Fire Protection of Norwegian Cultural Heritage

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1. ABSTRACT

The Norwegian Directorate for Cultural Heritage has been working systematically with fire protection since the 1980s.

Maximum safety with minimum damage has been a main objective in fire protection of historic buildings in Norway. A fire strategy and an extended cost-benefit analysis should always be carried out to prevent damage to the fabric of the building and unnecessary aesthetic intrusion.

Sprinklers were installed in the 1960s in some of the stave churches. During the 1980s sprinklers and fire detection systems were installed in a large proportion of the stave churches. The work was intensified at the beginning of the 1990s because of the threat of arson. During a period of less than five years´ extensive measures were carried out in the 28 surviving stave churches. In addition to the stave churches a program has been carried out to protect a selection of the other 400 most valuable churches built before 1800.

A pilot project has been carried out with the use of water mist. The Norwegian stave churches were the first application of this technology in historic buildings. Outdoor fire hoses, aspiration fire detection systems and video surveillance are other examples of technology adapted to the use in historic buildings.

There are more than 150 historic wooden towns and other old densely built wooden communities in Norway. Some work was done in Norway the early 1990s. A pilot project in the fortified town of Fredrikstad has recently been carried out to test relevant external detection systems. Heat sensitive surveillance cameras are also a potential method for external fire detection.

2. BACKGROUND

Fire has always been a great threat. In the Middle Age the cities burnt every hundred years on the average. The buildings were made of flammable materials, open fire was used for heating and cooking, and the means to extinguish fires were limited. During the 19th century the situation improved. Organised fire brigades were established in the cities. The threat of fire was one of the main reasons for establishing water works. In spite of better potential for fire fighting, fire is still the greatest threat to our Nordic built heritage. There is a lack of exact figures but the yearly loss of building due to fires is considerable.

There are particular challenges regarding fire protection in Nordic countries for instance:

- Highly flammable buildings (the whole building construction is often made of wood)
- Frost problems (temperatures below –30ºC are normal)
- Heating during long periods of the year
- Close distance between the buildings
- Windy conditions
- Remoteness of site (distance to fire brigade, unoccupied buildings etc.)
- Insufficient water supply in remote locations

The Directorate for Cultural Heritage has been working systematically with fire protection matters since the 1980s. Fire has always been a threat to historic buildings in Norway. The great fire in Bergen in 1955 laid half of the buildings in ashes. This was an eye-opener and an incentive to take fire protection seriously. During the 1960s sprinklers were installed in the buildings at Bryggen and two of the most important stave churches, Borgund and Urnes (the latter on the UNESCO World Heritage List). There was a new eye-opener at the beginning of the 1990s; in 1992 arsonists set fire to several churches among them the stave church at Fantoft outside Bergen.

3. KEY WORDS WORKING WITH FIRE SAFETY IN HISTORIC BUILDINGS

The following points demand particular attention:

3.1 Maximum safety with minimum damage

Any fire protection measures should give maximum security with minimum damage. There should be as little physical damage to the fabric as possible and minimum visual intrusion. Fire protection systems should never be allowed to dominate the building. Whenever possible cables, sprinkler pipes etc. should be placed in hidden areas, for instance in lofts or cellars. If it is necessary to make a choice between visual intrusion and physical damage, measures causing physical damage should be avoided, since these are normally irreversible. Most open systems can be designed to harmonise with the building if priority is given to right materials and positioning of equipment. Copper, for instance, is a material that will oxidise with time and naturally blend in with old surfaces. Copper pipes with brass sprinkler heads are consequently a natural choice in historic buildings. Copper wires should be chosen for external lightning conductors on churches.

3.2 Extended cost-benefit analysis

An extended cost-benefit analysis should be carried out prior to any installation of expensive fire protection systems. The first money invested normally gives a high effect on the safety of the building. By carrying out simple administrative measures at a very low cost it may be possible to reduce the risk of fire occurring in a building by up to 40 %. Controlling electric equipment and making sure litter is stored safely are measures that cost very little. Reaching a safety level of 100% is very expensive. In the Norwegian stave churches where the safety level is close to 100% the total installation costs have reached several hundred thousand dollars.

In an extended cost-benefit analysis not only monetary costs should be considered. It is as important to take into consideration the potential reduction of the value of the historic building resulting from the installations, for instance:

- Physical damage caused by drilling, fixing of cables etc.
- Long-term damage caused by inferior solutions, condensation, water leakage etc.
- Wear caused by maintenance, repair work etc.
- Visual intrusion
- Reduced usability of the building
- Damage to archaeological remains under the ground caused by water pipes etc.

3.3 Fire protection strategy

The situation should always be analysed thoroughly before any installation of fire protective systems. A strategy is vital to prevent damage to the fabric of the building and unnecessary aesthetic intrusion. Often comprehensive fire protection systems are installed in buildings after the owner has been in contact with a smart salesman.

4. FIRE PROTECTION STRATEGY

4.1 Risk assessment

A risk assessment should be the foundation of such a strategy. By focussing on the risk of fires, awareness among users and occupants will naturally result in fire protective measures, for instance routines for the use of electrical appliances. Other high frequency risks include wood stoves and open fires. Such an assessment will also lead to natural choice of fire preventive and fire controlling measures. As examples of potential causes of fires can be mentioned:

- Arson
- Defect electric installations, cables, fuses etc.
- Faulty use of electric appliances
- Faulty use of stoves and open fires
- Electric appliances
- Lightning
- Explosions
- Self-ignition
- Direct flame from nearby fires
- Radiation from nearby fires
- Sparks carried long distances
- Fires caused by building works, welding, cutting etc.

4.2 Local conditions

Potential causes of fire must be seen in relation to local conditions, i.e. practical and technical possibilities and limitations for instance:

- Likely development of the fire? This depends on structural materials, fire walls etc.
- Potential for fire fighting by occupants. Are fire extinguishers or fire hoses installed in the building?
- How to call the attention of the fire brigade? Must the fire brigade be contacted by telephone, are there fire-alarm boxes or fire detectors with automatic transmission of signals?
- Is the fire brigade on duty 24 hours or are they volunteers who must be called to the place of fire?
- How long does it take for the fire brigade to reach the place of fire?
- Type of equipment (fire engines, fire hoses etc.)
- Is there satisfactory access for the fire brigade and their equipment? In old buildings gates and door openings are often narrow.
- Water supply, reservoir with natural pressure, river or lake with pumps dependent on electricity? Sufficient water supply often decides the outcome of a fire.

4.3 Fire-prevention or fire-limiting measures

Fire-prevention measures should be given priority. The safety level is always better if a fire is prevented from occurring. However small, a fire will always cause great damage. Fire preventive measures are normally very cost-effective. In a small building with limited use it will often be cheaper and more effective to turn off the electricity when the building is not in use instead of installing expensive *fire-limiting* measures.

4.4 Administrative, structural or technical measures

Simple administrative measures can be carried out immediately, with limited economic resources. It costs very little to cut the grass around a building to prevent the spread of fire. Fireproof walls and fire doors are examples of *structural measures* to limit fires. Structural measures can often cause unacceptable damage to the fabric of the building. *Technical measures* on the other hand can be removed and the building returned to its original state. Sprinklers and alarm systems are examples of technical fire measures that are often preferable to extensive structural measures.

4.5 Fire-prevention measures

By focussing on the awareness of potential fire hazards, most causes of fires can be met with simple administrative fire-prevention measures, for instance:

- Information to occupants, leaflets, meetings etc.
- Safe storage of litter, fireproof dustbins, containers etc. (arson attacks are normally carried out with available flammable material)
- Contracts with builders responsible for flammable construction work, welding, grinding etc. (many fires occur during construction work)
- Routines and control of electric appliances and electric installations (most fires in Norway are caused by faulty use of electricity or defect electric installations)
- Routines and control of stoves, fireplaces, chimneys etc. (extensive use of fire causes a large number of fires in Nordic countries)
- Gravel path around wooden buildings (an important measure to prevent the spread of grass fires)
- Burglar-proof locks (an important measure to prevent arson)

4.6 Fire-limiting measures

After relevant fire-prevention measures have been planned there is still a risk of fires occurring. This risk should be seen in to relation the local conditions mentioned above. If the risk of fires still occurring and causing damage is high, fire-limiting measures should be considered. The objective of fire-limiting measures is to limit the extent and reduce the damages of a fire.

4.7 Administrative fire-limiting measures

These are measures to make the best use of available personnel and fire-fighting equipment. A fire is most likely to cause great damage before the fire brigade reaches the building. Potential for local fire fighting is therefore vital to the result of a fire. Examples of fire-limiting administrative measures:

- Fire drills
- Inspection by the fire brigade
- Instruction for the use of fire-fighting equipment
- Routines for handling of alarm signals

4.8 Structural and technical fire-limiting measures

Measures causing great structural damage, for instance construction of new fireproof walls and fire doors are often unacceptable in historic buildings. By installing technical equipment, for instance fire detection systems or sprinklers, extensive structural measures can be avoided.

4.8.1 Water supply

The outcome of a fire often depends on the local water supply, for example:

1. Public or private mains from public or private water works with natural pressure from reservoir.
2. Local water reservoir with pressure from electric pumps.

The former solution with water from water works is the most reliable water supply. Solutions dependent on pumps and local sources of water for instance a small lake or river may provide a limited amount of water and be subject to problems with frost and electric failures.

4.8.2 Fire fighting

Potential for local fire fighting is vital to the outcome of a fire. A fire is most likely to cause great damage before the fire brigade reaches the building. Local fire fighting can depend on:

- Fire detection + manual fire fighting.
- Automatic fire extinguishing systems.

Selection of measures will depend on distance to the fire brigade, potential for manual fire fighting, type of occupants, local fire fighting equipment etc. There is no point installing fire detectors with signals to the fire brigade if the fire brigade reaches the building after it has burnt down. With a long distance to the fire brigade, manual fire fighting should be based on fire bells and fire fighting equipment for the use of occupants.

Even in buildings with an automatic fire extinguishing system there is a need for manual fire fighting equipment because:

- A fire may cause great damage before an automatic fire extinguishing system is brought into action.
- An automatic fire extinguishing system will control the fire and is likely not to extinguish it completely. Some form of manual fire fighting will be necessary after the operation of the automatic fire extinction system.

4.8.3 Examples of manual fire fighting:

- Fire hydrants
- Fire extinguishers
- Interior fire hoses (fire hoses are easier to use and have a greater effect than fire extinguishers)
- Exterior frost-proof fire hoses
- Water mist guns (a possible solution in buildings without permanent water supply; disadvantages are a need for trained personnel and frost problems in unheated buildings)
- Dry sprinklers without permanent water supply (water from fire engines or external fire hoses). In lofts and towers fires easily get out of control and fire fighting can be risky in these areas. Dry sprinklers in lofts and tower are a cost-effective measure requiring little maintenance. Water is supplied by the fire brigade or from an external fire hose.

4.8.4 Examples of automatic fire extinguishing:

- Interior wet sprinklers *. Wet sprinklers are a simple and reliable system but cannot be used in unheated buildings unless filled with anti-freeze.

- Interior dry sprinklers *. Dry sprinklers require compressors or other devises to keep a constant air pressure and are subsequently more vulnerable to electric failures etc.
- Interior water mist * (high or low pressure). Requires limited amount of water and causes little damage on vulnerable painted interior surfaces.
- Exterior sprinkler systems or deluge systems (to prevent the spread of flames from nearby fires etc.)
- Gas extinguishing systems (normally not recommended in a historic building since they require an airtight structure).
- Inert aerosol (is not a recommended measure because inert aerosol is dangerous to people and requires a more airtight structure than an old wooden building to extinguish a fire)

* *Sprinklers* will extinguish and control a fire whereas *water mist* will primarily control and under certain circumstances extinguish a fire.

4.9 Acceptable remaining risk

There will always be a risk still remaining after fire prevention and fire-limiting measures are carried out. This risk is defined as a failure of fire prevention measures and potential causes of fire not met by fire prevention measures and failures in the fire limiting measures. The remaining acceptable risk accepted should always be disproportionate to the value of the building. If under no circumstance a loss of the building is accepted the remaining risk must be very low.

4.10 Handling of crisis and safeguarding of remains

Occupants and the fire brigade should be instructed how to extinguish a fire without causing unnecessary damage to the building. Frequently the work done to extinguish a fire causes more damage than the fire itself. Instruction on fire extinguishing methods, with necessary drawings of the building(s), should be in the building and at the fire brigade.

Plans should be carried out as to how to safeguard important remains after a fire. The building may contain valuable historical material.

5. FIRE PROTECTION PROJECTS IN NORWAY

5.1 Fire protection of stave churches

As mentioned above sprinklers were installed already in the 1960s in some of the stave churches. During the 1980s sprinklers and fire detection systems were installed in a large proportion of the stave churches. There were plans for installing fire protection systems in the remaining churches. The work was intensified at the beginning of the 1990s because of the threat of arson. During a period of less than five years extensive measures were carried out to minimise the risk of damage caused by fire in the 28 surviving stave churches. The following systems have been installed in these churches:

- Lightning protection systems
- Burglar detection systems (primarily to prevent arson)
- Fire detection systems
- Frost-proof outdoor fire hoses
- Video surveillance (in 15 out of 28 churches, primarily to prevent arson).
- Automatic sprinklers internally

- Water mist internally (a pilot project has been carried out in churches with surfaces likely to be damaged by the amount of water in sprinklers; the Norwegian stave churches were the first application of this technology to historic buildings)
- Sprinkler or deluge externally

The fire protection of the Norwegian stave churches has been carried out over a period of more than 30 years. A main objective in fire protection should always be to reduce the extent of installations. This may create a higher level of safety through easier management and less physical and visual intrusion. If we were to start all over again less comprehensive systems could have been possible in these churches.

One of the leading fire consultants in Norway has been responsible for the maintenance of the fire protection systems in the stave churches since the 1980s. Local caretakers carry out a weekly control.

5.2 Fire protection of other churches than stave churches

A program has been carried out to protect a selection of the other most valuable churches. 400 churches built before 1800 were given an offer of government grants to carry out fire protection measures (about 200 medieval stone churches and more than 200 wooden churches). About 300 of the churches accepted this offer. The total fire protective measures carried out in the stave churches are very expensive. A risk assessment and an extended cost/benefit analysis was carried out before choosing relevant measures in the other churches. The following fire protection was installed in these churches:

- Lightning protection system (lightning is the major cause of fires in Norwegian churches)
- Burglar detection systems (an important measure to avoid arson)
- Fire detection systems
- Frost-proof outdoor fire hoses (intended for the use of passers-by who first discover the fire)

The fire protection project lasted for 4 years between 1993 and 1997. Lack of government funding has stopped further fire protection of Norwegian churches. The situation has improved because of the project mentioned above. However, the level of safety is still far from satisfactory. Fire detection systems are installed in many churches but a main problem is the long distance to the fire brigade. Many churches are likely to burn down before the fire brigade reaches the place of fire. At 150 churches there are outdoor fire hoses. These can be of great use if there are passers-by or neighbours who discover the fire. The fire detection system should have fire bells or sirens to alert people in the surroundings.

Churches have lofts and towers where fires spread quickly and fire fighting can be hazardous. Dry sprinklers in lofts and towers are recommended in these churches. In the most valuable churches automatic sprinklers or water mist covering the entire building should be installed. Even at churches with good potential for manual fire fighting a fire is likely to cause great damage.

5.3 Fire protection of wooden towns

There are more than 150 historic wooden towns and densely built-up areas in Norway. Large wooden towns are unique for the Nordic countries and in the Baltic States. Some work was done in Norway the early 1990s. The towns of Risør and Tvedestrand made plans for fire protection of the old wooden centres of these towns. Some technical installations were installed, for instance dry sprinklers on the facades of some houses to create fire barriers. New fire engines were given to the towns Røros (mining town on the World Heritage List) and Risør on the south coast.

A report produced by IGP fire consultants in the 1980s recommended early fire detection as an important fire protection measure for the town of Røros. Extreme climatic conditions made it difficult in those days to find appropriate fire detection systems. Experience working with the Norwegian stave churches now makes it easier to find fire detection systems suited for the use in historic wooden towns. A pilot project in the old fortified town of Fredrikstad has been carried out to test relevant external detection systems. Heat sensitive surveillance cameras are also a potential method for external fire detection.

The following recommended fire protection measures have been carried out in Norwegian wooden towns:

- Administrative fire protection measures, for instance fire proof dustbins, control of electric equipment, chimneys etc.
- User awareness. Information to residents, meetings, leaflets etc.
- External fire detection**.** In densely built-up areas minimum there has been a main objective to avoid fire detection in each individual flat to reduce maintenance and problems with faulty alarms. What we have been looking for is a replacement for the old watchtower. A pilot project has recently been carried out to test fire detection systems in lofts and entrances. Heat sensitive surveillance cameras are also a potential method for external fire detection.
- Sprinklers on facades of the building to create fire barriers.
- Sprinklers in areas difficult and hazardous for manual fire fighting, for instance loft areas.
- Sprinklers in buildings with risky activities, for instance restaurant kitchens (to install sprinklers in all buildings is expensive; the number of fires can be reduced drastically by concentrating on risk areas).
- Sprinklers in building with high-risk residents (the centres of towns often have a large proportion of old age pensioners and people with drug or alcohol abuse, but this is a rather sensitive issue).
- Outdoor fire hoses and other equipment for fire fighting by occupants.
- Equipment for the use of the fire brigade adapted to the conditions in old wooden towns, for instance small fire engines.

There are plans for a pilot project to safeguard 12 selected Norwegian towns. The project depends on government funding to be initiated.

5.4 Other projects

Fire protection projects are have also been carried out in industrial buildings, large farms and manor houses, houses belonging to famous artists etc. Financial support by an insurance company has made these projects possible.

6. APPROPRIATE AVAILABLE TECHNOLOGY

The main objective maximum safety with minimum damage has made it necessary to adapt existing technologies in new ways:

6.1 The use of water mist in the stave churches

A large proportion of the wooden churches have richly decorated interiors sensitive to water. Water from one single sprinkler head would cause great damage in these churches. It was necessary to consider alternative extinguishing methods. Gas was out of the question since this requires an airtight building in order to be effective. Water mist has been used for fire protection in the North Sea oil industry. A program to test whether the technology was appropriate in the Norwegian stave churches was carried out in the early 1990s. Full-scale models of a stave church were tested at the Laboratory of Technology in Trondheim.

The results were very promising. The water mist proved to have the desired effect, and as a consequence water mist were systems installed in 11 stave churches (5 low pressure and 6 high-pressure installations). A water mist installation does not extinguish a fire. It only controls the fire. Additional fire fighting is necessary after the activation of the water mist. In some of the churches there are traditional sprinklers (that operate manually) in addition to the water mist.

6.2 Mini fire stations

Mini “fire stations” were developed for temporary use at stave churches without a permanent water supply. Standard containers were fitted out with a 50 metre fire hose and a water reservoir of 6 or 10 cubic metres.

6.3 Outdoor fire hoses

Potential for fire fighting by staff and passers-by is decisive to the outcome of a fire. Specially designed frost-proof fire hoses were therefore developed for use at the stave churches. Similar fire hoses have been installed at other churches, open-air museums and in wooden towns. The fire hose is 50 meters and can be combined with equipment belonging to the fire brigade.

6.4 Lightning protection

Lightning is the most common cause of fires in churches in Norway. As a consequence lightning protection was given priority in the program for fire protection of Norwegian churches. Standard installations were too intrusive on historic buildings. An architect and a lightning expert were therefore commissioned to develop methods for installations of fire conductors based on the theories of Faraday´s Cage. Copper wires were selected for the lightning conductors with specially designed copper clamps. The clamps are fixed directly to the surface of the building. This makes the lightning protection installations very unobtrusive. It is a common misconception that the lightning conductors have to be fixed at a distance from the surface of the building.

6.5 Fire detection

The extreme climatic conditions in many stave churches have made fire detection a problem. In many churches the temperature may reach –30ºC. In addition to this many stave churches are located in a damp climate. Fire detection systems designed for the use at normal temperatures are unable to handle these conditions. A pilot project with fire detection based on the principle of aspiration proved to be a success. Air is sucked from the church through plastic tubes to a central fire detection unit. A similar system is used in farm buildings in Norway where the climatic conditions are equally extreme. The aspiration system is very unobtrusive in buildings were the tubes can be hidden in loft areas.

Video surveillance

The threat of arson was the main reason for installing video surveillance systems at the stave churches. Unfortunately these systems have caused problems due to many faulty alarms. At the stave churches standard floodlights or infrared lights for the video surveillance systems were installed. This proved to give insufficient lighting. Standard video cameras require good lighting to function properly. This usually is no problem in the normal application of video cameras at industrial sites, prisons etc. Heat sensitive cameras are now tested as an alternative to avoid these problems.

6.6 Water mist monitors

A pilot project was carried out with water mist monitors at one of the stave churches. Cost in relation to the effect and reliability of the installations has stopped further use of this technology.

6.7 Other projects

A pilot project using wireless fire detection systems in stave churches proved unsuccessful due to maintenance problems and many faulty alarms. Installation of wireless detection creates minimum structural and visual intrusion to a building. However, there are indications that one of the main producers of fire detection systems in Europe will be able to deliver reliable wireless fire detection systems in the near future.