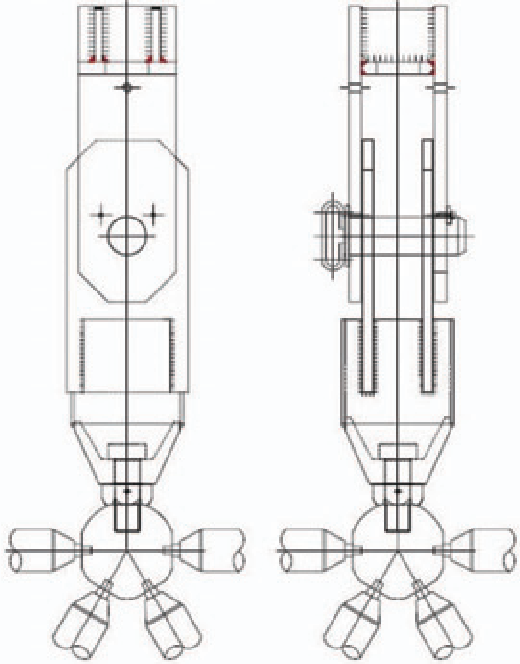

Figure 10. Detail of connection element

After lifting process was completed, steel sub-structure and columns were placed under suspended space frame system and some missing elements which prevent lifting process were added to system. Then, space frame was lowered onto the original permanent supports by VSL. A special purlin system was used on the space frame in diagonal direction to reduce the span of the cladding.

Figure 11. Inside view of the completed airbus a380 aircraft hangar and large doors

THE NEW AMIRY TERMINAL BUILDING

The Amiry Terminal (VVIP Terminal) will be exclusively used by the Emir of Kuwait and his guests as well as other countries representatives while visiting the country. The main contractor of the project, Ahmediah Trading and Constructing Co., insisted on having a new interesting design and this was required extra internal width and height and the latest state of technology but without losing the highest aesthetical concern. Construction works of The New Amiry Terminal Building are in the same contract with The A380 Hangar.

Figure 12. General view of the terminal

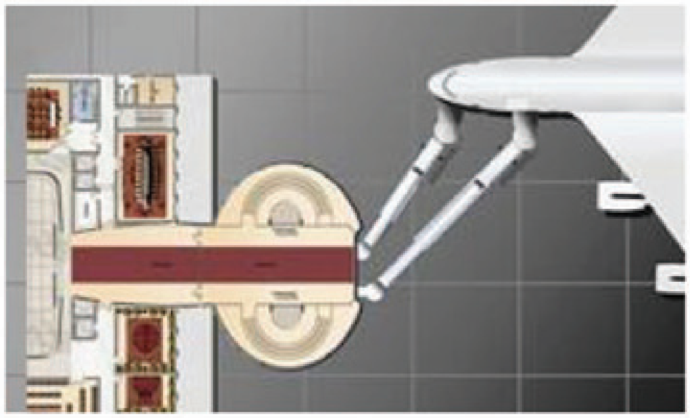

Figure 13. Taking passengers to the plane

GENERAL INFORMATION ABOUT THE PARTICIPANTS OF THE PROJECT

Employer : Minister of Public Works - Special Projects Administration
Contractor : Ahmadiah Contracting and Trading Company - Kuwait
Architectural Design Concept : Paul Andreu - France
Architectural Consultant : Associated Engineering Partnership - Kuwait
Structural Consultant : Farooqi Engineering Consultants - Kuwait
Designer, Supplier of Steel Structure : Uskon Space Frames - Turkey
Supplier of Composite Roof Cladding System : Arabian Profiles-UAE & Kalzip Roofing Sys-UAE
Supplier of Aluminium Cladding : Wuhan Lingyun Building Decoration Engineering Co. - China

The outer dimensions of the structure are 69m x 69m in plan. Distance from the highest point of the space frame to the lowest level is 35.523m. Modulation of the space structure varies depending on the complex geometry but, it is around 2.167m x 2.167m. There is a lateral space frame connection system on the top middle region to improve the structural behavior since this upper volume is not used for architectural purpose. Construction thickness between lower and upper layer of the space frame is 2.212 m. for this part.

DESIGN PROPERTIES OF THE PROJECT

Design calculations are as per Eurocode1 and Eurocode3 using Load and Resistance Factor Design Method. The loading criteria in the project are as follows:

- Space Frame Self Weight = 46.2 kg/m^2
- Cladding + Purlins = 41.0 kg/m^2
- Service Load = 25.0 kg/m^2
- Suspended Ceiling Load = 15.0 kg/m^2
- Live Load on Roof = 60.0 kg/m^2
- Wind Load = 168.0 kg/m^2 (V=80 mp/h)
- Temperature Differences = $\Delta t = \pm 22°C$ (for H<13m) ; $\Delta t = \pm 35°C$ (for H≥13m) ;
- Seismic Loads = as per UBC'97 (Zone=I , Importance Factor=1.5 , R=3.5)

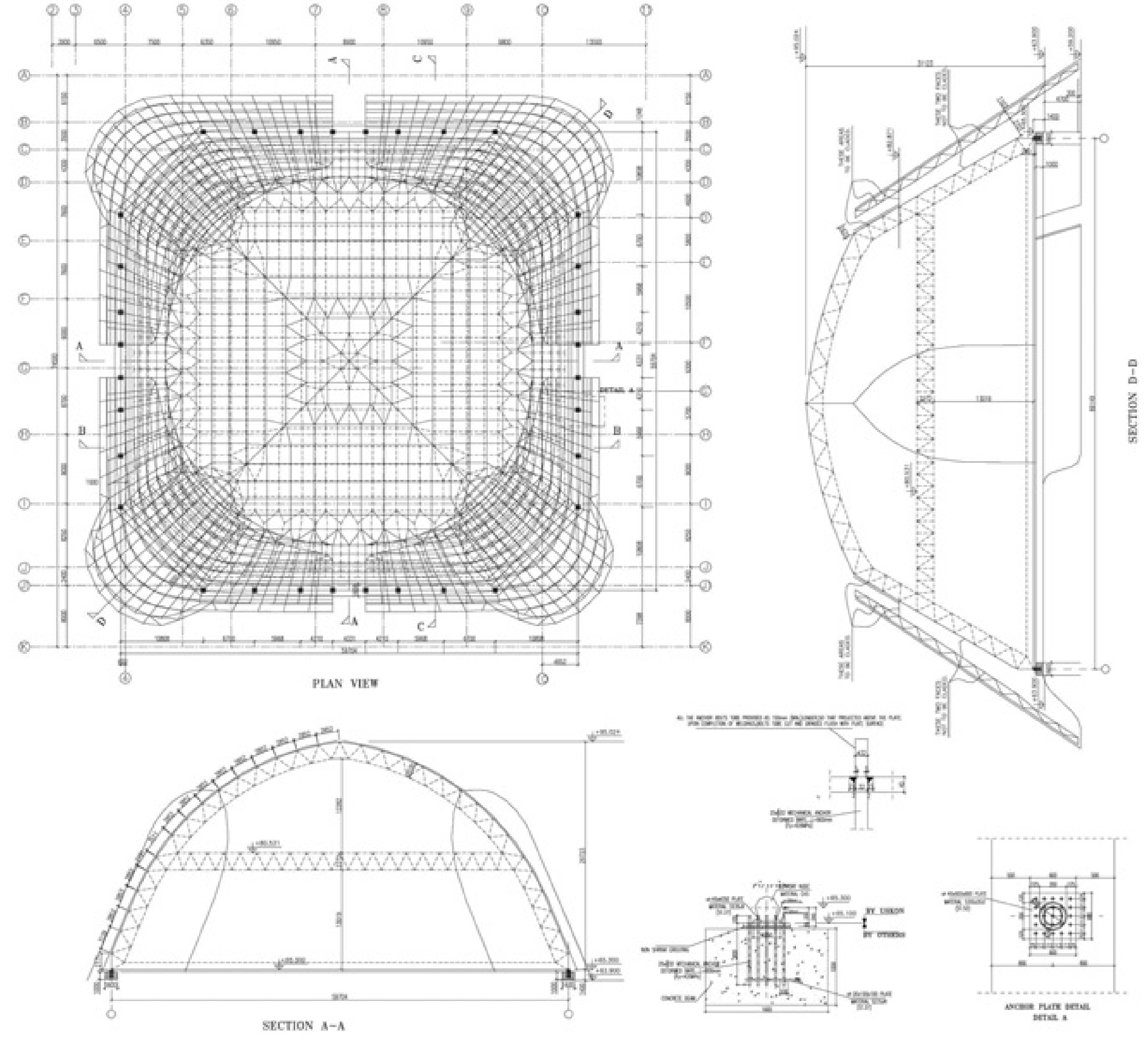

Figure 14. Plan view and sections of the Amiry Terminal Building (VVIP Terminal Building)

The space frame structure has been supported on the reinforced sub-structure using 32 no's of steel supports. Clear span of flat-sided and dome-shaped space frame structure is 59.70m. on both x and y directions. There are additional space frame layers in the structure integrated to the model. The system has been modelled together with these leaf shaped parts. SAP2000 software has been used in structural design calculations. Some information about the space frame structure are as given below.

- Area of Space Frame = 4368 m^2
- Number of Members = 15234 no's
- Number of Nodes = 3657 no's
- Number of Supports = 32 no's
- Span of the Space Frame = 59.7 m.
- Minimum Diameter of Pipes : D = 48.3 mm, t = 2.5 mm (S235)
- Maximum Diameter of Pipes : D = 219.1 mm, t = 8.0 mm (S235)
- Minimum Bolt Diameter = M12 - 10.9
- Maximum Bolt Diameter = M56 - 10.9
- Minimum Node Diameter : D = ϕ 75 mm
- Maximum Node Diameter : D = ϕ 280 mm

Figure 15. General view before cladding works

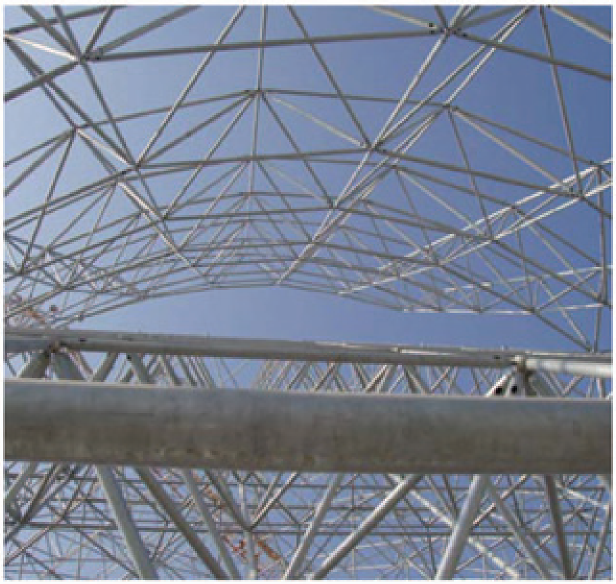

Figure 16. The main space frame structure

Figure17.General view after first layer of cladding

Figure18.General view after cladding works

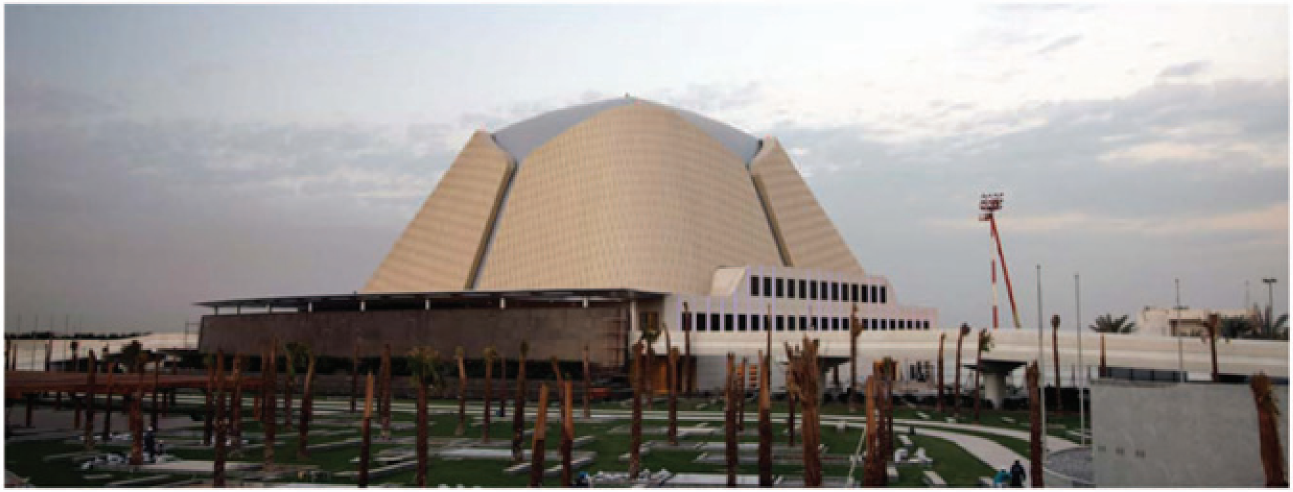

Figure 19. General outside view of the amiry terminal after completion of cladding works

ASSEMBLY WORKS OF THE SPACE FRAME AND PURLIN SYSTEM

Assembly Work is a part of the design of the structure. Erection of the space frame has been carried out on the site by using advantages of dome-shaped geometry. Depending on this property, installation process has been completed in a very short time. Another reason of completing assembly works in a short time was the advantage of the steel prefabricated space frame system.

A Secondary steel purlin system has been designed on the main space frame structure to cover structure by a special cladding system. Details of the purlins and cladding system were too complex especially for leaf parts and their connections to the main structure.

Figure 20. Inside view of the Amiry Terminal Building when completed

CONCLUSION

These two buildings were in the same contract and carried out by USKON Space Frame Company. These structures are made of prefabricated steel space frame system by using local materials supplied from Turkey. They had been completed at the beginning of the year of 2010.

Figure 21. General outside view of the space frames constructed in Kuwait International Airport