The Danish Church

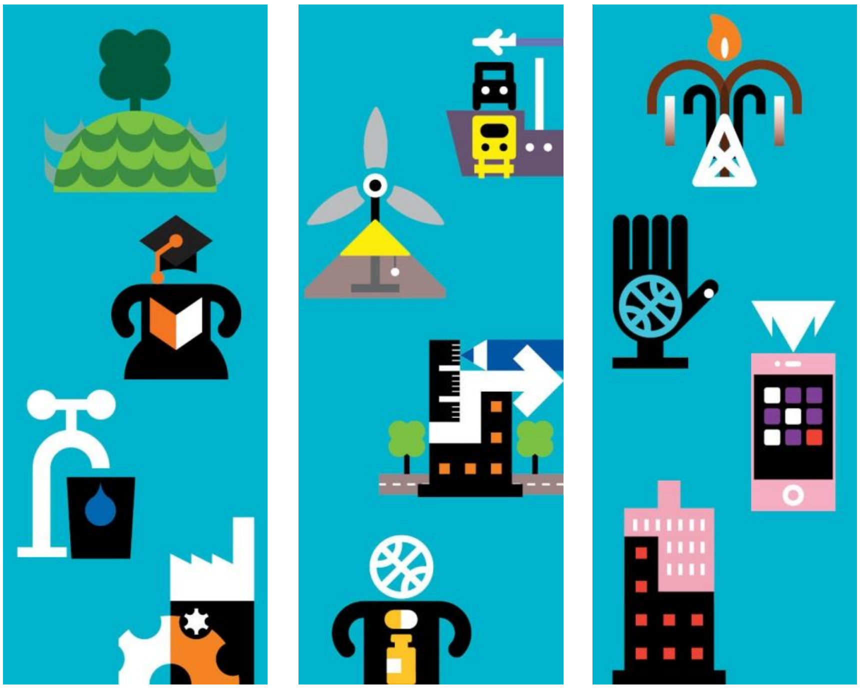
HEATING REPORT

MOTT MACDONALD

MAY 2015

C.F. Møller

St Katharine's
Den Danske Kirke i London



The Danish Church of Saint Katherine

Nave Heating Report

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Issue and revision record

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Contents

1 Introduction

Proposals are in hand for a refurbishment and re-arrangement of the accommodation and community rooms comprising the pair of three storey ‘aisles’ of the church and this will inevitably require significant modification to the existing heating, water, lighting and electrical services.

Little work is proposed in the worship space or nave except that the heating requires improvement.

Mott Macdonald have been asked to investigate the heating to the church and advise as to solutions for improvement.

The Client is very keen to employ renewable energy sources or at least a lower carbon solution.

2 Executive Summary

- A heat pump solution providing underfloor heating to the church nave appears both feasible and indeed optimal.
- The garden/churchyard has insufficient area for the use of slinkies or serpentine shallow pipe loops but if other land could be employed – such as the precinct – then this may be an option, but it has not been evaluated at this time.
- Boreholes represent the neatest option for heat source. It is recommended that permissions are sought for the drilling of boreholes to a depth of 100m in the churchyard/garden before taking the design too far.
- Up to 5 boreholes may be required –spaced at least 5.0metres apart.
- The capital cost of the heating installation serving the nave employing the borehole solution would be circa £ 103,000.
- It is recommended that so long as boreholes are permitted then a trial hole and thermal conductivity test be undertaken to establish the correct number and depth to suit the geology.
- If boreholes cannot be employed then an air source heat pump could be further considered. The cost saving would be circa 45,000.
- For the rest of the church it is proposed that heating would be predominantly by radiators fed by local gas fired domestic balanced flue boilers located: Vicarage and education/multi rooms, flat, kitchen and community area.
- The cost of all heating for these parts would be circa £42,000.

3 Existing Installation

The existing heating to the nave comprises an oil fired warm air blower located in the basement plant room and discharging upwards through two 700 x 700 floor grilles located towards the front of the church. The blower/burner is aged around 30 years or more.

This system is far from efficient or adequate and we understand that it can take at least 24 hours to heat the air of church to a reasonable temperature.

The reason for this is simply that it has to heat all the air in the church right up to the ceiling whilst the air is losing heat to the fabric of the walls, glass and floor.

We understand that on a mild day in winter the fabric surface temperature can be so low that it feels colder inside than it does outside.

The community areas and accommodation are heated by radiators on a low pressure hot water distribution system fed by a pair of oil fired boilers in the basement boiler room.

These boilers are aged around 20years, non-condensing and at the end of their economic life.

The system is zoned for community area and Vicarage

There is a 25mm gas supply to the church and this is used primarily for cooking.

4 Principal Considerations in Church Heating

This church is no exception in having a high thermal mass and a very slow response to changes in outside air temperature, solar gain and gains from people.

It also has a very high ceiling at over 13m., no thermal insulation in or on the walls and large areas of single glazing which are no doubt leaky so that the infiltration rate is high.

Furthermore, generally and historically the worship space (nave etc.) of the Church is occupied intermittently for short durations of a few hours around 4 times per week for services.

With a **convective** system such as exists here, because warm air rises, the occupants will feel no benefit until the whole of the body of air has been heated (from the top) right down to the floor level. Even then, unless the air temperature is excessive, if the walls and floors are very cold, the occupant will not feel comfortable owing to the radiant heat exchange with the cold surfaces.

Most of the heat is lost through the windows and roof and absorbed into the structure (without much benefit) and because it is hotter at the top most of the heat is lost from places where it has had little effect on the occupants 13metres below. Thus, it is inefficient

Furthermore, incoming cold air from open doors will stagnate at the low level whilst the warm air stays high. At the same time the cold walls, roofs and windows will cool the warm air so setting up a room convection pattern involving cold draughts.

For the above reasons the optimum heating solution in an intermittently occupied church is one where the fabric and air of the church are heated as little as possible and heat is delivered in short bursts directly to the occupants as and when required.

Outside of occupancy times the church can then be allowed to cool down and no energy or cost is expended in doing this.

Heating traditionally takes the form of radiant panel heaters or local radiators, fan convectors and exposed pipes at the periphery or between the pews.

Radiant panel heaters, whether electric, gas fired or boiler fed are not aesthetically pleasing and are difficult to accommodate satisfactorily, but are probably the most effective and efficient solution in an intermittently occupied space.

Exposed water filled heating pipes between the pews is the next best solution, but they require the pews to be fixed and do not allow for any flexibility in the use of the space.

Warm air blown across the floor can be effective but would require wall space for convectors or some form of low level discharge grilles if the air derives from under the floor.

Radiators are at least 50% convective and unless the occupant is seated where the surface radiation can be directly felt they are of limited value. They also require wall space, but ideally they would also be located amongst the pews.

Where the worship space is occupied for much longer periods such as for community activities during the week then another option is to provide a low level of **background heat** that will maintain the fabric surface temperatures at a 'comfort level' for most of the day. However, owing to the slow response of the fabric and the effect of the thermal store this generally requires the heating to be switched on for longer periods.

Depending on the level of 'background heating' some form of boost may still be appropriate but the boost heating suffers from all the drawbacks previously described.

5 Observations and Discussion

Unless warm air can be delivered directly at the occupants to provide effective local heating without draughts, a convective heating solution is rarely effective in a church with a very high ceiling: And indeed it is not effective here.

The optimum solution is one in which average internal surface temperature of the fabric can be maintained at a comfortable condition during occupancy, In this case, for any given comfort index (Dry resultant temperature is usually used) a lower air temperature can be tolerated.

However, to maintain the fabric at a relatively high temperature during occupancy also requires the fabric to be warm during unoccupied periods owing to the considerable time lag of the fabric. This uses significant amounts of energy as it increases the heat loss and requires a constant input of heat.

To reduce the energy consumption the nave would be double glazed and with well insulated walls and roof so that relatively high internal fabric surface temperatures can be maintained. In a new build this would be done but clearly for the walls and windows this is not feasible here.

Insulation of the roof/ceiling should however be considered.

The optimum comprise in this situation would be a warm floor and this would be obtained by using underfloor heating:

Having a radiant heating surface literally underfoot means that the occupants, wherever located will be directly heated. Also, as the air is warmed by the floor it will pass over them.

It is normally very expensive and disruptive to retro fit an underfloor heating installation into a Church and it is usually economical only if the floor is to be replaced anyway.

However, in this instance there is the opportunity of doing this whilst retaining the existing floor.

The principle draw-back is one of time lag: Underfloor heating cannot respond to rapid changes in weather, solar gain or other gains such as occupancy.

What it can provide is a relatively constant radiant temperature in the occupied space.

If this is space is used frequently then so much the better.

Furthermore, by not having to site fixed heat emitters in the occupied space the use of the church and layout of furniture remain very flexible.

6 Proposals

Fortunately, the existing floor is a mixture of stone slabs and timber parquet flooring set on a concrete slab sitting on stub walls over a crawlway. The overall thickness of the floor is around 120 to 150mm. and the crawlway is circa 1200 high which is sufficient to accommodate a man.

The stone slabs represent the perfect radiant heating agent and the timber is also suitable subject to limiting the temperature to avoid damage to the timber.

For comfort and to avoid damage, a surface temperature of 26º is considered the maximum.

We have carried out a thermal modelling exercise and calculation that demonstrates that if the floor is maintained to that temperature over the coldest period in winter (-5ºC. outside) then the internal dry resultant (comfort index) will be around 14ºC.

We suggest that this is suitable for most activities. In milder weather of course, it will be warmer.

To maintain the upper surface at that temperature it is necessary to heat the underside to circa 30ºC. This can be done with a form of underfloor heating.

The slab thickness is greater than would normally be designed and will therefore absorb and hold heat for longer making it very sluggish in response.

However, once heated it will remain stable.

Appendix A shows how an underfloor heating installation could be added in this situation.

The sketch shows the use of aluminium spreader plate fitted under the slab. This is to increase the heat transfer from the pipes into the slab. However, subject to further analysis it may be feasible to dispense with the plate and rely simply on a warm pocket of air (which would be simpler on site and a little cheaper), or to use a pre-routed insulation board adhered under the slab.

Access to the undercoft is limited to a single manhole at the organ end of the church. It is naturally ventilated to a small extent by air bricks and the head room is around 1200mm.

It is practical and safe to work in there subject to proper safety measures being taken and a cost allowance for these have been made.

We did not notice any sign of asbestos but a proper HSE survey should be undertaken prior to any further investigation in the space.

7 Heat Source

A mean surface temperature of 30ºC. can be maintained by maintaining a water temperature in the range 40 ºC to 28 ºC and this perfectly suits a heat pump installation.

We estimate that an input rate of circa 15kW. will be required.

The least cost heat pump installation would be air source. However, this would have the highest running costs and lowest efficiency in mid-winter periods when it is most required. It would also require a suitable location for the outdoor unit.

At this time we suggest it could be located at the rear of the church close to the boiler house entrance.

Noise may be an issue and this would need further investigation.

The next lowest cost option would be to use slinkies or other pipework buried in the ground at a depth of around 1200 to 1000mm. and would require an area of around 320 m^2. but with good separation between the loops.

This is not available within the confines of the garden but might be made up if the front drive/precinct could be included.

At this time it has been discounted.

Boreholes require a smaller plan area and between 3 and 5 boreholes at a depth of circa 70m each would be required spaced at least 5.0m. apart. Given that a certain amount of disruption to the landscape of the garden will be taking place the extra disruption from drilling may be palatable.

However, the drilling of boreholes is disruptive and expensive. Before committing to the number and depth required it would be sensible to conduct a conduction survey.

It will also probably be necessary to obtain permissions to drill and to disrupt the land adjacent to the Church.

8 Power supply

Assuming no major increase in electrical demand for such as new/increased electric kitchen equipment then the existing electrical supply will be adequate for whichever is chosen.

9 Budget costs for heating

i)	Removal of the existing		3,000
ii)	Borehole installation		42,000
iii)	G.S. heat pump and buffer	19,000	
iv)	Heating distribution/underfloor		32,000
v)	Allowance for additional health and safety	5,000	
vi)	Automatic controls	2,000	
vii)	Vicarage heating		14,000
viii)	Flat heating	10,000	
ix)	Community and kitchen heating		18,000
	Budget		145,000

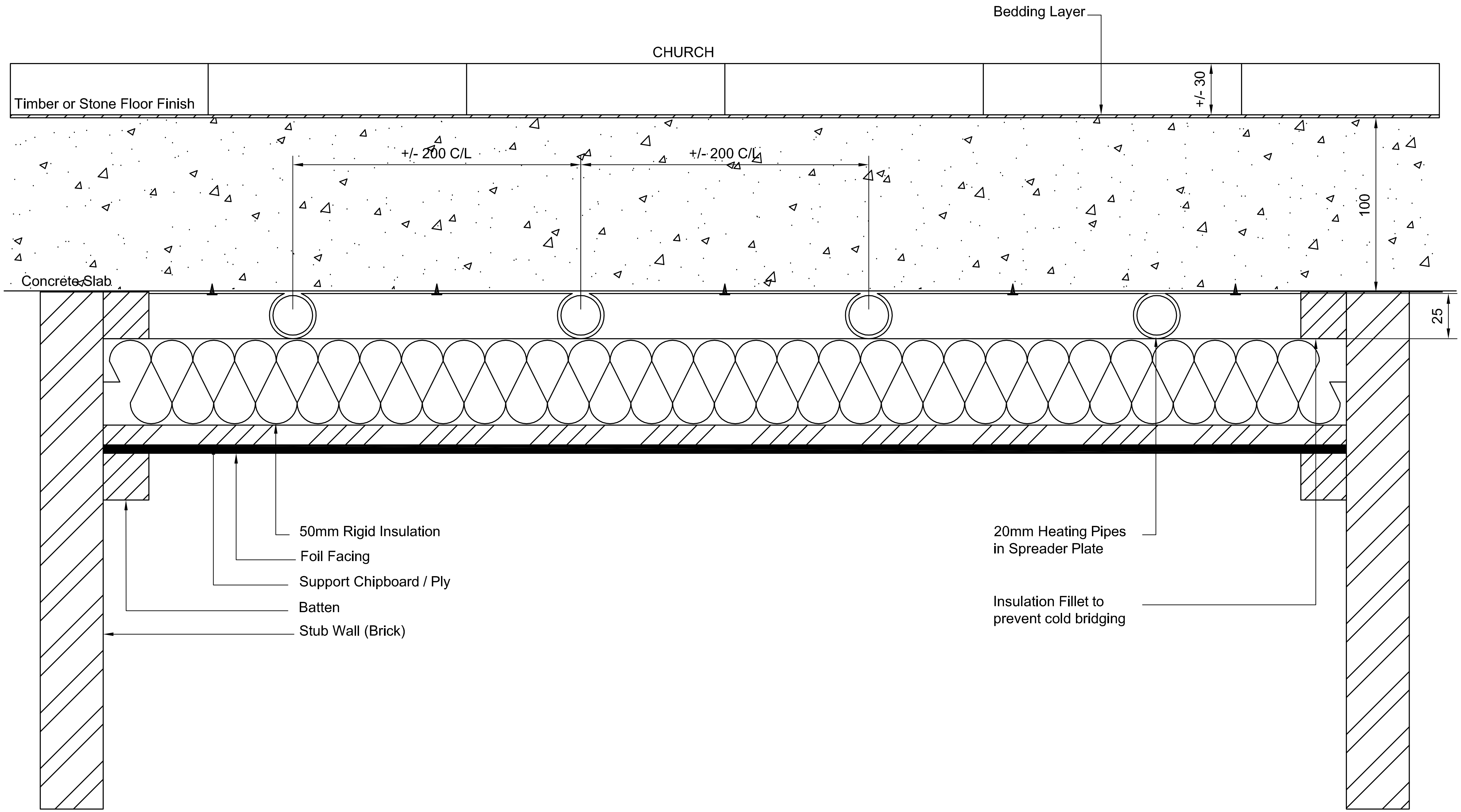
Lower capital cost

a)	Air source heat pump	saving	£45,000
b)	Shallow ground loops in lieu of boreholes	saving	£30,000

The ground loop and borehole costs include the digging/drilling groundworks, the removal of spoil and basic reinstatement/backfilling.

Appendices

Appendix A. Proposed Heating Sketch



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Client: The Danish Church

Rev	Date	Drawn	Description	Ch'k'd	App'd

Title: The Danish Church
London
Section Through Floor Showing
Proposed Heating

Drawn	S.Olley	
Checked		
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Scale at A3	NTS	

Drawing Number	Security	Status	Rev
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