TEST FACILITY FOR BUILDING INTEGRATED SOLAR ENERGY

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Abstract – Building integrated solar energy is characterised by a high degree of interplay with the building it is installed in and often also a high degree of interaction between different kinds of building integrated solar energy features. The high degree of interplay often creates major difficulties when trying to determine the performance of these solar energy components. Today, building integrated solar energy is either tested in real buildings or in test cells. Real buildings give problems because they normally are not well defined – e.g. cold bridges, uncontrollable thermal processes, people, etc. Test cells are normally much more well defined but often far away from reality – i.e. small, heavily insulated (2 and 3 dimensional heat flows and long time constants) – which increases the uncertainty when scaling to real buildings. A new concept for a test facility for testing building integrated solar energy has been developed. The concept is well defined as test cells but instead of heavy insulated exterior surfaces it is based on adiabatic surfaces – i.e. no cold bridges and 2 and 3 dimensional heat flows. The test facility has a realistic size – three story building with a floor area of 80 m^2. It is possible to test components not only in the south wall but also in the east, west and north wall as well as in the roof. The test facility both allows test of single components and test of the interplay between different components under well defined conditions. It is, however, also possible to introduce the interaction with other thermal processes normally taking place in a real building, by e.g. introducing a heat loss through the "adiabatic" surfaces.

1. INTRODUCTION

During recent years, there has been an increasing focus on building integrated solar energy. In building integrated solar energy, the actual building is used as a solar collector and/or storage, or the components of the solar energy systems constitute a natural part of the building's construction. Building integrated solar energy thus encompasses not only passive solar heating, but also active solar heating and PV where these are a part of the building.

The simplest form of building integrated solar energy is a window. The solar radiation through windows covers part of the building's heat loss in all buildings. To what extent the heat loss can be covered depends on the window type and the design and usage of the building. Other forms of building integrated solar energy are glazed spaces e.g. balconies and atria, but also double facades. Solar walls are a third form of building integrated solar energy where the external surface of the wall is covered with a transparent layer. The heat from the sun is trapped behind the cover and is then led to the building by a stream of air and/or by means of conduction through the wall.

Solar air heating systems will often also have a high degree of building integration - either because the solar collector is integrated into the wall or roof, or because the heat from the solar collector is stored in the constructions of the building - in walls or storey partitions.

Liquid solar heating systems may have a high degree of building integration. The solar collector can be integrated in the roof or the wall and the heat from the system can, for example, be given off as floor heating. PV can be integrated in facades/roofs or in windows.

In addition to the fact that the above-mentioned forms of solar energy can be integrated into buildings, they can also be combined/integrated with each other. PV and solar air heating can e.g. be combined so that the cover of solar air collectors consists of PV-panels. Here, the excess heat from the PV-elements is used to heat the air in the solar air collector. The solar air collector thus cools the PV-elements, so the efficiency of these is kept up. Air and liquid solar heating can be combined, so that a solar collector can heat both air and liquids. Passive solar heating can be combined with PV by integrating PV-elements in windows, etc.

Common for the above-mentioned building integrated solar energy features are that they often have a close interplay with the building in which they are located. The construction and usage of the building directly influence the output of solar energy, and the solar energy systems have direct influence on the thermal conditions - especially on the comfort level in the building. This means that it is not sufficient to test these forms of solar energy detached from the building, and nor is it possible to test exclusively the systems' sub-components as, for example, is done at present with liquid solar collectors and storage tanks for solar heating systems.

2. TEST IN OUTDOOR FACILITIES

Building integrated solar energy can be tested in real buildings, where they anyway will find their final use. But, since there is a need for controllable measuring conditions, which can be reproduced, real buildings will create problems - especially if there are people present in the buildings. Real buildings are normally not sufficiently well defined in order to achieve sufficiently precise measuring results. Moreover, many other thermal processes are taking place, which do not directly have anything to do with the component, which is being tested. Persons are even more poorly defined which makes it virtually impossible to account for them in a measurement programme.

In order to bridge the gap between laboratory tests and real buildings different outdoor test technologies has, therefore, been developed – especially the test cell technology.

Test cells normally has one surface for testing components while the other surfaces are heavily insulated in order to increase the measurement accuracy on the test component as the heat losses through the other surfaces will be small. However, the large insulation thickness introduces relatively large and uncontrollable 2 and 3 dimensional heat flows in the corners of the test cell. These 2 and 3 dimensional heat flows can constitute up to 15% of the total heat losses from the test room (Jensen, 1994). Moreover, the large insulation thickness introduces long time constants. This increases the uncertainty when scaling to real buildings

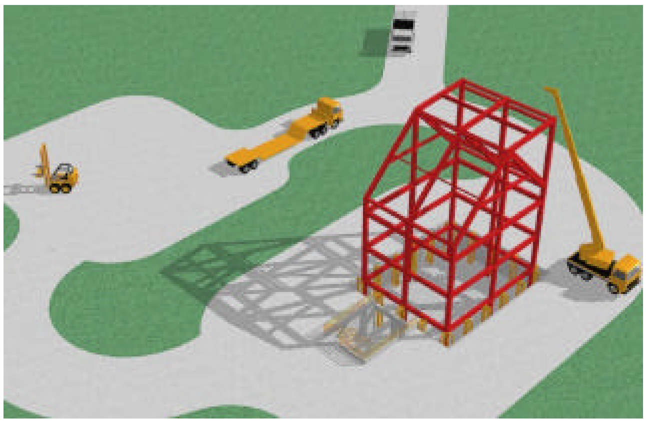
Attempts have been made to solve these problems in several of the test cells by introducing adiabatic surfaces by means of: a) an extra internal insulation layer with a controllable, electrical heating foil between the original and the new insulation or b) less insulation but with a heated space on the outer side of the insulation where the air temperature is maintained at the same level as in the test room.

However, the test cell technology still suffers from the often small test area where only components of a limited size can be tested and where the conditions in the test room behind the test area often will be far away from reality with regards to e.g. air flow pattern.

As a reaction to this the Solar Energy Centre at the Danish Technological Institute has developed a new concept for a test facility with the aim of including the best parts from test cells and real buildings (Jensen, 1997 and Jensen, 2000).

3. NEW CONCEPT FOR A TEST FACILITY FOR TEST OF BUILDING INTEGRATED SOLAR ENERGY

The test facility is well defined as test cells but instead of heavy insulated exterior surfaces it is based on flexible adiabatic surfaces – i.e. limited cold bridges and 2 and 3 dimensional heat flows. The test facility has a realistic size – three story building with at floor area of 80 m^2. All adiabatic surfaces can be replaced with test components or traditional walls in order to facilitate tests of several solar energy components under real conditions. It is thus possible to test components not only in the south wall but also in the east, west and north wall as well as in the roof. In addition it is possible to store heat in the internal constructions, e.g. the floor. The test facility both allows tests of single components and tests of the interplay between different components under well defined conditions. It is, however, also possible to introduce the interaction with other thermal processes normally taking place in a real building, by e.g. replacing one or more of the adiabatic surfaces with traditional surfaces. The latter is very important when validating/developing simulation programs in order to obtain an understanding of the interaction of



the thermal processes in the components with the thermal processes normally occurring in a building.

4. DESCRIPTION OF THE TEST FACILITY

4.1. Supporting Structure

The supporting structure of the test facility is a steel skeleton divided in three separate parts as shown in figure 1. The main part of the steel skeleton - referred to as the basis configuration – gives the basement and the two test rooms with a foot print of 80 m² (10 x 8 m²). On top of this it is possible to locate a roof module with a roof tilt of 45° for tests of roof integrated components. If further an extension module is placed on the roof module the test facility will allow for test of facades with a height of up to12 m as shown in figure 2 – referred to as the maximum configuration.

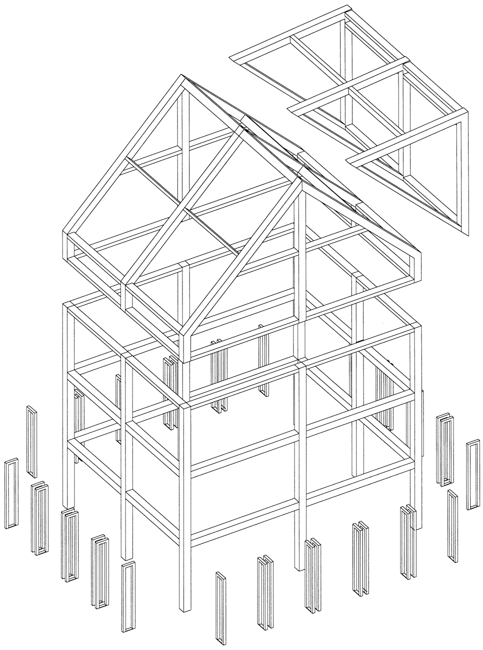


Figure 1. Components of the steel skeleton of the test facility.

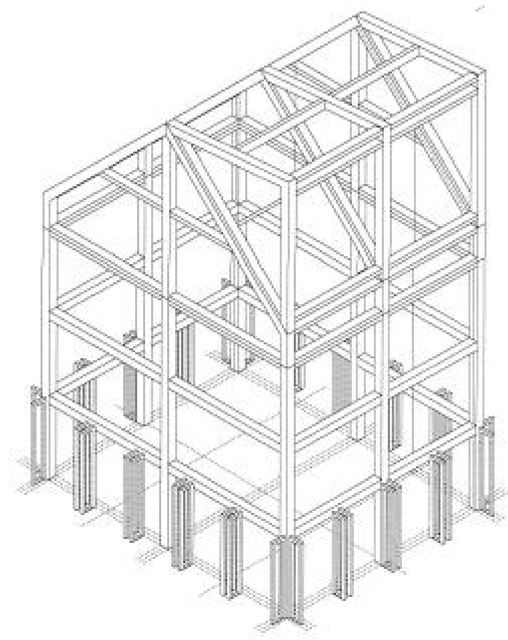
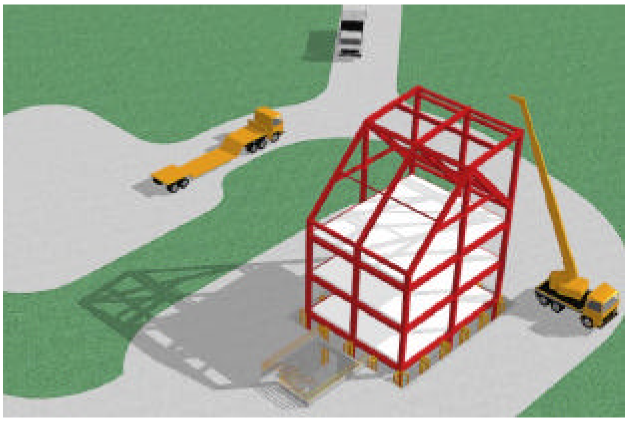


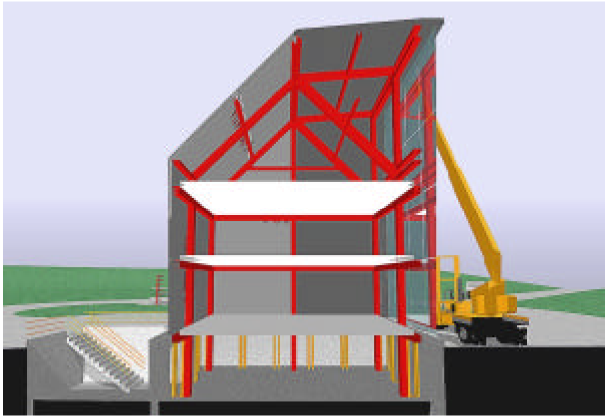
Figure 2. The components from figure 1 joint together to form the maximum configuration where it is possible to test facades with a height of up to 12 m.

The foot print of the basement is on all sides 1 m wider than the foot print of the test rooms. Steel columns to support the facades are located in the basement in this 1 m wide gap. The aim of this is to reduce (eliminate) the 2 and 3D heat flows in the lower part of the facades as the temperature in the basement and around the steel columns can be maintained at the same temperature level as the air just above the floor of the lower test room.

4.2. Floor Slaps

Real buildings normally contain a significant amount of thermal mass and several solar energy features use this mass for storage of heat – e.g. passive solar energy through windows or solar air heating systems where the heat is stored in the storey partitions.





In order to be able to represent this in the test facility the storey partitions will be hollow core concrete floor slaps with the possibility to circulate air through.

These hollow core concrete floor slaps will of course not act as adiabatic surfaces – which is nor the intention. However, in some tests it may be desirable to be able to operate with adiabatic surfaces also in the floor and ceiling. 2 dimensional dynamic calculations on the thermal behaviour of the storey partitions have shown that if 50-100 mm rigid foam insulation is placed on the floor and under the ceiling, the heat flow in and out of the concrete floor slaps can be reduced to a minimum which will not influence the test very much or which may be measured using heat flow meters and in that way be taken into account when evaluating the test results.

4.3. Adiabatic Surfaces

The concept of adiabatic surfaces is the main new feature of the test facility. The idea to use adiabatic surfaces was obtained from the Energy Monitoring Company's Test Room 3000 (Martin, 1994), which is a test cell with only a thin layer of insulation against the test room and a cavity on the outside of this insulation. The cavity can be maintained at the same temperature level as inside the test room.

The concept of the test facility was at first developed based on this idea of heated cavities in the exterior surfaces (Jensen, 1997). However, possible in a small one-room test cells this concept is very difficult to establish in a large multi floor test facility – especially if flexibility is the question.

Instead the concept of adiabatic panels was developed. The adiabatic surfaces will be build of easy removable adiabatic panels of an easy to handle size of 2 x 3 m² (width x height). Figure 3 shows an example of the test facilities in its maximum configuration covered with adiabatic panels on all facades.

The panels are mounted on the outside of the steel skeleton and secured to this and each other.

Figure 4 shows the principle of the adiabatic panels. The panels are sandwich constructions of two 35 mm plates of insulation foam with a thin liner of an aluminium sheet on each side. In the middle is a 50 mm air gap which may be ventilated by fans installed in the outer insulation plate in order to remove undesirable heat from the air gap. The panels is designed to have a heat loss coefficient close to the heat loss coefficient defined by the Danish building code: 0.3 W/m²K.

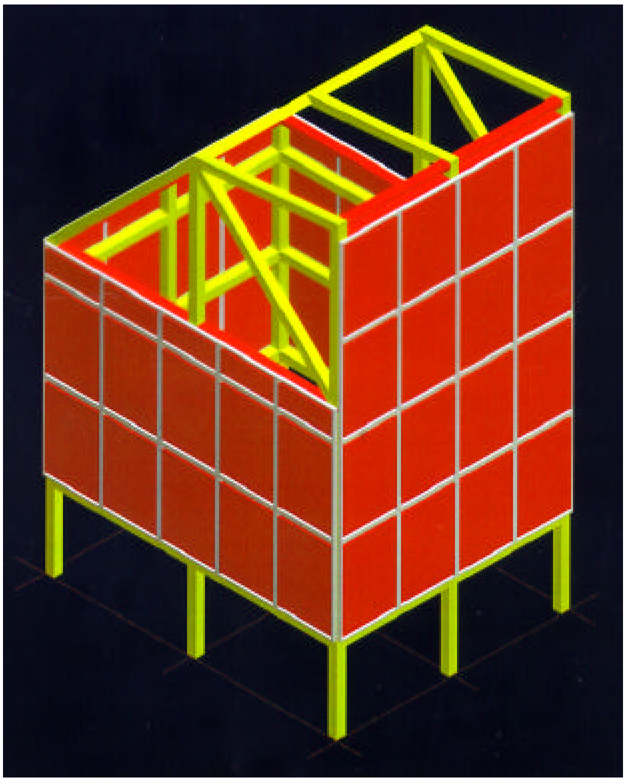
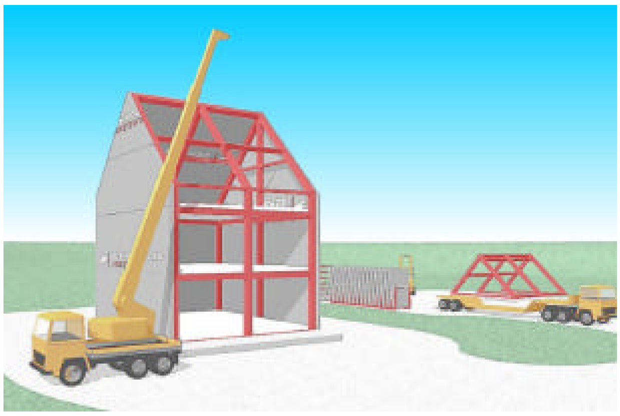


Figure 3. The test facility in its maximum configuration with adiabatic panels on all facades.



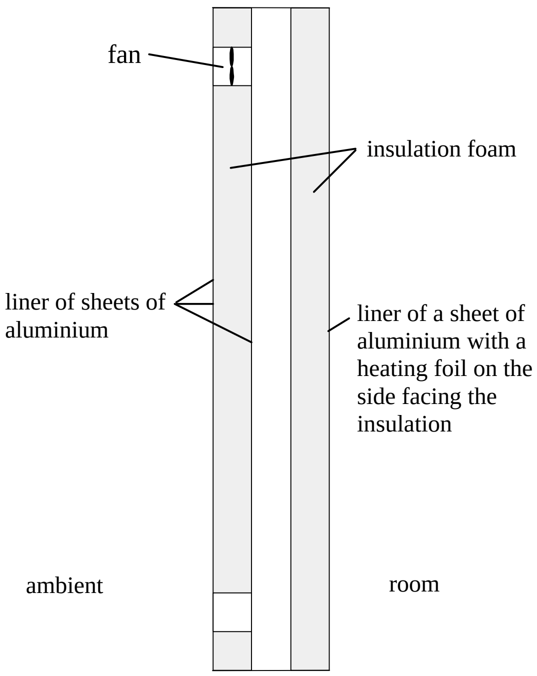


Figure 4. The principle of the adiabatic panels.

Heating foils are – in order to obtain the adiabatic feature of the panels – located on the back side of the aluminium liner facing the room. The temperature of the aluminium sheet facing the room may thus be controlled to a desired temperature as long as it is higher than the ambient temperature. To be able to match the temperature stratification, which may occur in the test room during a test, the four heating foils of the panel – see figure 5 – may be controlled individually.

The panels will act as adiabatic surfaces when the heating foils are controlled so that the surface temperature of the aluminium sheet facing the room is identical to the room temperature of the air just in front of the surface. When it is desirable to perform test with a heat loss through the "adiabatic" panels these can be controlled to create any given heat loos between zero and the heat loos created with no heat from the heating foils and the air gap flushed with ambient air. The air gap of the panels will also be flushed in the case when solar radiation hits the outer surface of the panels and raises the temperature of the air gap to near room temperature. This will else make the control of the internal surface temperature difficult due to a too low heat loss through the panel.

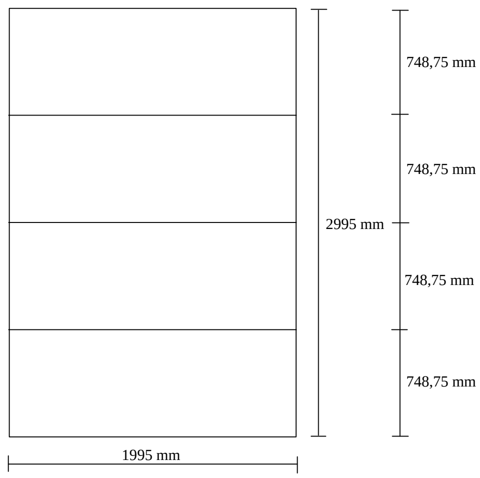


Figure 5. The location of the heating foils of the adiabatic panels. Dimensions without insulation strips.

However, the main problem when creating an adiabatic surface using limited sizes of panels is the cold bridges created by the connections between the panels. Major effort has, therefore, been devoted to develop connections, which will only create neglectable cold bridges. A connection which only create a very small cold bridge has been developed, where the temperature at the connections differs less that 0.2 K from the temperature at the middle of the panels with a identical heat supply at the edge of the panels compared to the middle of the panel. Figures 6-8 show isotherms for a vertical connection, a horizontal connection located in front of a floor partition and a verti-

cal corner under the following conditions: ambient temperature = -12°C, room temperature = 20°C. The 2D thermal calculations was performed using the simulation program HEAT2 (Blomberg, 1997).

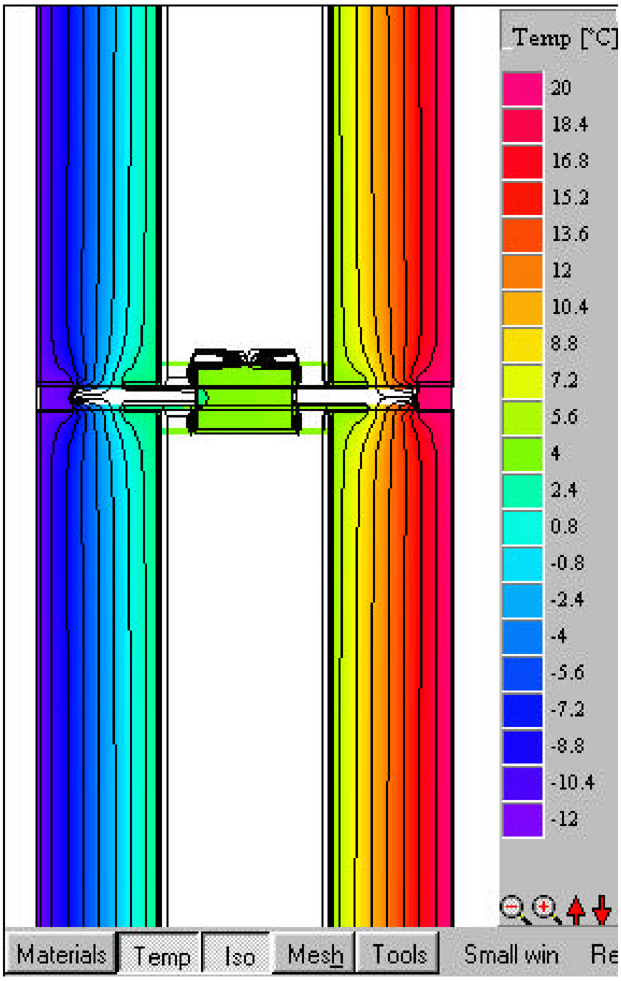
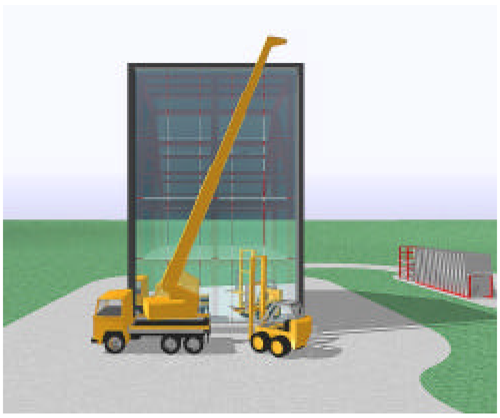


Figure 6. Isotherms for a vertical connection between two adiabatic panels.



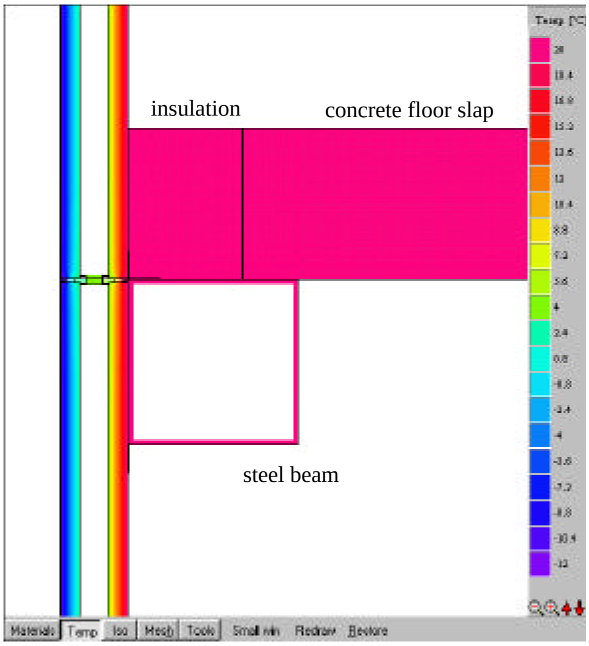


Figure 7. Isotherms for a horizontal connection between two adiabatic panels located in front of a floor partition.

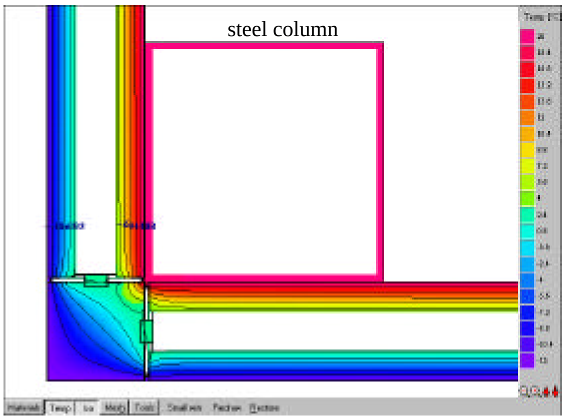


Figure 8. Isotherms for a vertical corner with a corner module and two adiabatic panels.

A more detailed description of the adiabatic panels may be found in (Jensen, 2000).

4.4. Future Work

When writing this paper the final work is being carried out. This involves: how to control the adiabatic panels, the necessary sensor set including measuring system and calculation of the price of the test facility.

After that the work of raising the necessary funding for the erection of the test facility will start.

5. KONKLUSION

It is believed that the developed concept for at test facility for test of building integrated solar energy will form a major break through by really bridging the gap between laboratory tests and real buildings.

It will be possible not only to test the components in a controlled well defined environment where all other thermal processes occurring in a building may be eliminated it will also be possible to introduce these other thermal processes in a controlled way - e.g. gradually in order to gain important information on the interplay between the components and the building. This will lead to more valuable information than if only testing the component detached from the building.

It is believed that the manufactures, the consultant, the architect, the researcher when using the test facility will be able to maximise the knowledge on building integrated solar energy to a larger extent that possible today. This will lead to better performing components both with regards to energy saving and thermal comfort in the building.

6. ACKNOWLEDGEMENT

The work behind the concept and design of the test facility for testing building integrated solar energy was financed by the Danish Agency for Trade and Industry.

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