

Performance of Dynamic Insulation

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ABSTRACT

Dynamic insulation is when air is drawn into a building through its insulation. It is being used successfully in Scandinavia largely, but not exclusively, on a domestic scale. The McLaren Sports Centre at Callander in Scotland, which was occupied in July 1998, is the first major building in the UK to incorporate the technique. It incorporates a sports hall, bowling hall, squash courts and a 20m swimming pool. Each has air introduced from pressurised ceiling voids through a dynamic insulation layer. Of particular interest is the performance of the roof above the swimming pool area where a significant moisture load exists by comparison with the cooler and drier sports hall.

The architects have experience in sports building design and innovation in pursuit of sustainable development. They maintain a commitment to health and affordability as intrinsic elements of sustainability for community buildings. They chose to incorporate dynamic insulation because a number of claimed benefits could support them in pursuing structural soundness, a healthy indoor climate, low velocity and well distributed air and capital and running cost benefits. Sport Scotland, are committed to ensuring that encouraging and supporting healthy activities is underpinned through the procurement of cost manageable *healthy buildings for healthy pursuits*. They have supported the development of dynamic insulation and, with Sport England and the DETR Construction Directorate, they have supported work to appraise and optimise the performance of the building. This paper reports on the history of the technique and research to date.

1.0 The Concept

Dynamic insulation is when ventilation air is introduced through a building's fabric. It is one of a number of innovations concerned with building fabric which have been applied by architects seeking to reduce capital and running costs associated with mechanical systems, without loss of comfort. There is also potential for indoor health benefits through improved moisture stability and avoidance of problems associated with lack of adequate maintenance of supply side ductwork. ^{1,2} Heat, usually lost in conduction, is recovered by air drawn into the building through the insulation. The insulation acts as a counter-flow heat exchanger. There are many examples of its use in buildings with high moisture content and a constantly high ventilation rate. Typically these were farmsteadings but the idea has slowly been introduced into housing, schools, offices and sports halls. In Sweden several hundred buildings incorporated dynamic insulation.

2.0 History

Dynamic insulation emerged as a concept in the 1960's, but is traceable to mid 19th Century Germany where research was undertaken into transportation of air and moisture through buildings and building materials. This led to publication of values for air change rates in dwellings and air permeability of common building

¹ Bearg D.W. *Indoor Air Quality and HVAC Systems*, 1993, Lewis

² Fanger O.L. *Hidden Oils in Sick Buildings* ASHRAE Journal 1988

materials.³Theresearchdevelopedtoproducedetaileddescriptionsofairflowsthroughcompositeporous walls.⁴Inthe1960 's porosity was investigated as a potentially positive attribute, initially through studies in agricultural buildings. Work developed simultaneously in Austria, Canada, Norway and Sweden.

In 1965 Pattie, in Canada, sets out the thermal principles of dynamic insulation and a mathematical technique for calculating its effect. ⁵Subsequent projects quantified the contribution of dynamic insulation to ventilation, indoor air quality and reduction of energy consumption. This provided experimental evidence, supportive thermodynamic theory, calculation methods and the first measured data on the relative heat recovery efficiencies of different ventilation rates and envelope constructions. Pattie went on to design and construct his own dynamically insulated house. Work in Sweden researched the effects of air exchange on surface temperatures and changes in transmission of heat by convection and radiation. ⁶

Also in the 1960 's, Grue, in Norway, identified heat recovery occurring in traditional steadings as a result of the stack effect drawing air across hay stored at high level. ⁷This led to development of dynamic insulation in farm buildings and in 1968 the principle came into common use in Scandinavian animal houses. ^{8-9,10}

In the 1990 's Brunsell, in Norway, monitored performance of dynamically insulated houses and found a zero U-value in building elements, without draught, was possible but, the construction was vital to the success. ¹¹ A study carried out in 1993 in Japan indicated 50% of the transmission loss from a family house could be recovered using dynamic insulation giving well distributed and preheated draught free, ventilation. ¹²

3.0 Physics

3.1 Pro -flux and Contra -flux

Dynamic insulation relies on controlled constant air flow through a membrane due to a pressure difference across it. The pressure differential, can be induced through natural or mechanical means. Air is typically

³Pettenkofer M.V., *Über den Luftwechsel in Wohngebäuden (Air Change in Houses) Literarisch - Artistische Anstalt der J.G.Cotta & Eschen Buchhandlung*, 1858, München

⁴M Ercker M., *Versuche über die Porosität einiger Baumaterialien sowie über den künstlichen und natürlichen Luftwechsel in Stallgebäuden (Porosity of building materials and artificial and natural air change rates in barns)*, Journal f. Landwirtschaft, 1870. 18: p340 & 402

⁵Pattie D.R., *Heat transmission of porous materials in ventilation*, Trans. of the American Society of Agricultural Engineers (ASAE), 9, 1966. Paper 65: p.409, 410, 416.

⁶Thoren T., *Hallbyggnader med dynamisk isolering*, R:661986 Byggnadsforskning, Stockholm, Sweden

⁷Liddel H.L., Roalkvam D and McKenzie I., *Dynamic Insulation (Pore Ventilation)*, CIBSE 1996

⁸Grue T., *Pustende byggningskonstruksjoner (Breathing building construction)*, ASE Stillwater, Oklahoma, 1974

⁹Dalehaug A., *Utrekning av dynamisk U-verdi for treullsementplater*, 1988, HBT, NTH

¹⁰Halliday S.P., Ed., Gaia Research Seminar *Dynamic Insulation in Practice*, McLaren Community Leisure Centre, Callander, November 1998 ISBN 0953312623

¹¹Brunsell J.T., *The Performance of Dynamic Insulation in Two Residential Buildings*, Air Infiltration Review Vol 16 No 4, 1995

¹²Dalehaug A., *Dynamic Insulation in Walls*, Hokkaido Prefectural Cold Region Housing and Urban Research Institute, 1993

exhausted through a fan assisted vertical flue although there are examples of the pressure differential being achieved by exploiting and enhancing the stack effect.

Fig 1. Temperature Gradient through wall in contra -flux & pro -flux mode
When air travels in the opposite direction to the conduction it is referred to as contra -flux insulation and when in the same direction, pro -flux. If the pores of the material are fine then the air transmission is directly proportional to the effective pressure difference. In the case of contra -flux flow heat -exchanger results between cold air being introduced into the structure and conduction heat loss. The existence of an non -linear temperature gradient through the wall has been used to provide evidence of the existence of bulk air flow, Figure 1.

3.2 Dynamic U -value

The dynamic U -value, U_{dyn} is the U -value of the wall modified by the air velocity across it and the insulation thickness.¹³ The effect of the heat exchange when air is drawn into the building is to reduce the effective U -value of the wall by an amount which corresponds to the heat gains from convection. As the air velocity increases the U -value decreases, towards zero.

Where large areas are used the air velocity is of the order of m/h. Even at these low air velocities, well below the 0.1 m/s recognised as the threshold for comfort, very high values of thermal resistance occur.

Fig 2. Dynamic U -value

This has been validated and quantified using steady state models developed by Sorsell¹⁴ and Taylor.¹⁵

3.3 Temperature of Internal Wall

One impact of the air flow through the wall in the case of contra -flux flow is that the temperature of the internal wall is reduced as a consequence of air exchange and this reduces the radiant temperature.¹⁶ This has been quantified for a range of air flow rates, temperature differences and insulation values.

3.4 Stratification

The use of the ceiling as the dynamic insulation membrane enables energy saving to be achieved not merely by improved U -value of the construction but also by the removal of the hot -air cushion at the underside of the ceiling. This stratification cannot be readily avoided except through the use of high temperature radiant systems.

3.5 Condensation Risk

A significant amount of building damage is due to air leakage from inside to outside because of a local or general overpressure. Creating an underpressure internally will prevent the outward air flow that causes condensation. In buildings with a high moisture content, such as swimming pools, creation of an underpressure is recognised good practice but there is a risk it brings pollutants from the construction into the building. With a dynamic membrane the temperature profile is influenced by the air flows such that most of the temperature exchange occurs at the internal edge of the insulation, and potentially beyond the insulation in the contiguous

¹³ *Dynamisk Isolasjon - Teori og principper* Byggforskserien 472..451 Sending -21995

¹⁴ Sorsell A., Research Consultancy Gaia Architects

¹⁵ Taylor B. J., The air permeability of Building Materials: Measurement and Application, February 1996.

¹⁶ as9

air, Figure 3. The constant airstream from the cold to the warm side effectively ventilates the construction and the building. Because the air is always moving to the warm side, where its potential to hold moisture increases, and because at typical ventilation rates the velocity of the incoming air overcomes the outward diffusion of water vapour, condensation cannot occur.

Figure 3. Temperature gradient with ceiling pore - ventilated

Provided that air continues to flow, the building membrane effectively creates its own vapour barrier. Gaps, holes or blockages in the insulation, or along the supporting frames, which allow uncontrolled air leakage from the internal, normally, warm side, to the external, normally cold side, will distort the isotherms and could give rise to local condensation. It is important to ensure a uniform air flow resistance, hence the resistance layer is best installed as a continuous unbroken sheet.

3.6 Indoor Air Quality

Without evidence, no benefits in indoor air quality can be anticipated purely as a consequence of the dynamic insulation, although: -

Advantages will accrue from removal of intake ducts which are recognised sources of indoor pollution. The terminal filtration aspects, should theoretically contribute to indoor air quality benefits, because of the big surface and low velocity, provided that filtration occurs at the correct scale and does not give rise to the build up of secondary pollutants. Research by S ¹⁷ Sallvik indicates that clogging of the fabric is unlikely to be a concern but further research is required.

Gases, particles or biological activity in the insulation do not cause problems.

The selection of benign materials will contribute to improving indoor air quality by removing pollutants at source.

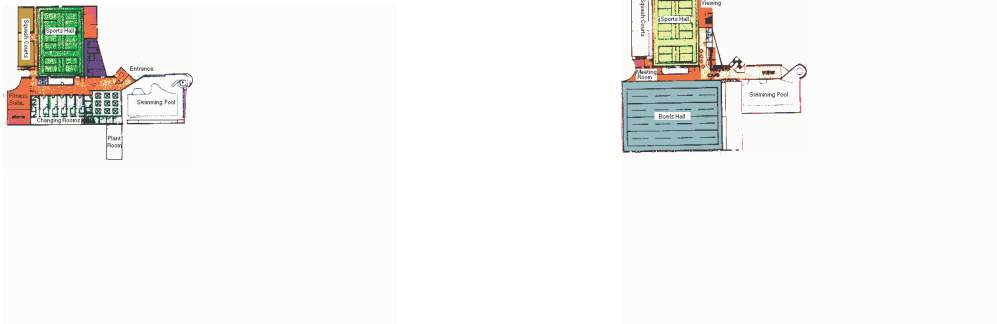
Dynamic insulation also permits large quantities of air to be delivered without causing disturbance through high velocities and wide difference in the incoming room air temperature without giving rise to discomfort. This offers a possible alternative, for example to perforated ceilings used in operating theatres, computer suites and clean rooms. It has sometimes been claimed that counter -flow of moisture and pollutants through dynamic insulation would allow reductions in ventilation rates and savings in capital and running costs. There is no evidence to indicate that diffusion through the fabric, of moisture or pollutants, is likely to be significant against the air flow. The most likely means of removal is with moisture through exhaust air.

¹⁷Sallvik K., *The influence of clogging on the air permeability in porous materials used for air inlets* Internationales Symposium über Porenluftung 1988, "Porenluftung 1988" BAL Gumpenstein, Austria.

¹⁸Nelson G., *The Architecture of Building Services* Batsford 1995

4.0 Project Analysis

4.1 Building Layout



4.2 Design Strategy

The aim at MCLC was to provide an energy efficient and healthy building.

4.2.1 Detail Design - Energy Issues

Form and Fabric

The building is set into the hillside to reduce surface heat loss. The % of glazed openings is small. The windows in the pool hall are all double glazed. The insulation level of the main structure are $0.39 \text{ W/m}^2 \text{ K}$. Heat loss was to be reduced by lower loft temperatures than in a traditional design. Attention was paid to the integrity of the roof void and internal spaces to ensure minimum fan power and minimum infiltration/exfiltration.

Reducing the Temperature Profile of High Spaces

The dynamic insulation is driven by the extracts supplemented by overpressure in the loft. The supply air is heated as it passes through the ceiling insulation and by heat exchange below the ceiling with radiation from the heated floor and pool and mixing with air already in the pool hall. The downward flow of air reduces stratification.

Providing all pool heating from heat recovery

Heat is recovered from the air extracted from the pool hall and wet changing areas to a heat pump with evaporator in the pool hall exhaust and condenser in the main pool water circuit. This provides heat for the pool water which is a constant heat load all year round, rather than preheating the supply air, which often requires no heating. In normal operation the heat recovered can exceed the pool heating load, excess is dumped.

Keeping ventilation rates to an acceptable minimum

The aim was to provide an optimum air change rate for building integrity, fresh air requirements of users and dilution of pollutants. The air is injected through the dynamic insulation to the main sports areas and then cascaded into the ancillary areas before being exhausted from the building.

Low temperature heating systems

Underfloor heating is provided to the ground floor areas. In the pool hall and wet changing areas it is supplemented by perimeter radiators, convectors and a pipe coil. The bowl shall be heated by thermostatically controlled radiators. The space heating installation comprises a lead gas-fired condensing gas boiler plus a high efficiency boiler. Underfloor heating and low return temperature is consistent with using condensing boilers at maximum efficiency.

Efficient domestic hot water delivery

Demand for hot water in sports/swimming halls is high and a large number of dry and wet changing facilities have been included to accommodate the potential use of neighbouring playing fields. Hot water is supplied from three conventional atmospheric gas boilers with plate heat exchangers to provide instantaneous hot water whatever the usage pattern. The major advantages are avoidance of hot water storage with associated management, space and health implications but the boilers need to be adequately controlled with low standing losses.

Efficient and well controlled lighting

Dry changing, sportshall and squash courts all have presence detection to ensure economic usage of electrical power. Lights for the swimming pool, bowls hall, circulation and outdoor areas are operated from a central panel at reception, which, if appropriately managed should encourage efficient operation.

4.2.2 Detail Design - Health Issues

Minimum use of ductwork

This is consistent with concerns about the build up of contaminants and ongoing maintenance requirements of inlet ductwork

Specification of benign materials

The overall strategy for materials is that they should: -

A downward ventilation strategy

Normally ventilation air is introduced at high velocity and creates turbulence in the internal air. This is intended to create homogeneity and dilute pollutants in the internal air. Dynamic insulation is intended to push away the polluted air and create less air movement and mixing. With the extract close to the pool surface, the most polluted and humid air will be extracted.

Highly efficient filtration of inlet air

This is consistent with contemporary understanding although more research may be required.

Moisture Buffering

High internal temperatures and vapour production make the control of relative humidity fundamental to the preservation of the building structure and fabric in a sound condition. Extract for the building is via the changing rooms and shower areas; and the moisture laden areas are the last to be ventilated. The incoming air is warmed and hence its capacity to hold moisture increases and there is no risk of condensation provided that the flow is even and that there are no leakages which would allow warm air to travel outward. The use of hygroscopic materials was intended to reduce moisture oscillation and cut down problems with mould, bacteria and viruses.

The pool hall volume is approximately 1500 m³ with air at 30 °C and 60% RH. The air volume capacity to absorb moisture is 18 kg. In the event of a system breakdown the hall will reach 100% RH after 24 minutes. The overpressure in the top of the building will be a minimum of 10 Pa (outside air temperature -5 °C). Warm air at 100% RH will leak into the construction. In a normal swimming pool design the insulation materials cannot take any moisture and it is absorbed by the timber. When the system restarts the construction will only dry out very slowly and condensation remains a big risk. In the dynamic insulated pool hall, the ceiling has a maximum capacity of 400 - 500 kg of moisture. In breakdown mode the capacity is about 200 - 250 kg (4 - 5 hours) The moisture will enter the loft and escape through leaks. When the system starts again the construction will be ventilated and dry out quickly.

Pool treatment

A primary design parameter was the desire to reduce disinfectant use and consequently the free chloramines which contribute to chlorine smell, poor indoor air quality and eye irritations. A particular concern in pool design is the lack of adequate air circulation in certain areas, in particular above the pool water, which can lead to unacceptable concentrations of pollutants and/or increased ventilation requirement. UV pool water

treatment, which inactivates bacteria and helps breakdown chloramines and other pollutants, was considered and then selected through the tender process. Additional neutralising chemicals and chlorine disinfectants are used alongside the UV, on a carefully controlled basis, to provide the necessary pH residual chlorine.

4.3 Design Specification

The system is designed for an outside winter temperature of -5°C & 100% RH.

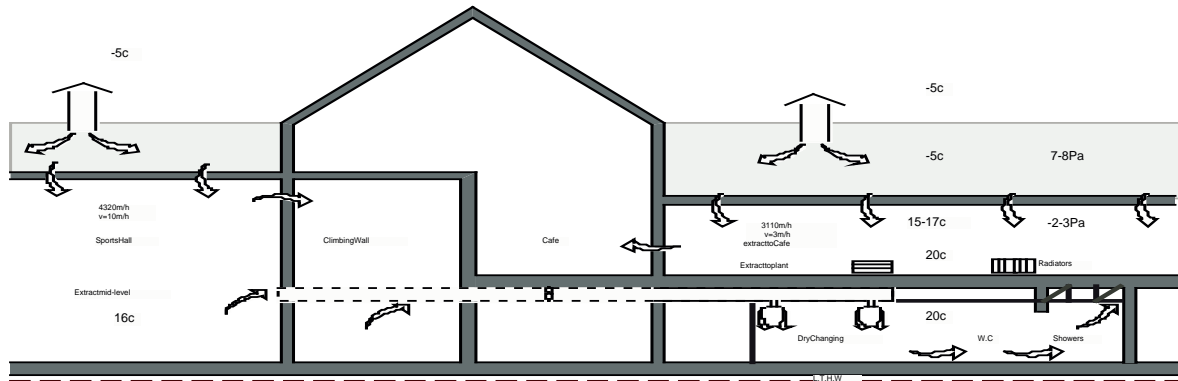


Figure 6. Profile of bowl hall in winter

Constant volume dynamic ventilation is supplied to the squash courts, sport hall, bowl hall and wet changing area. With variable volume flow to the pool hall. The dry changing have conventional supply and extract ventilation and staff rooms are naturally ventilated via openable windows.

BOWLSHALL: -Design temperature at occupancy is 20°C . Ventilation of $3110\text{ m}^3/\text{h}$ (0.8 ac/h) is provided by blowing air into the loft of the bowl hall, Figure 6, creating a pressure differential of approximately 10 Pa, and a velocity of 3 m/h. An air temperature of 15°C - 17°C was predicted at the top of the room. The air passes on via transfer grilles to the first floor 'street' and cafe/viewing area and is extracted via the server and kitchen extract. Supplementary heating is provided by thermostatically controlled low temperature radiators.

SPORTSHALL: -Design temperature is 16°C . Unheated ventilation air is supplied into the pressurised roof void using two air handling units, each with a design duty of $1.38\text{ m}^3/\text{sec}$. It is then drawn into the hall (velocity of 10 m/h) via the dynamic insulation to achieve 9°C - 11°C by exchange in the fabric and hot air at the top of the room, Figure 7. The air is extracted through two grilles, and transferred to the changing rooms using two ceiling void air handling units rated at $0.78\text{ m}^3/\text{sec}$ each. A small amount of air ($0.26\text{ m}^3/\text{sec}$) is also transferred to the climbing wall when its extract fan operates.

POOLHALL: -The swimming pool area is ventilated by the air supplied via the dynamic insulated ceiling. With a high internal temperature and air change rate, the heat required by the fresh air is much greater than in the sport hall and bowl hall; and greatly exceeds the normal heat loss in the ceiling. The temperature deficit is intended to be made up by the space heating (under floor and radiators) in the swimming pool. Preheating of the supply air was provided as a precaution.

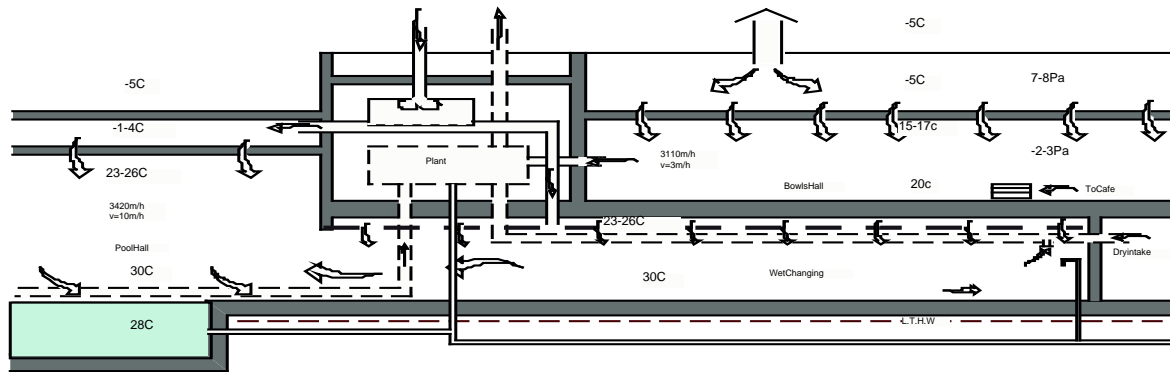


Figure 7: Profile of swimming pool hall in winter

The air is extracted from the pool hall to the wet changing area and shower rooms then to an air-to-water heat pump which preheats the pool water. The required fresh air volume and associated extract rate is determined by a humidistat in the pool hall extract, set at 60% +/- 5% humidity. This varies the supply air volume, raising it to a preset (but adjustable) high speed if the RH rises above 70% and falling to a preset low speed if it falls below 60%. A minimum of 1.7 ac/h is available to control humidity during quiet conditions and 4.6 ac/h is available for peak ventilation requirements. Normally the maximum fan speed is set lower than this but the management have a boost facility for temporary running at full speed in the event of perceived poor air quality or high summertime temperatures. The pool cover allows the ventilation rate to be reduced at night. The summer condition allows for a loft overpressure of 25 Pa and a pool hall underpressure of 7 -10 Pa with an exchange through the ceiling fabric of 25 m/h.

The wet changing area is an extension of the pool hall. It has underfloor heating and air delivered through the ceiling at a velocity of 12 m/hr. Design temperature at occupancy height is 20 -30°C and a ventilation rate of 1400 m³/h. Air is extracted to shower spaces and then combined with the swimming pool extract to pass over the heat pump evaporator coil.

Additional Ventilation Aspects

The insulating material in the ceilings is hygroscopic cellulose fibre and its ability to emit and absorb water contributes to stabilising the humidity of the internal air and reducing ventilation requirements. According to research at SBRi the humidity buffer in the surface of materials in dwellings deals with 3 times more humidity than the ventilation system over short variations (24 hour).¹⁹

Where dynamically insulated systems are run with extract only they may be sensitive to wind and occupancy. There will be some minor effects when systems are operating without a pressurised loft but the effect is minimal when such a loft exists. At McLaren the existence of the pressurised loft makes this system robust. Open doors and windows will have some minor impact on the air flow with less air being drawn through the dynamically insulated ceiling if the underpressure indoors is reduced. This situation is not critical unless a large area is opened toward high wind - unlikely to occur at critical cold times of year. However this would cause a significant overpressure and could lead to flow reversal and condensation. The sports and bowls halls could tolerate this situation for a short time but the pool hall situation is more sensitive.

5.0 The Monitoring

The monitoring focuses on

The performance of the dynamic insulation in maintaining a comfortable environment;

Heat and moisture transfer through the dynamic insulation layer to identify both the temperature and moisture profiles and the risks of any damage to the fabric or the dynamic insulation itself through high moisture levels, particularly over the wet areas;

Energy requirements;

Ways of further optimising the application and use of dynamic insulation and associated mechanical plant in this and future applications.

The swimming pool area and sports hall are being monitored as these are most typical of wet and dry sports areas. Both also have their air plenums in the roof void, under an insulated slated roof for the swimming pool and an uninsulated profiled metal roof for the sports hall.

The building was handed over in July 1998. During the first year's defects liability period, monitoring was devoted to getting a feel of what was going on. In the second year conditions above, below and in layers within the dynamic insulation have been monitored in the two areas using vertical arrays of temperature and moisture sensors which project 100mm above the control layer and several metres into each room. The swimming pool has an additional short string and additional sensors at various positions in the roof void, this is because the ceiling in the swimming pool is stepped. The differential pressure is measured across the swimming pool roof. Swimming pool supply and extract air is monitored at the plant room, with respect to volume, r/h and temperature. The supply air is also monitored in the roof. Short surveys have also been used to reconcile observed patterns of consumption with metered data. These used a variant of the EARM. ²⁰

There are external sensors for wind speed, temperature and relative humidity. Temperature and humidity sensors indicate the extent of solar gain and any condensation above the sports hall.

6.0 Conclusions

i. Structural soundness

The roof is a especially vulnerable element in swimming pool design. Moisture meter readings of timbers in the roof space, the Warmcell and Heraklith gavelow measurements of 10% or less, confirming that the pressurised dynamic insulation is successfully resisting backflow of water vapour. Owing to a shortfall in the capacity of the extract system, the pool hall is overpressurised and moisture can leak into the fabric and the rest of the building. This might cause moisture damage, although none is yet apparent. Clearly there is an extra risk if the extract fans break down although the situation could be remedied when the extract was reestablished.

If the inlet fans break down with windows and doors closed the underpressure will be maintained by the extract fans. This might not be enough to maintain the inward air flow through the dynamically insulated ceiling but it will help to protect the building from moisture damage. Any alarms regarding breakdown or inefficiency in fan operation need to be clear to allow problems to be acted upon appropriately and remedied quickly.

If both systems break down the air flow in the ceiling will reverse and increase the risk of condensation in the ceiling and in cold weather possibly in the roof space. In a dynamically insulated ceiling using hygroscopic material there is a buffer effect, which is not normally available, before a dangerous level of humidity arises which would create lasting damage. Mould, fungi etc. require longer periods of high humidity.²¹ Risks during a breakdown will be reduced if the pool cover is in place to reduce evaporation.

During the monitoring period there have been several plant breakdowns in which the buffering effect of the insulation was demonstrated, together with the rapid restoration of dry conditions once the plant restarts.

It clearly requires integrated design of the fabric, primary structure and services to provide the innovative combination of a tight building with controlled infiltration through a designed building membrane. It is apparent that proper construction is crucially important to the ceiling integrity. This may require close site supervision and/or installed monitoring. Any alarms regarding breakdown or inefficiency in the fan power need to be transparent to allow problems to be acted upon appropriately and remedied quickly. Also during any breakdown or extended maintenance the pool cover should be in place to reduce evaporation. If the construction is undertaken properly there should be no problem of insulation or air short circuits. A positive dialogue between designers and contractors is important to ensure that the air and thermal integrity of a dynamically insulated ceiling performs to the highest specification.

ii. Healthy and satisfactory indoor climate

'Healthy buildings for healthy pursuits' is one of the priority interests of one of the sponsors - Sportscotland - and was a significant factor in the development of the technique. To date - sensations of air quality remain wholly subjective. The atmosphere in the pool hall is good but the extent of the contribution of the dynamic insulation to indoor air quality cannot be quantified.

The monitoring suggests little or no counter diffusion of moisture; and hence presumably of other gases. All of the evidence for counter -flow diffusion appears circumstantial and the physical laws governing the process indicate that the majority of indoor pollutants and internal moisture would be transported by air movement and extracted through vents, rather than diffused.

iii. Functional Benefits

Initially air flows in the spaces were more complex than anticipated owing to the effects of thermally induced air circulation and the lack of complete commissioning of some items of plant. It would be interesting to investigate similar buildings to identify whether similar local turbulence effects are evident.

²¹Effect of Insulation on the Biodeterioration of Buildings - <http://www.vtt.fi/inf/>

More recent data indicate lower rotational air velocities. A fuller appraisal will be possible when the defects liability period and associated snagging is completed.

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iv. Capital and Cost Benefits

Minimising Plant

At McLaren plant reduction was largely resisted to ensure failsafe innovation but the experience and the monitoring programme will identify opportunities to reduce plant and will enable future design to benefit.

Energy Efficiency

The energy conservation potential of the dynamic insulation at McLaren is equivalent to the heat recovery in the insulation, the de-stratification, possible reduction in air change rate and fan power (yet to be verified); and avoidance of parasitic losses which would have occurred if the air supply units in the dry areas had used heater batteries.

Transfer of air across the dynamic insulation appears to be as designed and the relatively tight ceiling construction means that the 50% margins allowed for on supply fan capacity are too high.

Energy savings of up to 50% have been quoted for buildings using dynamic insulation. However, there is a lack of any real information on achieved energy savings. SSC Study 47 drew attention to the need to modify figures quoted in the Norwegian context with respect to energy, CO₂ and cost data to take account of the different temperatures, lower building costs, different fuel tariffs and fuel mix of the Scottish context.²²

A preliminary study was undertaken to coincide with installation of monitoring equipment. This was to check the performance of the dynamic insulation and to make a brief assessment of the pattern of energy use and the potential for savings prior to final installation of the equipment. The energy costs were higher than anticipated, accentuated by the omission of some energy consuming facilities (e.g. sauna, steam room, fitness room, external lighting, security and sound systems) from the original estimates. The study identified scope for energy cost savings largely through closer attention to operation and control settings; improved operation of conventional systems and variable volume operation of air to the swimming pool ceiling void. Of note was the decision to change the fans installed to half their maximum design duty and the large scope for economies on swimming pool water pumping, particularly overnight.

As of February 2000 the building was operating at 390 kWh/m² gas and 190 kWh/m² electricity against good practice benchmarks of 360 kWh/m² and 150 kWh/m². There is still major scope for reductions through fine-tuning, improved management procedures and minor alterations.

The monitoring work has been supported by the DETRC Construction Directorate's Partners in Innovation Scheme, by Sports Scotland and Sport England.

²² SSC47, Gaia Research 1997