#10952

Session 1:

Principles of FES and Advanced FES

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The Principles of FES and Advanced FES

1. Introduction

The necessary conditions for human survival are often defined as food and shelter. Although shelter also implies some form of refuge, it may largely be taken to mean thermal comfort.

Historically, thermal comfort has been attained through the evolution of traditional building styles which suit the local environment. Thus the Eskimos' development of igloos was influenced by the availability of materials, the Native Americans' developed lightweight tent-like structures to suit their migratory lifestyles and regions such as Spain and North Africa developed buildings with thick walls to provide a stable, comfortable thermal environment. This final building type 'works' by using the thermal inertia of the walls to mediate the daily temperature swing - smoothing out the effects of hot days and cold nights to a comfortable average.

The examples of a desert building and a Wigwam define the extremes of construction - thermally heavy and thermally light. These building types have radically different behaviours, as shown below:

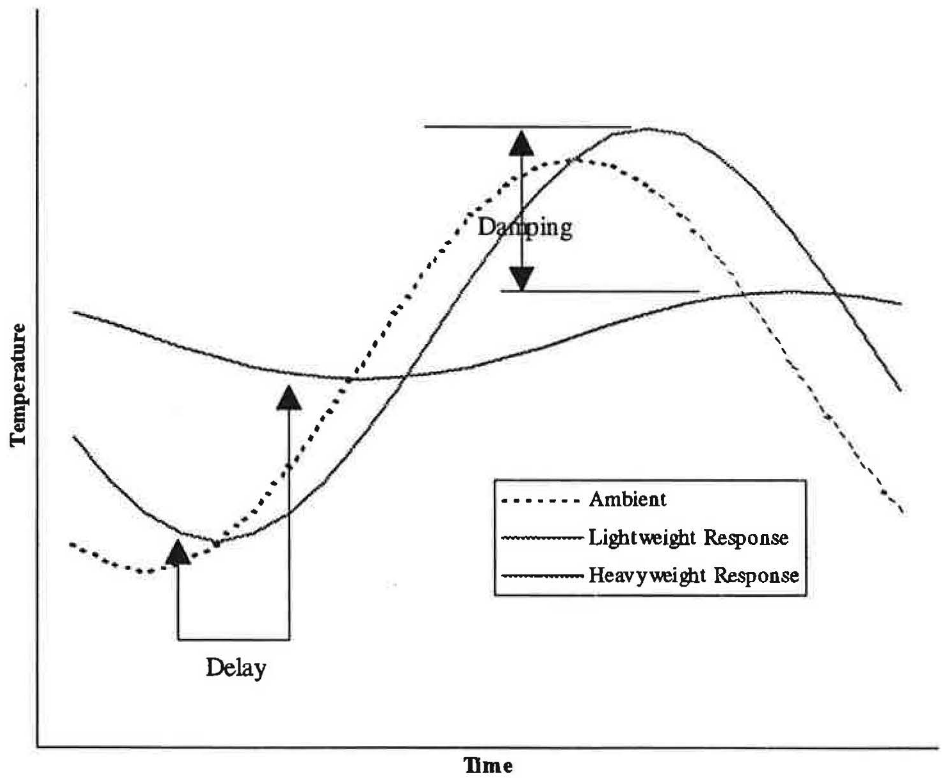

Figure 1

A thermally lightweight building is highly reactive, with internal temperature responding quickly to an injection of energy. Thermally heavy buildings, in contrast, have a high thermal inertia. They act as a 'thermal sponge' or a 'low pass thermal filter', absorbing heat energy for little change in temperature. As shown above, thermally heavy buildings respond to a periodic daily temperature cycle with a profile which is both damped and delayed in comparison to a lightweight building.

In the correct application, the attributes of either of these construction types can be beneficial. Thermally lightweight buildings are ideally suited to intermittent occupancy, where it may be necessary to raise the building's temperature at short notice. Thermally heavy buildings are best suited to applications with extended occupancy, such as hospitals and offices.

Any mismatch between a building's application and its thermal mass results in energy and cost penalties. The classic example is a traditional church, which has a very thermally heavy design but intermittent occupancy. In order to raise the church to a comfortable temperature it is often necessary to start heating several days in advance of the Sunday service.

Another mismatch between design and application can be found in some modern office buildings, which have high heat loads and a thermally lightweight construction (highly insulated with high levels of fenestration, suspended ceilings and fitted carpets). This leads to difficult temperature control problems which are too often solved by increasing the air conditioning and heating plant - using excessive energy to mask problems out rather than taking care to design them out. In an extreme case this behaviour may even lead to the use of energy for heating and then further energy for cooling in the same 24 hour period, as illustrated in Figure 2.

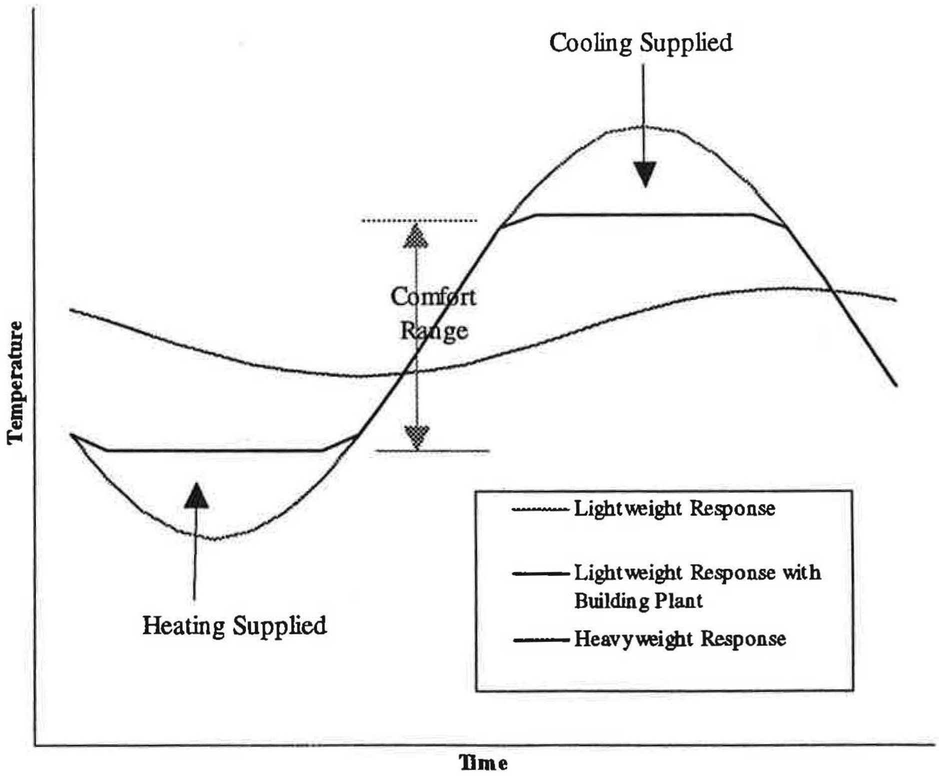

Figure 2

The result of this profligate use of energy is environmental degradation and financial cost.

It is the application of thermally heavy buildings for office use which is the subject of today's seminar. The considered use of a building's structural mass to store energy for temperature control purposes is known as 'Fabric Energy Storage' or FES.

2. Fabric Energy Storage (FES)

FES can be applied with free or mechanical ventilation. In its simplest form, it may involve simply leaving a window open at night as shown below:

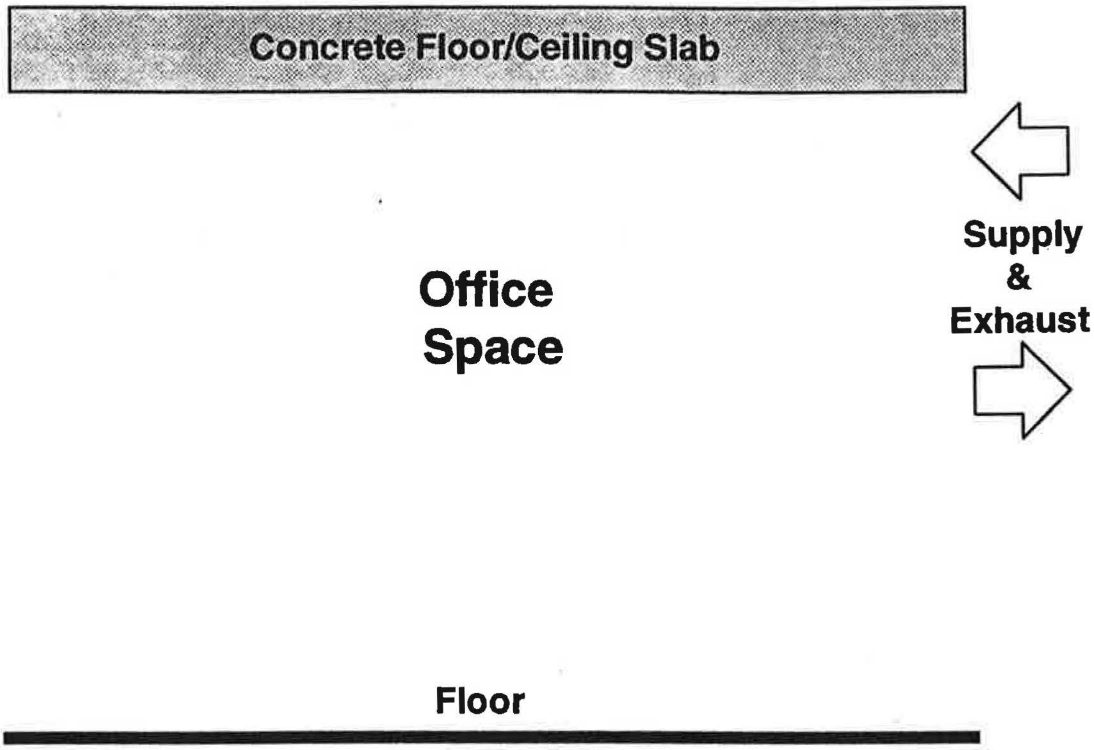

Figure 3

In more sophisticated installations it can involve under-floor mechanical ventilation with high level extract, as indicated in Figure 4. The under-floor ventilation yields forced convective heat transfer between the air and the slab whilst free convection and radiation occur at the top of the room.

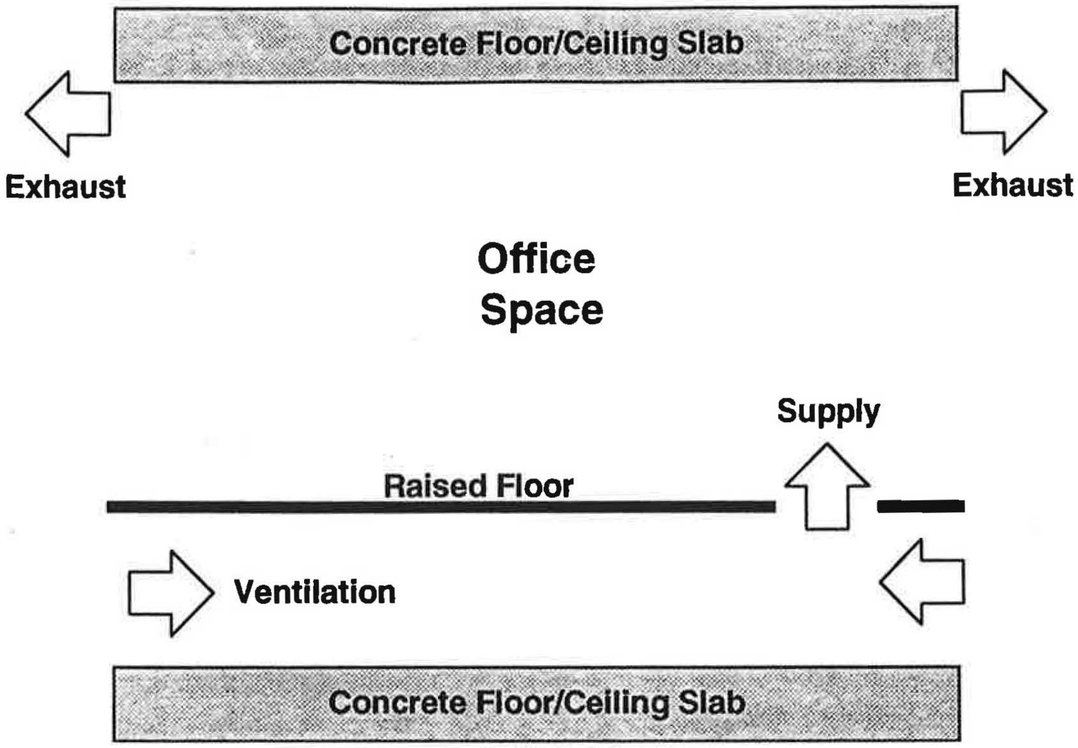

Figure 4

2.1 Benefits of FES

- FES provides the potential to store uncontrolled heat gains (solar or internal) without an excessive temperature rise and then either use it to avoid the need for heating later in the day or store it until it can be purged by night time free cooling.

- FES also allows the utilisation of off-peak electric heating which can be stored in the building's structure until the occupied part of the day. This will reduce running costs as well as limiting the building's maximum demand.

2.2 Difficulties with FES

- The control of an FES building must be pro-active rather than reactive. If the building becomes uncomfortable it will take a lot of time and energy to regain comfortable conditions. In naturally ventilated FES buildings it is particularly difficult to regulate the provision of night time free cooling.

- The heat transfer between the air and the structure is limited as FES relies on external heat transfer, the mechanisms for which are radiation and convection. Convection is dominated by the thermal resistance of the boundary layer of still air which adheres to a surface. Free convection does not produce large enough air velocities to significantly reduce this boundary layer and, whilst forced convection offers some improvement, air velocities are still low and it is difficult to keep the air stream in contact with the slab.

- In naturally ventilated FES buildings, where windows or ventilation pathways must be left open, the provision of night time free cooling can cause security concerns.

The correct application of FES will reduce energy consumption and so CO_2 emissions and cost. It will also reduce refrigerant usage. However, the uncertain and difficult-to-control nature of the heat transfer can lead to uncomfortable occupancy conditions.

One enhancement to FES is to force ventilation *through* the building's structure as well as passing it over an external surface. In this manner, additional forced convective heat transfer is achieved between the ventilation air and the thermal mass. Variation of the duration and flow rate of mechanical ventilation provides the opportunity for enhanced control of the heat exchange.

3. Advanced FES

Advanced FES has been applied in traditional architecture for thousands of years. Figure 5 shows a traditional desert dwelling from the area of modern-day Iraq. Ventilation is supplied via the roof-top wind scoop and passed through a cavity wall before entering the occupied space. Hot day time air is thus cooled by interaction with the walls and the heat transferred is later returned to warm the cold night air.

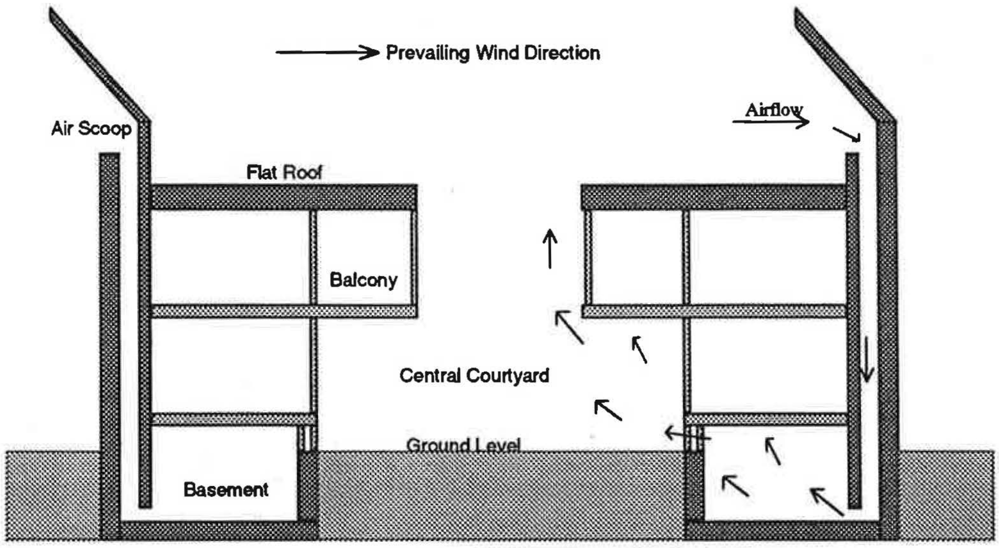

Figure 5

More recently, advanced FES has been applied to providing low cost cooling in modern, energy efficient offices. This provides all the benefits of 'simple' FES, but with enhanced comfort and control.

Several advanced FES systems have been applied in the UK, as shown below:

3.1 Plenum and Slab

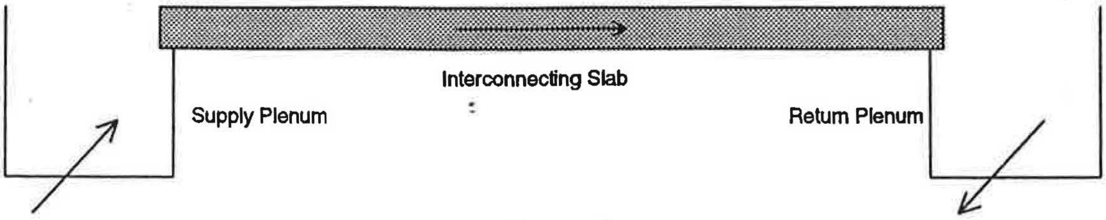

Figure 6

The 'Plenum and Slab' system was the first to be applied in the UK, in 1978. Air is supplied through a number of large plenums which are inter-connected by the hollow cores of the building's floor slabs. This system was used at the South West Regional Headquarters of the Central Electricity Generating Board, which is a prestige office building at Bedminster Down, Bristol. It was the first UK building to apply an advanced FES system and is, to September 1997, the only building to use Plenum and Slab technique.

The building has been fairly successful although it was necessary to retrospectively install some small mechanical cooling plant which is used on around 10 to 15 nights each year.

The Plenum and Slab design is not fully optimised for advanced FES. It seems to have focused upon the slabs as a method of providing an in-built under floor supply system, viewing the benefits of thermal storage as a secondary advantage.

3.2 The Generic Slab

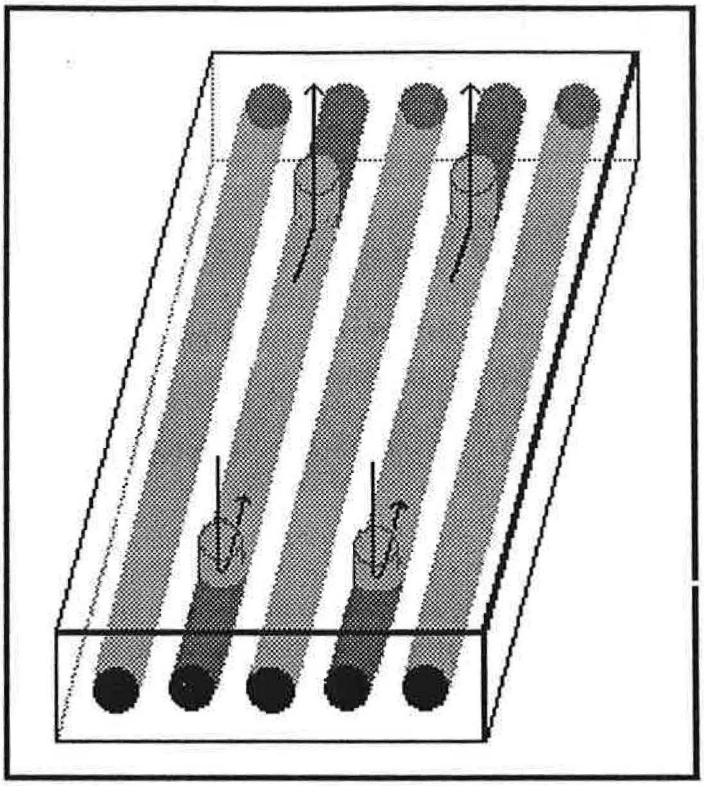

Figure 7

The generic slab, shown in Figure 7, was applied in 1994 in the Ionica building at Cambridge. The 4,000m^2, 3 storey office has been monitored by both the BSRIA and the BRE. It was designed to use a complicated mixture of passive stack, wind driven and mechanical ventilation along with openable windows, external shading and evaporative cooling.

An article written shortly after the building's construction predicted that the slabs would provide a cooling potential of between 10 and 15W/m^2, although the associated air flow rate and temperature differential were not stated.

3.3 The Hollow Core Screed

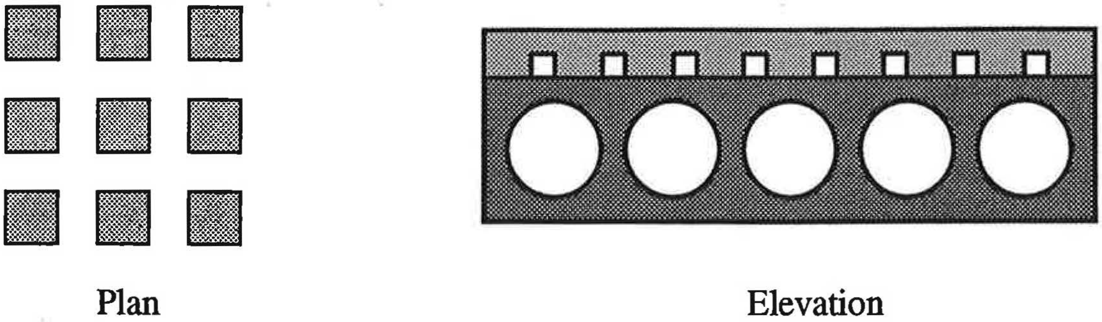

Figure 8

December 1993 brought the announcement of a patented advanced FES system which uses a hollow-core screed to distribute ventilation air. This technique is the only advanced FES system that may be retrofitted into an existing building, although it has yet to be put into practice. The complicated air path and small core height are designed to produce highly turbulent airflow and good heat transfer, however, there are unresolved concerns about inspecting and cleaning such a narrow air path.

3.4 The Termodeck Slab

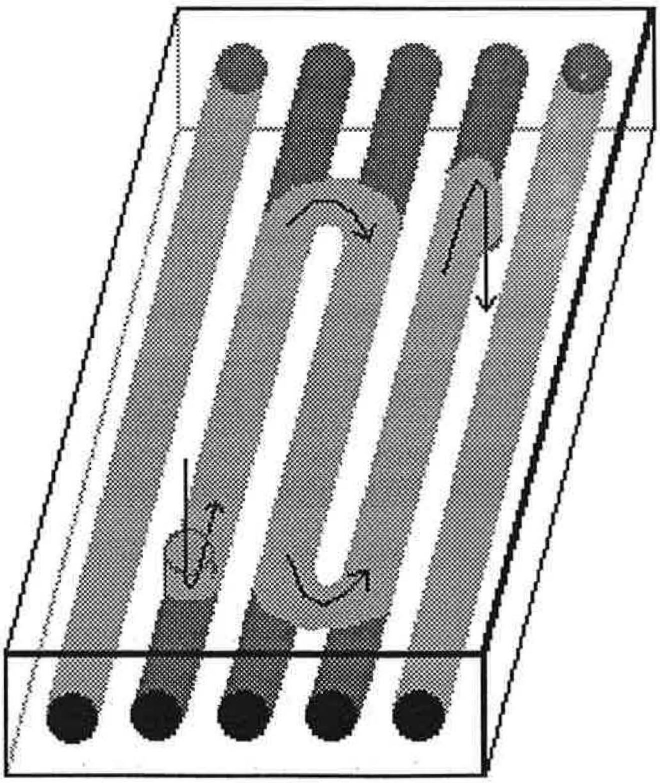

Figure 9

The most widely applied advanced FES system has been the patented Termodeck slab, which is shown above. The technique originated in Sweden in the late 1970's and has been applied in over 1,000,000m² of commercial buildings in Sweden, Belgium, Holland, Saudi Arabia and the UK.

The standard layout of a Termodeck building is very simple, as shown below. The exposed slabs are fed from a main supply duct which runs along a central corridor and is hidden behind a false ceiling. Air is supplied to the offices via ceiling diffusers and exits via high level grills back into the central corridor ceiling plenum, from where it is extracted.

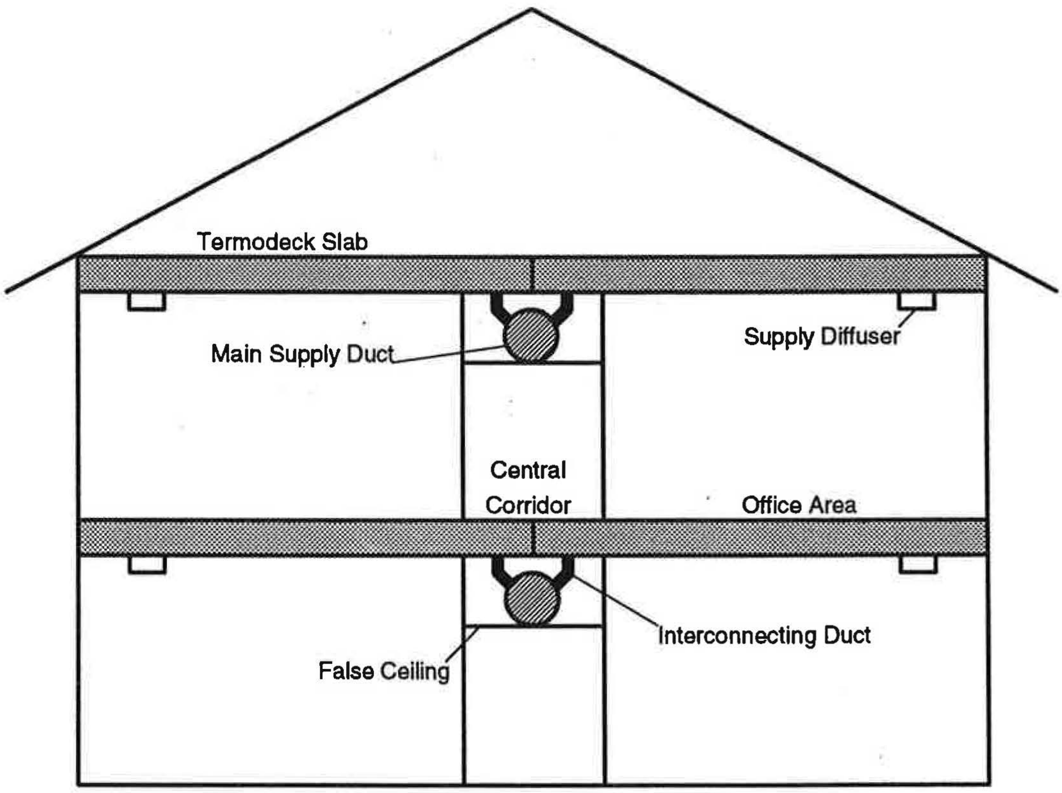

Figure 10

The Weidmuller Interface office at West Malling, Kent was the first UK application of Termodeck. It is a 2,400m^2, two storey office with supplementary heating and cooling from electric heater batteries, an indirect evaporative cooler and air supply via low level diffusers to provide displacement ventilation. Independent monitoring of the building has been undertaken by EA Technology, results from which will be described in later presentations.

The University of East Anglia's 'Elizabeth Fry Building' was the UK's second Termodeck project. The 3,250m^2, four storey building contains lecture halls, meeting rooms and a restaurant. In contrast to the Weidmuller building, it is laid out along traditional Termodeck lines with ventilation ducts hidden behind a false ceiling along the central corridor and air supply to the rooms via ceiling diffusers.

4. Summary

4.1 Benefits of Advanced FES

The benefits provided by advanced FES include:

- Stable, comfortable temperatures
- Low energy consumption leading to;
    low running costs
    low CO_2 emissions
- No refrigerant usage for air conditioning
- Reduced space required for heating and cooling plant
- Full fresh air ventilation