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# The UFH/C System with PE-Xa Pipes is a Perfect Sustainable Solution for a Large Mosque Project

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## SUMMARY

In this paper we would like to show the capability of radiant floor heating being used with complete plastic pipe system for the large space area of a large mosque (the Isfahan Mosalla Project). Human comfort is a critical consideration when designing a mosque in Iran and the traditionally-used normal unit heater or air-based system rarely meets the comfort criteria in these projects. A full plastic pipe solution is a superior solution when considering the quick and correct installation and commissioning of such a system in a large construction project. In this paper we describe the challenges we faced in this project.

## KEYWORDS

*Radiant Floor Heating and Cooling, Thermal Comfort, Mosque Heating and Cooling.*

## ABSTRACT

An under-floor heating system is frequently the most appropriate solution for different applications all over the world. Using the low temperature of around 40˚C is a great step towards lower consumption of energy and also towards having better thermal comfort for the user of the system.

For the first time in Iran, a project for construction of a mosque in Isfahan city wanted to check the possibility of using a UFH/C system. The area of this project is 23,000 sqm using 230 km of three-layer PE-Xa pipe, making it the biggest use of an UFH/C system in Iran to date.

Many challenges existed here. The first was to check what output the UFC could supply for such a system. For cultural reasons, the floor of a mosque is mostly covered by Persian carpets, which is very good insulation. Secondly, to design such a huge project needed reliable software to calculate the system output based on different scenarios and to choose the best system. Thirdly, regarding installation, there were some challenges regarding how to balance the UFH/C loop. An interesting aspect of this project was the requirement to use PP-RCT three-layer with GF pipe to make the UFH/C manifold buried in the floor, a request by the owner in order to have a high quality solution.

## INTRODUCTION

Floor heating systems have been used since ancient times due to their advantages compared to other heating systems. The floor heating system for large volume sites with high ceilings, such as hangars, gymnasiums, churches, mosques, etc., means that a floor heating system seems a preferable alternative when considering human physiology, as the vertical temperature gradient in a room heated from the floor is negative. The cost of this heating system is also very reasonable for these spaces. In floor heating, a more comfortable room can be obtained due to the fact that the velocities of air flow resulting from heat transfer with natural convection are smaller than 0.1m/s, as the temperature distribution in indoor air is more homogenous than other heating systems. Floor heating systems are affected less on cold days, when sudden temperature drops occur, because heat is accumulated in the floor (1).

The Isfahan Mosalla Project features unique architectural and structural designs, since the owner of the project wanted to mix the Iranian traditional Islamic art with modern materials, which is not an easy task. The Mosalla is the largest complex featuring a metal shell, including a special dome-shaped structure that includes single welded mesh layer with node works and the net pattern of classic wooden window(2) (See Fig.1and Fig.2). From an architectural point of view they use an origami concept along with Iranian traditional geometry to create an intelligent pattern (2).

Fig.1: Mosalla Project interior

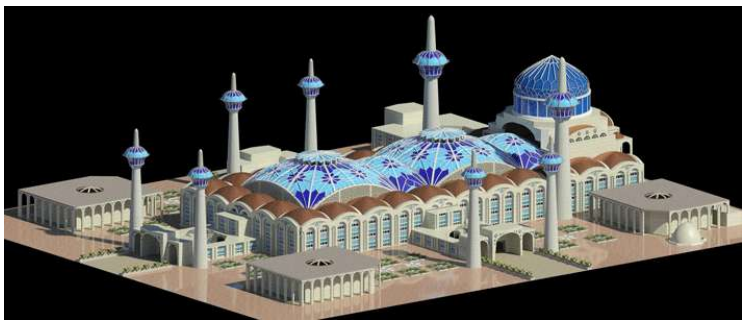

Fig.2: Mosalla Project exterior

The floor area is 23,000 sqm, consisting of 44 modules of 500 sqm of radiant floor heating concrete slabs. The owner preferred not to see any of the manifolds inside the area so we could not use ordinary wall-mounted manifolds, and we used 44pcs of manifold manufactured from 90mm three-layer PP-RCT+GF Pipes designed especially for this project.

In the next section we will describe the challenges we faced during this project.

## CHALLENGES AND EXPERIMENTATION

They were many challenges and experiences during this project, each of which we discuss in turn:

- **Choosing the Right Plastic Pipe Material:**

Iran is basically a multilayer aluminum pipe market, and PE-X pipe is a relatively new material in the market with few producers. For this reason, as with most of the projects in UFH/C involving multilayer pipe to date, the owner held a tender and asked all top producers to declare their technical and financial proposals, in order that the most appropriate pipe material was chosen. The finalists were PE-Xa three-layer pipe with EVOH layer, and the PE-RT multilayer pipes, from two manufacturers, each produced and manufactured in Iran. In the end ,the technical committee approved the PE-Xa three-layer pipe, after an examination of the technology used for the production of these pipes (extrusion with infrared oven and no necessary for further post treatment), as well as considering the flexibility and ease of installation, along with a consideration of price.

Therefore the pipe used for this project was three-layer PE-Xa with raw material from Borealis Borpex 2591 with EVOH and an adhesive top layer, co-extruded. The size of the pipe was 20x2mm.

- **Choosing the Right Manifold with Enough Technical Features:**

To choose the right manifold shape and material, the most important consideration was that this should buried in the concrete slab long-term. Therefore the material of the pipe should be safe when in direct contact with concrete and chemical additives. We found that PP-RCT is one of the best materials for this application, applied with Socket Fusion as the welding fitting and the pipe are compatible. The pipe and fittings material was BOROUGE RA140E, which have very good weld ability when used together.

The pipe structure was three layers with PP-RCT+GF in the middle layer to absorb the thermal expansion of the pipes.

All of the 44pcs of manifolds were prefabricated and tested in the factory with special fixtures to be sure about the quality of the manifold on the actual site. Around 3,000 m of the 90 mm three-layer PP-RCT/GF pipes were used to make the manifold and connection to the main feeder pipes.

 

To make the branch from collectors, we used the weld in saddle to make the installation easier and safer. It is also cheaper than the branching tees. In Fig.3 the pipe and manifold connections can be seen.

Fig.3: Pipe and manifold connections

- **Choosing the Right Type of Isolation Layer:**

Choosing the right isolation is a very import issue when employing a UFH/C system. Firstly, the project should meet the requirement of the EN 1264 Norm; secondly it should minimize the energy waste from the floor into the ground; and lastly the cost should be considered. The Technical Committee chose two final materials for this application: XPS and EPS. To choose between these two materials we asked for K Value test report, which showed that EPS had K Value equal to 0.04 w/m.ºK, and XPS had K Value equal to 0.0302 w/m.ºK. The XPS was shown to be more resistant and durable when in contact with water, and had a density of 35 kg/m2. The EPS in Iran had a maximum density of 25kg/m2. With this technical comparison the Technical Committee choose XPS for the floor insulation layer.

- **UFH/C Output:**

To calculate the output of the radiant floor heating and cooling, we used the Willms Gmbh HT2000 Software and the EN 1264 assumptions. The floor structure of the Mosalla consisted of 1cm thickness Persian carpet on Top, 3cm marble stone below, and 20mm mortar below that. Also, over the 20mm pipe at a 10 cm distance we had 50mm screed thickness. By these assumptions we reached to 70.5 w/m2 for heating with the floor surface temperature of 26.6˚c and 30 w/m2 for cooling the floor surface temperature of 21˚c . These figures were acceptable for the owner. The Mosalla had a separate air handling unit with a dehumidification option, and a hot and cold coil to supply the rest of the load requested for this area.

- **Air Purging in the UFH/C System:**

One of the features that is very important for a UFH/C manifold is the air vent or air purging options. To be sure that the air is venting outside correctly, we searched for many solutions on this topic and in the end we used Air Vent valves on each polymer manifold, and also put an industrial air and dirt separator in the mechanical room.

- **Concrete Slab-Making and Fixation of the Pipe:**

The installation time of the UFH/C system of this project in Iran may be a record. The 23,000 sqm floor structure consisted of 46x500 sqm slabs, and each 500 sqm concrete slab took one or even sometimes shorter than a day .The total installation procedure took 40 days.

The floor structure was to be finished and to consist of a thick 12mm iron mesh with spacer and the pipe was to be fixed with mesh with cable ties. The number of cable ties for this project was over 1,200,000pcs and it took 25 workers for 40 days.

One of the important characteristics of the PE-Xa pipes is the ability to recover and maintain easily, which was a must-have specification for such a huge project. Often when concrete workers try to finish the surface of the final concrete they trample the pipe underfoot, but since these pipes were pressurized they could recover their original shape, thereby minimizing maintenance. Three times the pipe surfaces were accidentally damaged by sharp edges during the concrete finalization. By using the coupler and cutting the damaged pipe, maintenance was able to take place.

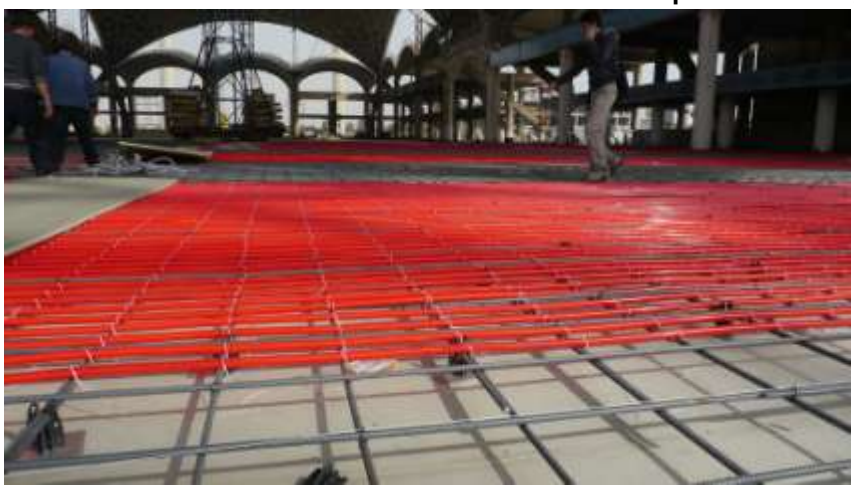

Fig.4: Pipe laying /fastening the cable ties with pipe to the iron mesh

Fig.5: Pipe laying /fastening the cable ties with pipe to the iron mesh

Fig.6: Floor structure

- **Flow Homogeneity in Loop:**

The design of the main manifold and the buried polymer manifold in this project was reverse return configuration to ensure the correct flow in each slab to add the flow homogeneity much better used balancing valves in the beginning of each manifold also .The geometry of the Mosalla project floor helped a lot to divide the floor to nearly equal areas.

- **UFH/C Specification :**

The source of heated water is gas boiler and the source of cooled water is air cooled chiller, the flow rate inside each 500 sqm is about 80 lit/min . Also the length of each loop is between 90 to 105 m with 20 mm Pipe . The Related humidity of the weather in Isfahan city is around 20 %. The Type of circulator the owner used in this project is variable speed circulator enable them to open and close some zone base on the demand,

- **Polymer Manifold Installation:**

All polymer manifolds were pre-fabricated and tested in the factory to ensure high quality. On-site, the welding technicians connected the pre-fabricated parts using the DVS 2207-11 Standard with Ritmo Prisma 125 Welding Machine. After preparing of the full manifold and passing the cooling time, each manifold was to be under pressure for 12 hours and after that the connection between pipes and manifolds was complete.

Fig.7: View of the 500 sqm slab with laid pipes

## LESSONS LEARNED

- Using full plastic piping system is a reliable solution for UFH/C system. The Contractor only found 3 leaks during this project and the reason was because of physical damage to the pipe by concrete workers which were found and repaired.
- Condensation is not a problem because we were far above the dew point temperature and in full load mode, which meant around 35,000 people were in the Mosalla area. The air conditioning system was first set to dehumidify the area to enable the UFC to work properly. Only the steel main feeder had a problem with condensation, which was isolated after the problem was found.
- The on/off function of the UFH/C should be chosen with consideration of the characteristics of the system. Turning the slab off two hours before unoccupied hours and back on two hours before occupancy used less energy than running the slab at lower loads throughout the day.
- If welding was to be required in preparation of the manifolds then it is much better to prefabricate them in a protected area, not on the working site. This is mainly because welding precise need special environmental conditions which are difficult to achieve in the actual site. So using the prefabricated manifolds was very advantageous during this project.

## CONCLUSIONS

Industrial Saloon and Structure are traditionally heated by either a hot water unit heater or a fired infrared (IR) heater. When a unit heater is used, the heat will rise to the ceiling due to stratification. There have been attempts to design units that lessen the problem by forcing air circulation, either by adding ceiling fans or by introducing air at high velocity from the top towards the floor. Temperature spot checking and data logging indicate the vertical temperature variation is significant. The average temperature in the space is much higher than the temperature at the occupant level. The gas fired infrared (IR) heaters are not suited for all cases due to potentially hazardous situations. ASHRAE Applications Handbook provides a good list of the factors that should be considered before considering infrared heating. Due to high temperatures, IR heaters must not be placed where they could ignite flammable dust or vapors or decompose vapors into toxic gases.IR heaters must be located with the recommended clearances to ensure proper heat distribution. Stored materials must be kept far enough from heaters to avoid hot spots.

When the ceiling height is over 5m, under-floor heating is an excellent choice for heating. Using low temperature water for the system makes the energy waste in the Mosque saloon very low because of the lower temperature difference. Also you will have the heat in the area you need it for the occupants A plastic piping system is the best choice to use in a UFH/C system, because of the flexibility, quality, durability and price. Only minor modifications involving control valves and sensors are required for monitoring the system.

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