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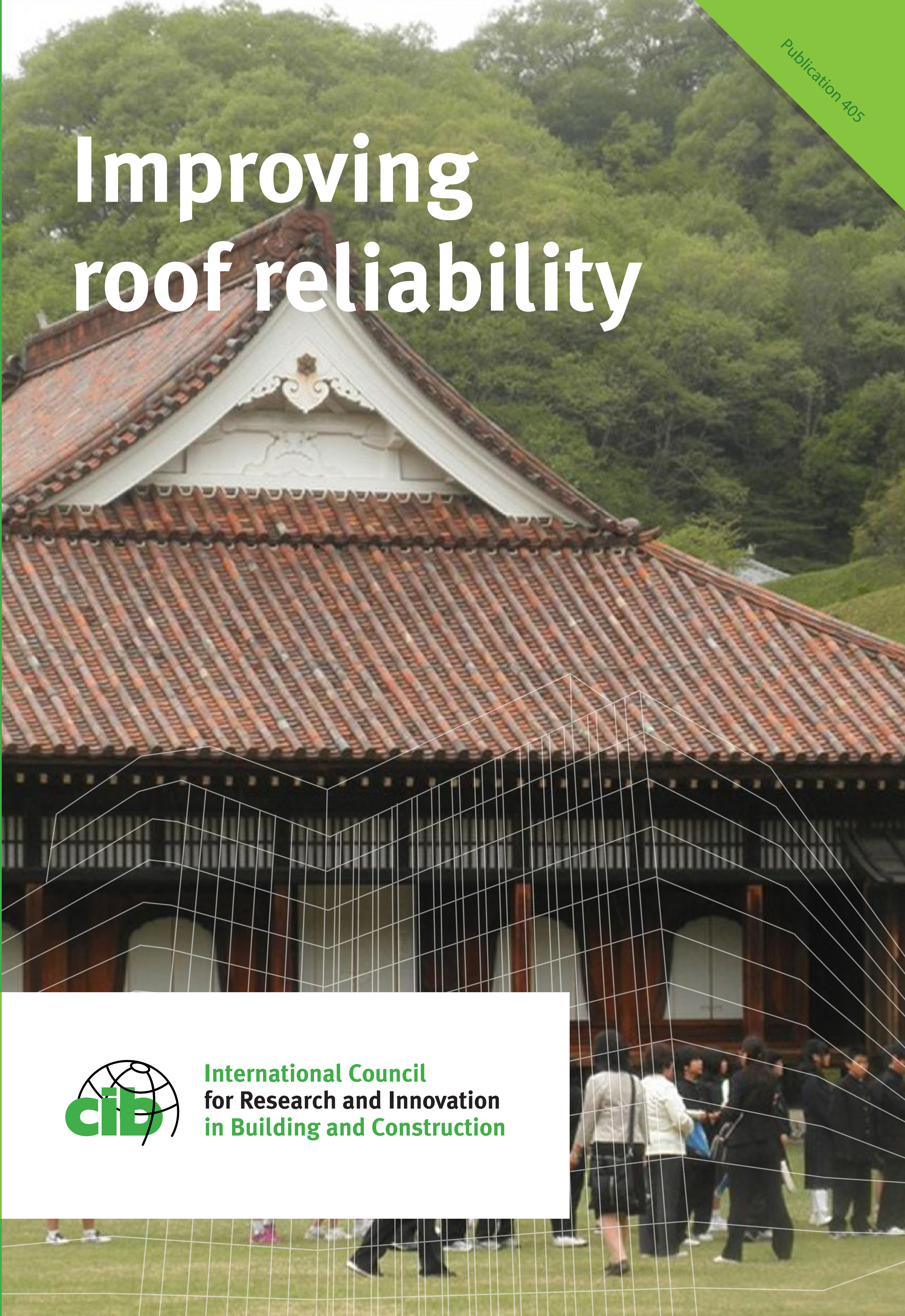
Improving roof reliability



International Council
for Research and Innovation
in Building and Construction

'IMPROVING ROOF RELIABILITY'

FINAL REPORT OF THE RELIABLE ROOFING TASK GROUP

CIB W083 COMMISSION ON

ROOFING MATERIALS AND SYSTEMS

CONTENTS

1. ABSTRACT

There are concerns about the number of recently completed buildings where there are recurring rainwater leaks through their roofs several years after completion. For some building users there is a need for a high degree of confidence that the roof will not leak. Such buildings include computer centres, hospitals, civic buildings and court houses.

An International Commission of recognised experts and roofing specialists was established to gather information from different countries to improve our understanding of the reliability of roofing, seeking improvements from an international perspective.

Lessons learned from a reliability engineering approach used for improving vehicle manufacture can benefit the roofing and cladding industry, such as introducing element redundancy. The issues are often to do with the management of people. In reviewing the findings of building inspections there are common issues that recur, presenting an opportunity to learn from the experience and to change practice.

The Commission has developed a summary of the key points of best practice. These common principles or 'tenets of reliable roofing' are offered for the benefit of the building owner, designer, contractor and manufacturer seeking to improve roof reliability.

2. INTRODUCTION

Building owners, their professional advisers and main contractors are becoming increasingly concerned about the number of recently completed buildings with recurring rainwater leaks through the roofs several years after completion. Not all new buildings have roof defects and it is difficult to obtain balanced national pictures. However, the problem does appear to be widespread and occurs on both steep-slope and low-slope roofs. For building owners and facilities managers the reliability of their roofs is important.

After completing a project no one likes to receive a request to return to the site to resolve a problem. For a designer this could mean lost time with no fee. For a contractor there are additional costs in time and materials. Delayed payments are a problem for many in the industry and one of the underlying causes is recurring water leakage, often minor in extent and sometimes due to multiple sources, but enough for a client to justify delaying final payment. For the manufacturer and supplier there is a potential loss of confidence, making it harder to sell next time. Call backs are generally unwelcome news and it would be a good thing to learn from our current experiences and work towards getting the roof right the first time.

Some owners need a high degree of confidence that the building envelope will not leak. Such critical buildings include:

- Telephone exchanges and internet server rooms
- Offices housing time dependent operations, trading rooms and call centers
- Hospitals, particularly operating rooms
- Civic buildings, including parliamentary buildings and court houses
- Cathedrals and churches
- Museums, exhibition halls and art galleries housing valuable goods
- Nuclear facilities
- Electrical power supplies

The consequences of roof leaks interrupting a building's operations can result in significant financial losses. Minimizing these risks is in the interests of the building owners and their insurers. This in turn should result in a better quality, more robust and more reliable roofing system being specified, built and maintained. Owners expect a leak free roof for the building life, although unfortunately the industry isn't always confident that it can provide such a system.

The CIB W083 Commission

The CIB W083 Commission on Roofing Materials and Systems consists of 40 roofing specialists drawn from more than 15 countries. In March 2006 a Task Group was established to develop our understanding of the reliability of roofing systems, and specifically to identify and prioritize practical actions that can deliver improvements.

Previously the Commission has examined the topic of roof sustainability and identified key points of best practice, published in the 2001 report 'Towards Sustainable Roofing'. Arising from the discussions it was recognized that in sustainability audits and other energy studies the assumption is often made that the roofing system will perform satisfactorily for its full anticipated life span. Sometimes this would be a bold presumption. An environmentally friendly roof system that leaks and needs to be replaced after a couple of years is not a sustainable roof system.

3. DEVELOPMENT OF RELIABILITY STUDIES

During the past three decades there has been a growth in reliability engineering studies, particularly in the aerospace, vehicle production and electronics industries. Consumers are acutely aware of the problem of less than perfect reliability with domestic products such as televisions and vehicles, and they have now come to expect these products to work first time and continue until they become obsolete. These studies have been highly developed in Japan where quality and reliability were adopted as national priorities. Owners expect the same levels of service from their building envelopes, particularly meeting the basic requirement of providing a dry internal space.

Reliability has been defined in BS 5760 as 'the ability of an item to perform a required function under stated conditions for a stated period of time.' One measure of a roof's reliability is the number of times the roofing contractor must be called back to the site to resolve a problem.

There are many reasons why a roof might leak and result in a need for remedial work. Knowing as far as is practicable the potential causes of failures is fundamental to preventing them, although it is rarely possible to anticipate all of the causes and a level of uncertainty needs to be taken into account.

Reliability can also be expressed as the number of failures over a period. Durability is a particular aspect of reliability, related to the ability of an item to withstand the effects of time dependent mechanisms such as fatigue, wear and corrosion. Durability is usually expressed as a minimum time before the occurrence of wear out failures.

The reliability engineering study during design, manufacture, assembly and service should address the anticipated and possibly unanticipated causes of failure, to ensure that their occurrence is minimised.

There are also different perceptions of what kinds of events may be classified as failures. We know that all failures, in principle and almost always in practice, can be prevented. In his book 'Practical Reliability Engineering', O'Connor has observed that:

i) Failures are caused primarily by people (designers, suppliers, assemblers, users, maintainers). Therefore the achievement of reliability is essentially a management task, to ensure that the right people, skills, teams and other resources are applied to prevent the creation of failures.
ii) Reliability and quality are not separate specialist functions that can effectively ensure the prevention of failures. They are the results of effective working by all involved.
iii) There is no fundamental limit to the extent to which failures can be prevented. We can design and build for ever-increasing reliability.

4. HISTORICAL LESSONS

4.1 Element redundancy

As a starting point the Committee sought examples of roof systems with long lives. A good example is the Shizutani School in Japan which was commissioned by Lord Mitsumasa Ikeda in 1666. The story is told that his vassal, Nagatada Tsuda, was instructed to build the school and was told that he should construct the roofs so that they would not leak, otherwise he would lose his life. The threat of capital punishment was a keen incentive for the builder to get his roof right the first time!

Figure 1: Lecture hall of the Shizutani School, built from 1666

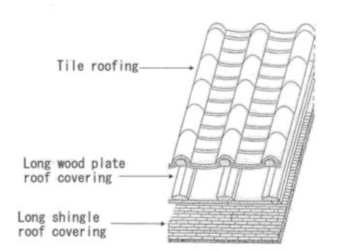


Figure 2: Roof structure of three layers

The roof system chosen consisted of three layers: clay tiles placed over long wooden plates, which were laid over a shingle roof covering. If the outer tiles were to crack, rainwater would run off the wooden plates. If they were also split, then the water would run over the shingles. The water would not get through the roof into the school. The vassal survived and the three layer roof system has withstood the tests of time.

Lessons can be drawn from the construction of the Shizutani School roof, lessons which perhaps we have forgotten. The builder recognized three centuries ago the importance of introducing element redundancy. If one layer is not perfect and does not perform there is a second layer that can drain the rainwater off the roof.

Today a formal definition of redundancy is 'the existence of more than one means for accomplishing a given function'. A good example of how element redundancy has been introduced into a modern roof construction is the tile and slate roof system with underlayments draining to the eaves gutters.

In certain weather conditions some wind driven rain and snow can find its way below the tiles into the roof space below. The introduction from the 1950's onwards of bituminous underlayments on top of the timber rafters and below tiling battens had the beneficial effect of draining these small amounts of water and snow down to the eaves gutters. This development in tiled roof construction more than 50 years ago has improved the reliability of sloped roofs by forming in effect a double layer roof. Since there is redundancy in the system, the passage of rainwater through the outer layer onto the secondary underlayment does not result in failure because the building remains dry. The roof system is reliable.

In the U.S.A. element redundancy has been recognized by the Federal Emergency Management Agency in their Design Guide 577 on improving hospital safety in earthquakes, floods and high winds. Published in June 2007 this recommends for hospitals in hurricane prone regions installing a secondary roof membrane over a concrete deck to avoid water entry if the roof is hit by wind-borne debris. Introducing element redundancy at the design stage to improve roof reliability.

4.2 Retain knowledge

The late Dr Bob Booth, a materials scientist and one time Technical Director of the Canadian Roofing Contractors' Association, observed that one of the biggest obstacles to improving roof performance is the departure from the industry of knowledgeable, experienced and caring workers; be they tradespeople, consultants, material suppliers or building owners. In the fast growing economy of Canadian cities there were many new roofers who were novices. If the foreman was not both knowledgeable and insistent upon doing a good job, then an unreliable roof was often the result.

In many countries the closure of businesses due to a shortage of work, has led to staff redundancies and ultimately the loss of skills and knowledge in the industry. This is in addition to the natural retirement of key workers.

There are many centres of roofing excellence supported by product manufacturers, trade associations, regional training groups and specialist consultancies. It is important that these facilities continue to be funded and actively used. The need to promote more trades schools is recognised internationally with new centres being established in Europe by the International Federation of Roofworkers (IFD) directed by Detlef Stauch. These training centres can also demonstrate to designers and tradesmen how roofing components are put together in practice in workshop conditions.

The roofing industry, like all professions, is constantly changing. There is a need to keep up to date with these changes and expand our knowledge to maintain a professional status. The pace of change is such that it is no longer enough to rely on the results of our initial education, however good, or the training leading to membership of an institution. There is a need for continuing commitment for enhancing skills and capability during the whole of our professional careers. It is the responsibility of each individual to take on this continuing professional development for his or her own benefit.

Knowledge of roof design and performance is recorded and written down in many different forms including:

- Standards
- Building Regulations and Technical Standards
- Codes of Practice
- Agrément certificates
- Trade Association manuals
- Product literature

A library was once just a collection of printed books, manuals and leaflets. Today this information is also available on-line, on a computer or mobile phone, sometimes for a fee. Reference libraries can prove invaluable. When a question arises at the design or construction stage reference to an authoritative source can offer the answers needed. Libraries do need to be maintained and someone within each organisation needs to take responsibility for this.

What is important is for those in the industry to be aware of this written information, to know where to find it and then to use it. As Harry Harrison observed in his preface to the BRE book on 'Roofs and Roofing', there is no shortage of guidance on roofing, *'the problem is that people do not use the guidance that exists.'*

5. PRESENT DAY ROOFING ISSUES

5.1 Product substitution

Problems with poor roof performance have often stemmed from late substitution with alternative products during the construction phase, often to save costs. One view is just to say "no" to substitution, although the designer would still need to provide an explanation. An alternative view is that product substitution can aid innovation which is important for a developing industry.

When drafting project specifications the designer usually takes considerable care in recommending the chosen products. At the construction stage the general contractor's buyers are likely to check that the named products are the most economical, particularly on design and build contracts and at the value engineering stage of major projects. The contractor typically would not be aware of the overall design considerations and how changes could affect other building elements.

It is not unusual for designers to come under intense pressure to accept what may appear to be cheaper alternatives. The limited time to make such decisions can result in inadequate assessment. The alternatives may be of a lesser quality, have narrower application limitations, have reduced manufacturer technical support and on-site inspection, and perhaps lack the reassurance of satisfactory references from previous projects. With the benefit of a more rigorous assessment it may be that product substitution does not give an overall cost saving. Within the Committee, members shared their experiences with product substitution. An architectural practice based in the U.S.A. would only consider substitution at the time of bidding. In Israel it would be common practice to give three equivalent products in a specification. In Germany often only performance requirements would be specified with product selection left to the bidder.

Sam Vesely, a waterproofing consultant from Israel, presented a series of criteria for assessing the acceptability of a substitution. These include the need to supply a full set of relevant documents, referencing appropriate standards where they exist, restricting the number of requests for changes, and recognizing that it is only the specifying architect or engineer who is authorized to issue an approval that the substituted product is equal to that specified.

Product substitution presents challenges to the design and construction team who could benefit from a formal decision-making process that considers performance requirements, cost benefit analysis, service life and timing. Taking greater care with product substitution and developing an 'intelligent caution' approach improves roof reliability.

5.2 Contract documentation

Firmino Siqueira, a roofing contractor, designer and college lecturer based in Sao Paulo, Brazil identified the lack of contract documentation as being a key factor. In a survey of 315 projects where there had been post completion call backs, 227 were on jobs without a project specification, 72% of the survey total.

At the start of a project there is a need for someone to set out in written documents what will be required of the roof. Often this can take the form of repeating a written specification from a previous project, although there is a need to consider how the new project differs from the last and to make amendments. For example, no two roofs are in exactly the same location and each will have a different degree of site exposure to wind and rain that may need to be considered in the design.

Every roofing project should have a basic roof plan, drawn to scale and showing gridlines to aid cross reference. Ideally the roof plan should also show principal dimensions such as length and width of roof slope and directions of fall. In addition an arrow pointing north is helpful and particularly important for setting out the direction of laying roof sheeting so that side laps do not open into the prevailing wind.

Designers can gain greater confidence that their specifications are in a standard format, covering known and relevant issues by using the National Building Specification system. Further details of the system which is regularly updated are given at www.theNBS.com

In developing the design and specification for a roofing project there is a need to co-ordinate with other disciplines, including:

- architects, co-ordinating interface details.
- structural engineers, identifying a means of support for the roof and attachment against wind uplift.
- civil engineers, identifying positions where rainwater downpipes can enter the underground surface water drainage system.
- building control officers, to check compliance with Building Regulations.
- building service engineers, identifying locations for mounting rooftop equipment and service penetrations.
- lightning conductor specialists, to locate routes for earthing straps
- other specialists such as acoustic engineers.
- construction planers, co-ordinating access routes on congested sites and developing the programme.

Not all projects require an input from all disciplines, although for larger and more complex schemes there can be a need for wide ranging involvement in the roof design over a long period of time. The introduction of building information modelling (BIM) techniques can aid this co-ordination in preparing the contract documentation, provided that all of the disciplines are knowledgeable and experienced in developing and modifying the project model with confidence. It will be important that all of the drawings can be made available in a usable paper format for those working on site.

The contract documentation should clearly set out which parties will be taking responsibility for which tasks, such as completing the roof design and preparing detail drawings. These tasks will cost money to do properly, costs that should be allowed for in quotations. In refurbishment projects of existing roofs someone will need to identify the condition of the elements to be retained, such as the structural deck.

When a project runs smoothly these responsibility issues do not arise. In contrast when there is a difficulty, previous assumptions on responsibility are challenged as unsuspecting parties may learn to their cost. Identifying the project responsibilities in advance can help to avoid future misunderstandings. What may be accepted commercial practice in one part of the country can be quite different in a neighbouring region.

5.3 Positive drainage

One of the principal issues that effects roof performance throughout the world is the provision of adequate drainage. Peter Kalinger, the Technical Director of the Canadian Roofing Contractors' Association reported an increase in the number of membranes applied on roofs that were flat, with manufacturers claiming that it would not affect performance due to the impervious nature of the membrane materials. This practice has grown with the popularity of garden roofs. As a result leakage rates have increased in Canada, along with the costs and difficulty in affecting repairs.

There have been similar experiences reported in the United States. Walt Rossiter, previously of the National Institute of Standards & Testing and now Director of Technical Services at RCI, has concluded that a dead flat membrane roofing system is a design mistake. Slope is essential and should not be compromised due to cost. Tom Bollnow, a Senior Director of Technical Services at the National Roofing Contractors' Association based in Chicago, has also highlighted concerns of inadequate drainage, pointing out that this is a design issue for both new and re-roof situations.

For a waterproof roof with long term ponding, in the event of a puncture a large volume of water will slowly find its way down into the inside the building, spoiling internal finishes and equipment and adversely affecting the building use. In contrast for a waterproof roof with positive drainage there isn't the same volume of water acting as a reservoir. This significantly reduces the potential amount of water entry. Many lay people share the view that flat roofs will ultimately leak and are often surprised that they are not laid to shallow falls.

The ponding of rainwater on a roof can lead to the following consequences:

- in the event of damage, water ingress to the interior will be increased.
- it may cause progressive deflection of the deck, 15 mm ponding on a 500 m² roof has a dead load of 7.5 tonnes.
- it encourages the deposition of dirt and leaves, which can be unsightly and may obstruct outlets and/or become a slip hazard.
- it can lead to thermal stresses, algae, moss and mould growth and other vegetative growth which may decrease the life expectancy of roof finishes.
- ice may become a slip or wind blown hazard.
- it may contravene the terms of the warranty for the waterproofing membrane.

Codes of practice have specified minimum finished falls for waterproof roofs for many years. In the current code of practice for flat roofs with continuously supported coverings is BS 6229, which states at Table 6 that the minimum finished falls for a roof covered with built-up bitumen sheet, mastic asphalt, single ply membrane or a liquid waterproofing system should be at least 1:80. Further allowance should be made for deflection of the structural members and decking under dead and imposed loads, and for construction tolerances. BS 6229 advises that in the absence of a detailed analysis, a fall of twice the minimum finished fall should be assumed for design purposes. In other words a design fall of 1:40.

The design and construction of a roof laid to falls requires more care and attention at the design stage of the project. In Ireland where rainfall rates are high it is common practice for the architect to set out the rainwater outlets on a waterproof roof, identifying the directions of fall and calculating the changes in height. This is an important co-ordination role in ensuring adequate heights of upstands around roof edges and establishing door threshold levels. In the UK the same level of detailing is often missing from architect's detail drawings, and not considered to be within the scope of their design work. This omission has been found on occasions to be the cause of drainage problems on completed buildings.

It is recognised that creating a fall does add to initial construction costs. Where there is roof mounted equipment with upstands that penetrate the roof and interfere with the flow of rainwater, falls should be introduced to prevent the build-up of water, such as the introduction of tapered boards known as crickets. In practice there will be some areas of ponding immediately after rainfall. Erik Brandt advised that in Denmark ponding to a depth of up to 10mm over an area of up to 2 m^2 would be permissible. In North America ponded water is defined as any water that remains on a roof more than 48 hours after is stops raining.

Roofs laid to falls have fewer performance problems and less call backs to site to resolve leaks after completion.

5.4 Co-ordinate details

Many experienced roofers will tell us that the way to build a good roof is to sort out the details, and to do this at the start of the job. Construction projects are often unique, bringing together differing materials and components using various tools operated by workmen with different skill levels and experience, aiming to produce a weathertight roof that will experience unpredictable weather conditions and yet need to last for the life of the building. The risk of unsatisfactory performance such as a roof leak or wind damage that results in a call back to site, can be greatly reduced by paying careful attention to the details at both the design and construction stages.

The starting point of the detailed design is the project specification that usually sets out the sources of the components and their base materials, with reference to national standards and methods for installation and testing.

It is good practice for large scale drawings of typical details to be drafted, such as for roof edges, rainwater outlets and service penetrations. These drawings show the plans, elevations and sections and should be drawn to scale and annotated, listing the components such as the fasteners. The details may from part of the project Building Information Model. These drawings should use standard symbols and notation for ease of use of all parties, including those purchasing the materials, the installers, the checking engineers and the site inspectors.

Clear detail drawings also help to demonstrate in advance that the new roof construction will comply with standards and good practice. For example, showing that waterproof membrane upstands extend to a height of at least 150 mm above the roof plane. Drafting and checking the details does take time and does cost money. However, the savings in reduced assembly times and ultimately in performance soon outweigh the detail design costs.

Following the drafting of the details there is a need for the installer to read and understand the drawings before commencing work. Discussions can follow, talking through the planned sequence of assembly, identifying the tools and equipment that will be required. Feedback from the site team to the designers can improve the practicality of the roof assembly.

The independent checking engineer can serve a useful role at this stage, checking that the proposed details will comply with the project specification whilst offering constructive comments. The overview should seek to ask basic questions; will the detail be weathertight, structurally sound and durable? The review may also consider dimensional tolerances and the allowance for potential movement in the details due to drying shrinkage or thermal movement.

The details also need to be passed to the project architect responsible for co-ordinating the interfaces, such as with the wall heads and building services. Co-ordinating the details on large multi-disciplinary projects can present a challenge particularly when there is a shortage of time between the appointment of the roofing specialist and the start on site.

There are at least four practical ways of improving roof details:

i) Use standard details

It makes sense to use common details wherever possible which have been developed jointly by manufacturers and installers over a number of years, using available products that have a proven performance. Lessons learnt from previous projects can lead to progressive improvement in the standard details.

ii) Engage experienced designers

Tom Hutchinson, an architect based in Chicago and past president of the RCI is an advocate of the importance of designers preparing large scale clear details. To highlight the importance of these drawings and to promote better practice the Roofing Consultants Institute in North America hold document competitions at their annual convention. This gives an opportunity for roof designers to promote their work whilst being judged by their peers.

iii) Do a trial assembly

Experience has shown that on large projects and where there is significant repetition it is a cost effective and worthwhile exercise to carry out a full day trial assembly of an element of the roof in advance. It is important that such a mock up uses the actual components and materials specified and detailed, and preferably assembled by the tradesmen who will be carrying out the works. This gives a good opportunity to check the compatibility and assembly tolerances of the details, whilst looking for improvements and simplification. This also helps to demonstrate the buildability of the roofing details.

iv) Keep the details simple

It is not always practical to rationalise the number of details and to keep them simple. However, where it is possible to do so there can be savings in the number of components on a project with less scope for confusion in materials supply and handling, site assembly and final inspection.

A significant number of roof call backs are a result of flaws in the detailing of the roof, from design to installation. Careful attention should be given to the detailing by adopting standard details that are simple, practical and robust. On complex roofs and on large roofs with significant repetition, the construction of a full scale mock-up in advance is helpful for checking that the details can actually be built and for seeking improvements.

5.5 Manage effectively

Much has been written about the proper management of roofing works on site to avoid mistakes or errors. In 1980 the textbook 'Roofs: Design, Application and Maintenance' was published. Written by Maxwell Baker and sponsored by the National Research Council of Canada, much of the practical advice is still relevant today.

Cooperation is necessary between all parties involved during building construction, but particularly between the roofing contractor and the general contractor since both are responsible for assuring that the application is carried out in a correct manner. In general, proper techniques of construction for roofs include plant assembly and job scheduling, protected storage of materials, preparation of deck surfaces, construction on dry roof decks during dry weather, correct application temperatures and protection of the finished work. Good job organization and management is essential to obtain good workmanship, and this may be particularly important for winter construction when conditions may be less than most desirable. Work should be completed each night as if the crews did not expect to return to the job for weeks, a situation that sometimes happens.

Weather conditions during application and damage by other trades after application are among the principal factors causing roofing problems. The roofing contractor should not be expected to work under wet conditions, or cold conditions that are much below 0ºC. If this is unavoidable, arrangements should be made for temporary roofing which should be removed for proper application of the permanent roofing when conditions are satisfactory. Alternatively, roofing under a temporary shelter or covering may be a practical solution in some instances. The time schedule of the whole construction needs to be worked out so that little or no work of other trades is required over the roof after the roofing has been completed. When this is not possible a temporary roof may again be logical, with the final roofing laid only after all other trades have left. Special protection needs to be provided by the building contractor when it becomes necessary for even a small amount of construction traffic to take place over completed roofing.

For the construction of a reliable roof there is a need for advance planning to ensure the proper sequencing of work, together with the timely supply of the correct materials, tools and equipment. On completion of a roof it is important to protect the finished surfaces from damage by follow-on trades.

5.6 Competent applicators

Workmanship is extremely important in the application of roofing as all mistakes affect the life of a roofing system. Good workmanship is usually obtained through the art and skill of workmen and craftsmen. With the increase in machine production and the reduction in hand-craft there is a tendency to think that craftsmanship is no longer important. If art and skill are lacking, however, satisfactory application of building materials and systems is unlikely to occur except by chance. Problems will seldom be due to a deliberate attempt to produce poor work, but rather to a lack of appreciation of all the factors involved and their effects on the finished work.

The importance of national training schemes for roof applicators and tradesmen is widely recognized. Examples of good practice include:

- In Germany the International Federation of Roofworkers organize formal training programmes for roofers. These have been expanded to include Estonia.

- In Denmark there is a formal training programme lasting three years covering both bituminous and synthetic membrane roofing.
- In Israel there have been successful training courses led by Michael Marton and trade associations.
- In Japan training is organized by the Japanese Waterproofing Association.
- In North America the National Roofing Contractors' Association and the Canadian Roofing Contractors' Association organize regular training courses.

As roofing systems develop and materials change there is an ongoing need for all in the roofing industry to continue their professional development. Roofing failures are reduced where there are established training schemes for roofing tradesmen supported by organised roofing trade federations. Applicators should have experience in the chosen roofing system.

5.7 Inspection and testing

The quality of a waterproof roof is dependent upon the quality of the materials and workmanship on site. Kyoji Tanaka explained the importance of performing field inspections and testing in Japan to ensure that the roof membrane has been properly applied. The inspection and tests should be carried out by a person in charge of the quality of waterproofing membranes, such as the roofing contractor or, if possible, a third party. The following items and procedures are undertaken in Japan to ensure that the roofing works proceed smoothly.

i) During application:
- the condition of the deck should be checked before starting work, examining the smoothness and cleanliness of the surface, and the moisture content of the deck.
- the quality of the waterproofing materials should be determined by checking labels, tags and documents attached to the products.
- the preparation of sample specimens made by the same method as the actual membrane on site, can be helpful for testing the properties of the membrane such as thickness, strength and lap strength.
- checking the work at each stage with reference to the construction manual or a checklist is strongly recommended.

ii) After application:
- visual inspection of the completed membrane. In particular, parapets, corners, areas around doors and joints of sheets must be carefully examined.
- a flood test on the membrane roof may be helpful to ensure the watertightness of complicated roof shapes and the roof drainage system.
- the cutting of test specimens from a completed roof membrane should be avoided due to the higher risk of water leakage at the repaired sample area.

Non destructive test methods are widely used in some countries, including electrical earth leakage testing, 'Sparks' testing, and infra-red thermography. It is recognized that the technicians carrying out the tests need to adopt a systematic and conscientious approach. Care is necessary in interpreting the results to draw the correct conclusions.

Tommy Bunch-Nielsen advised that in Denmark the roofing contractor is liable for the satisfactory performance of the roof for ten years and this gives an incentive to operate internal quality control procedures, although these are not mandatory. It is understood that in Germany third party field inspections and testing would not be appropriate, although in contrast in the United States it is common.

6. LOOKING FORWARDS

6.1 Adequate resources

There is a constant demand to reduce costs, to build cheaper roofs. Eventually an absolute minimum cost to design, manufacture and install a roof system will be reached. Below this price there is loss of confidence that the roof will remain wind and weathertight for the given lifespan.

It has been observed that on occasion the cost of the floor finishes in a building entrance of a commercial building, are significantly more than the roof directly above even though the roofing would be expected to have a much longer life. The consequences of a failure of a roof to perform are often overlooked when evaluating project budgets.

At the specification stage of a project when comparing alternative roof systems of different initial costs and anticipated lifespan, a full life costing exercise can be helpful in identifying adequate resources for both the initial construction and maintenance phases of the roof. There is an ongoing need for the roofing industry to collectively promote the value of the reliable roof and to this end adequate resources are needed. These essential resources include:

i) Finance

The project team should ensure at an early stage in a project that there will be adequate finance to procure the building, including the roofing elements, and that money will be available to pay at the agreed times.

The roofing elements of work are often completed during the latter stages of the project. In the event of an overspend on earlier elements it is important to resist demands to reduce roofing costs to meet the fixed overall project budget. In the past this scenario has been an underlying cause for problem roofs, when early cost overruns have meant that there were inadequate financial resources to pay for a proper roof. The consequences of cost reduction for the roofing element need to be carefully considered in advance.

Allowance should be made for variation in the basic cost of raw materials. Zinc has increased by 17% in the year to October 2014 and aluminium by 5.7%. In contrast the price of lead has fallen by 6% and asphalt waterproofing by 1.4%.

ii) Time

To state the obvious, it takes time to design, manufacture and install a roof. Data from the Mace Business School in the UK tells us that the current lead times for waterproof membrane roofs are of the order of six weeks and for metal cladding fourteen weeks. This includes for the production and approval of fabrication drawings and the procurement of materials

Installation of many roof systems is also weather dependent, requiring dry conditions and with air temperatures above 5ºC. The construction programme should make allowances for inclement weather delays if roofing works are planned for the winter months.

iii) Materials

Roof performance depends upon an adequate supply of roofing materials of the correct quality and thickness being available to meet the construction programme.

iv) Equipment

To properly assemble and join roofing systems there is a need to provide the right tools for the job that are in good working order and serviced. This is particularly important on some roofing systems, such as automatic heat welding machines for single ply membranes, and seaming tools for metal standing seam roofs.

v) Skilled applicators

Ultimately the performance of the roof is dependent upon the skill and care of the tradesmen, frequently working without supervision assembling roofs that are progressively closed up. A reliable roof depends upon the provision of an adequate number of tradesmen who are able to meet the construction programme.

Resources are needed to build a roof, both in terms of finance to pay for the materials and labour, and time to do the work. At the bid stage assess the full life costing of the roof when comparing alternative schemes and methods.

It may be possible to construct a roof cheaply but there is a significant risk of a call back and having to rework the details, increasing long term costs. This is probably the most obvious cause of roof failures, although it is not often written down or openly recognised.

6.2 Planning for maintenance

Peter Flueler shared his experience of planning for maintenance in Switzerland. Architects and engineers develop on behalf of the building owner a maintenance plan which includes safety issues, identified risks and measures to be taken to meet the objectives of the plan. Experience has shown that the initial safety and maintenance plans are not adjusted when buildings are enlarged, changed or renovated, when the service life is prolonged and when the building changes ownership.

In the UK guidance on the maintenance of membrane roofs is given in BS 6229 Annex B. In order to properly care for a roof the following measures should be implemented:

- maintain historical records.
- control roof access.
- conduct six monthly inspections, with additional inspections following construction on or adjacent to the roof, when new equipment is installed and following unusual weather conditions, fire or vandalism.
- report leaks or roof damage immediately.
- ensure routine maintenance is carried out.
- use only competent roofing contractors for major maintenance and repairs.

The development and application of a reliability based system for the service life prediction and management of maintenance and repair procedures for low-slope roof systems were described in a paper by Brian Kyle and Peter Kallinger given at the Fourth ISRT in 1997. The effects of maintenance practices and also of roof traffic on the service life of roofs were modelled.

After completion of a roof there will be an ongoing need for the building owner to take responsibility for planned maintenance in the form of routine inspections and good quality repairs as necessary. Restricting roof access to only those who have a need to go onto the roof minimises everyday damage.

6.3 Learning from experience

In New Zealand Bill Porteous undertook a survey of literature on building failures in 1992. Two generic causes were considered: natural causes and human error.

The natural causes where 'building elements are attacked by nature' can be grouped into those related to dampness and moisture, movements, and chemical/biological changes. The second generic cause due to human error is perhaps of particular interest in considering the reliability of roofing systems and where there is often scope for improvement in management. Types of human error were identified and include:

- defective materials
- overlooked site condition
- ignorance
- over-emphasis on first cost
- defective documentation
- unanticipated consequence of change
- specialist contractors' lack of knowledge
- design too difficult to build well
- dereliction or negligence
- poor communication

Each of these ten types of human error have been developed in the Porteous paper. The 'unanticipated consequences of change' is of particular relevance to the topic of substitution of products. It is noted that many of the problems from the 1960's are still current today and in particular the lack of knowledge.

'Learning from experience' is a recommendation that can help prevent problems. Constructive feedback after a project is completed can lead to product development and future innovation. For example, in the U.K., there have been reports of intermittent rainwater leakage through laps in metal panel roof systems laid to shallow falls and particularly on long roof slopes in exposed locations. Site observations have identified sliding movements at end laps in extreme temperatures, and the need for fixing and sealant details to be designed to accommodate expansion and contraction.

There is an opportunity to learn from these experiences. In the first instance it should remain the roofing material manufacturer's responsibility to maintain and update technical information regarding the installation and performance of its roof systems. Independent feedback about building defects has been provided historically by trade associations and government sponsored research groups such the Building Research Establishment in the U.K., although this work is diminishing.

In Germany the long running series of Building Defects books published by the Fraunhofer Institute in Stuttgart are particularly useful for students and also as part of the continuing professional development for roofing industry members. Technical articles in journals and papers presented at conferences can be effective means to transfer knowledge.

Discussion forums on the internet are likely to become more common for sharing information, although the need for independent moderation is recognized. By developing appropriate means to share feedback in a constructive way we can learn from experience and improve roof reliability of the roof systems we design and build.

7. TENETS OF RELIABLE ROOFING

The challenge for the Committee has been to summarise and group together the many points of good practice to produce a simplified short document that would be useful and relevant to the construction and property industries globally.

Arising from discussions a summary was drafted of what appears to be best practice in forming a reliable roof, based on published reports, advisory papers and the experience of the members. It is important that this summary is in a form that will be of practical everyday use for designers, suppliers and contractors alike, ideally on one page and widely circulated. The tenets follow the sequence of a typical project:

Start	tenet 1
Plan	tenets 2-7
Do	tenets 8, 9
Verify	tenets 10, 11
Improve	tenet 12

The underlying basic principles or 'tenets' of reliable roofing are set out in a logical sequence for a typical roofing project, starting with the preparation of the roof design and contract documentation, proceeding to the procurement of materials and engagement of contractors, followed by construction, commissioning and maintenance. It is recognized from the outset that within the industry we have a significant knowledge base and that on completion of a project there are opportunities to offer constructive feedback.

1. Retain and disseminate knowledge base
2. Prepare contract documentation
3. Adopt positive drainage
4. Introduce element redundancy
5. Co-ordinate details
6. Ensure adequate resources
7. Substitute with care
8. Manage effectively throughout the project
9. Engage competent applicators
10. Inspect and test
11. Plan maintenance
12. Learn from experience

Figure 3: The tenets of reliable roofing

Taken on their own each tenet could be considered to be simplistic and no more than common sense. However, when they are considered as a whole they can make a contribution to promoting good practice in the design, construction and maintenance of roofing systems. The underlying importance of training and experience is common to all of the tenets. The tenets are given in Figure 3 and the full text with supporting information given in Appendix A1. This two page document has been translated into eight different languages to assist in circulating good practice.

8. CONCLUSIONS

The CIB W083 Commission on Roofing Materials and Systems has examined the concept of roof system reliability and identified a dozen common principles of best practice.

The twelve tenets of reliable roofing are a set of commands that promote best practice. These are particularly important for critical buildings such as hospitals, power supplies and data centres, where there should be adequate resources for the design and construction team.

With the translation and widespread circulation of these tenets the Committee hopes that the reliability of the roof systems we design and build will improve.

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TRANSLATIONS OF TENETS OF RELIABLE ROOFING APPENDIX A

The 'Tenets of Reliable Roofing' have been translated into the following languages, in the hope that the concepts will be more widely circulated, discussed and implemented.

1 English

2 French

3 Portuguese

4 Spanish

5 German

6 Danish

7 Japanese

8 Korean

9 Hebrew

10 Italian

TENETS OF RELIABLE ROOFING **A1: English**

As roof systems become more complex we face the risk of losing sight of the principal objective of a roof in providing shelter from the wind and rain. As an industry we all aspire to build roofs that meet the building owner's need for protection from the weather. It is recognised that on occasion roofs do leak or become detached. The CIB Commission set out to identify specific actions and priorities that will improve confidence. Each command or 'tenet' on its own is no more than common sense. However, when read together, the instructions will help to improve the reliability of the roofs we design and build. The need for training and experience is common to all of the tenets.

Objective: To collectively identify actions and priorities that can improve the reliability of roofing systems.

1. Retain and disseminate knowledge base

Across the world we already have the knowledge in centres of excellence of how to build a reliable roof. There is an ongoing need for the transfer of this knowledge through training and continuing professional development. The loss of experienced personnel through retirement or redundancy is a threat.

2. Prepare contract documentation

The drafting of project specific drawings and specifications is an essential early stage. There should be proper co-ordination with other roof related disciplines, including structural, heating & ventilating and plumbing. Consideration should be given to the long term maintenance of the roof including a safe means of access.

3. Adopt positive drainage

Roofs laid sloped to drains have fewer problems and less call backs to site to resolve leaks after completion. Drainage outlets need to be properly designed with sufficient capacity and connected into the rainwater goods system.

4. Introduce element redundancy

A double layer roof is a good example of a roof which has inbuilt redundancy. If the outer layer were to leak there would still be a secondary drainage path below so that rainwater does not enter the building. Another practical example is the introduction of an overflow pipe through a roof parapet.

5. Co-ordinate details

A significant number of roof call backs are a result of flaws in the detailing of the roof, from design to installation. Careful attention should be given to the detailing by adopting standard details that are simple, practical and robust. On complex roofs and on large roofs with significant repetition, the construction of a full scale mock-up in advance is helpful for checking that the details can actually be built and for seeking improvements.

6. Ensure adequate resources

Resources are needed to build a roof both in terms of finance to pay for the materials and labour, and time to do the work. At the bidding stage assess the full life costing of the roof when comparing alternative schemes and methods.

7. Substitute with care

Changing a specified part of a roof system to an alternative product can introduce unforeseen difficulties in the future, such as a lack of compatibility, ultimately increasing the risk of water ingress. Documentation of product performance is needed in the consideration of an alternative. A cautious approach should be adopted to the substitution of products, particularly if the changes are hurriedly proposed, whilst recognising the value of innovation in construction.

8. Manage effectively throughout the project

For the construction of a reliable roof there is a need for advance planning to ensure the proper sequencing of work, together with the timely supply of the correct materials, tools and equipment. On completion of a roof it is important to protect the finished surfaces from damage by follow-on trades.

9. Engage competent applicators

Roofing failures are reduced where there are established training schemes for roofing tradesmen supported by organised roofing trade federations. Applicators should have experience in the chosen roofing system.

10. Inspect and test

Checking the quality of materials and work during the roof assembly is recommended, recognising the difficulties in putting the roof right after completion. Non-destructive test methods can be beneficial in identifying timely corrective actions.

11. Plan maintenance

After completion there will be an ongoing need for the building owner to take responsibility for planned maintenance in the form of routine inspections and good quality repairs as necessary. Restricting roof access to only those who have a need to go onto the roof minimises everyday damage.

12. Learn from experience

On completion of a project there is an opportunity to critically review the performance and to give constructive feedback to the designers, contractors and manufacturers. This leads to product development. This virtuous circle can reduce the repetition of mistakes whilst raising general standards and the expectations of the building owner that the roof will be reliable. This is a motivator for innovation.

PRÉCEPTES DE LA TOITURE FIABLE A2: French

Introduction

Dès que les systèmes de toiture deviennent de plus en plus complexes, nous sommes confrontés au risque de perdre de vue l'objectif principal d'un toit; en offrant un abri contre le vent et la pluie. En tant qu'industrie, nous aspirons tous à construire des toits qui répondent aux besoins du propriétaire de l'immeuble soit la protection contre les intempéries. Il est reconnu que, des fois, les toits fuient ou deviennent détachés. Le comité de CIB a décidé d'identifier des actions spécifiques et les priorités qui amélioreront la fiabilité. Chaque commande ou «principe» à lui seul tient du bon sens. Toutefois, lorsque lues ensembles, les instructions contribueront à améliorer la fiabilité des toits que nous concevrons et construisons. Le besoin de formation et d'expérience est commun à tous les préceptes.

Objectif

Identifier collectivement les actions et priorités qui peuvent améliorer la fiabilité des systèmes de toiture.

1. **Conserver et diffuser les connaissances**

   À travers le monde, nous avons déjà des connaissances, dans les centres d'excellence, de la façon de construire un toit fiable. Il y a un besoin constant pour le transfert de ces connaissances par le biais de formation continue et de perfectionnement professionnel. La perte de personnel expérimenté, soit par le biais de retraite ou de redondance, est une menace.

2. **Préparer les documents liés contrat**

   La rédaction des plans et devis spécifiques au projet est indispensable dès le début. Il devrait y avoir coordination avec les autres disciplines liées aux toitures, incluant le plan structurel, le chauffage et la ventilation, ainsi que la plomberie. Il faut que le maintien de la toiture à long terme soit considéré, y compris un moyen sécuritaire d'accès.

3. **Implémenter le drainage positif**

   Les toits qui sont inclinés vers des drains ont moins de problèmes, et lorsque complétés, moins de retours sur site pour résoudre des fuites. Les points de drainage doivent être correctement conçus avec une capacité suffisante et connectés au système de manutention de l'eau de pluie.

4. **Introduire la redondance des éléments**

   Un toit ayant une membrane double est un bon exemple d'un toit qui a intégré une redondance. S'il y a une fuite dans la couche extérieure, il y aurait encore une voie de drainage secondaire dessous afin que l'eau de pluie n'entre pas dans le bâtiment. Un autre exemple est l'addition, à travers un parapet de toit, d'un tuyau de trop-plein.

5. **Coordonner les détails de méthodes d'assemblage**

   Une attention particulière, de la conception à l'installation, est requise afin d'éviter les retours sur site pour corriger les défauts de toiture. En adoptant des méthodes d'assemblage standardisées qui sont simples, pratiques et résistantes, les retours sur site seront réduits. Pour les toits complexes et les grands toits ayant plusieurs répétitions, la construction d'une maquette à pleine échelle est utile pour vérifier que le toit peut être construit tel que conçu, et pour évaluer si les méthodes d'assemblage proposées peuvent être améliorées.

6. **Assurer les ressources adéquates**

   Des ressources sont nécessaires pour construire un toit à la fois en termes de financement pour les matériaux et la main-d'œuvre, et le temps pour effectuer le travail. À l'étape de l'appel d'offres, lors de la comparaison des méthodes et des régimes alternatifs, évaluer le plein coût de la vie du toit.

7. **Substituer avec prudence**

   Le changement d'une partie d'un système de toit à un autre produit peut introduire dans le futur des difficultés imprévues, tel que le manque de compatibilité, et en fin de compte accroître le risque d'infiltration d'eau. Afin d'évaluer une alternative, il faut que le rendement du produit soit documenté. Tout en reconnaissant la valeur de l'innovation en construction, une approche prudente devrait être adoptée lors de la substitution de produits, en particulier si les changements sont précipitamment proposés.

8. **Gérer effectivement pendant le projet**

   Afin d'assurer la construction d'une toiture fiable, il est nécessaire de planifier à l'avance l'enchaînement approprié du travail, ainsi que l'approvisionnement opportun des bons matériaux, outils et équipements. Lorsque la construction du toit est terminée, il est important de protéger les surfaces finies afin d'éviter des dommages qui pourraient être causés par autres corps de métiers qui suivront.

9. **Engager les installateurs compétents**

   Dans certaines localités, les associations de commerçants en toitures ont créé des programmes de formation pour les gens de métier; réduisant ainsi le taux des défauts et les bris de toitures. Les installateurs devraient avoir l'expérience avec le système de couverture choisi.

10. **Inspecter et faire les épreuves**

    La vérification de la qualité des matériaux et du travail lors du montage du toit est recommandée, reconnaissant qu'il est plus difficile de corriger les défauts après l'achèvement. Les méthodes non destructives d'essai peuvent être bénéfiques à l'identification opportune des actions correctives.

11. **Planifier l'entretien**

    Lorsque complété, le propriétaire de l'immeuble aura besoin d'assumer la responsabilité de planifier l'entretien soit le biais d'inspections régulières et si requis les réparations de bonne qualité. En limitant l'accès du toit uniquement à ceux qui ont besoin d'y accéder, des dommages causés seront minimisés.

12. **Apprendre de l'expérience**

    L'achèvement d'un projet représente une occasion d'effectuer un examen critique du rendement et de donner une rétroaction constructive aux concepteurs, entrepreneurs et fabricants afin de contribuer au développement de produits. Ce cycle virtuel permet de réduire la répétition des erreurs tout en augmentant les normes en générales et les attentes du propriétaire de l'immeuble que le toit sera fiable. Il s'agit d'un facteur de motivation pour l'innovation.

PRINCIPIOS DE UMA COBERTURA SUSTENTÁVEL A3: Portuguese

Introdução

À medida que os sistemas de cobertura se tornam mais complexos, surge o risco de se perder de vista o principal objetivo de uma cobertura, que é propiciar abrigo contra vento e chuva. Como uma atividade industrial, nós todos almejamos construir coberturas que satisfaçam as solicitações das intempéries. Sabe-se que às vezes coberturas e telhas vazam, são danificadas ou arrancadas. O CIB se propôs a identificar ações e prioridades que aumentarão sua confiabilidade. Cada item ou tópicos por si só não é nada mais que bom senso. No entanto, quando lidos como um todo, as instruções vão ajudar na melhora da confiabilidade das coberturas que projetamos e construímos. A necessidade de treinamento e experiência é comum a todos os princípios.

O grupo de trabalho CIB W83 é um comitê conjunto sobre materiais e sistemas de impermeabilização, que reúne pesquisadores de mais de 20 países, para que, de forma criteriosa, numa visão global, discutam as evoluções e necessidades de melhoria das coberturas.

Objetivo: Identificar coletivamente ações e prioridades que possam aumentar a confiabilidade dos sistemas de cobertura.

Princípios a serem observados:

1. **Registrar e difundir a base de conhecimentos**

Já temos ao redor do mundo o conhecimento, em centros de excelência, sobre como construir uma cobertura confiável. Existe uma demanda viva para a transmissão deste conhecimento através de treinamentos e desenvolvimento profissional contínuo. A perda desta experiência pela redundância e pela aposentadoria do pessoal experiente é uma séria ameaça.

2. **Preparar a documentação para contrato**

A combinação dos desenhos e especificações do projeto específico é uma iniciativa essencial. Deve também existir uma coordenação adequada com as outras disciplinas relacionadas com a cobertura, incluindo estrutura, climatização e instalações hidráulicas. Deve se levar em conta a manutenção de longo prazo da cobertura, assim como meios seguros de acesso.

3. **Adotar escoamento positivo**

Coberturas com caimentos apresentam menos problemas e menos retornos para eliminar vazamentos após a obra pronta. Os ralos de captação devem ser projetados adequadamente, com capacidade de vazão suficiente e conectados aos sistemas de redes de água pluviais.

4. **Introduzir redundância básica**

Uma cobertura com camada dupla é um bom exemplo de cobertura com redundância incorporada. Se a camada mais externa tiver algum vazamento, ainda haverá a secundária abaixo, para impedir que a água entre na edificação. Outro exemplo prático é a introdução de um extravasor, ou tubo ladrão, através da platibanda, como um alerta de problemas em escoamento ou drenagem.

5. **Coordenar detalhes**

Um número significativo de chamadas de volta a obra resulta de falha no detalhamento da cobertura, do projeto, e da instalação. Cuidadosa atenção deve ser dada ao detalhamento adotando padrões que sejam normatizados, simples, práticos e robustos. Em coberturas complexas ou grandes áreas com muitos detalhes repetidos, a construção de um campo de provas é uma grande ajuda para conferir se os detalhes são exequíveis e para introduzir melhoras.

6. **Garantir recursos adequados**

Recursos são necessários para se construir uma cobertura, sejam eles financeiros para pagar pelos materiais e mão de obra, assim como tempo e prazos para executar os trabalhos. Nos estágios iniciais avalie o custo desta cobertura por sua vida útil, para comparar com soluções alternativas e métodos diferentes.

7. **Substitua com cautela**

Alterar a especificações de um componente de uma cobertura por produto alternativo pode trazer algumas complicações imprevisíveis no futuro, como incompatibilidades, aumentando o risco de infiltrações. Documentos que informem a performance prevista do material são necessários se analisar uma alternativa. Uma abordagem cautelosa deve ser adotada numa substituição de produtos, especialmente se a mudança é proposta na correria, sem, no entanto, deixar de considerar o valor da inovação na construção.

8. **Gerencie com eficiência ao longo de todo o processo**

Na construção de uma cobertura confiável é necessário um planejamento para garantir a sequência certa dos trabalhos, aliada ao suprimento de materiais, ferramentas e equipamentos na hora certa. Após a conclusão da impermeabilização e montagens, é importante proteger as superfícies acabadas contra danos de atividades subsequentes.

9. **Envolva aplicadores competentes**

As falhas de impermeabilização são reduzidas quando os métodos de treinamentos dos trabalhadores são rotinas definidas e apoiadas por associações de classe do setor.

10. **Inspecionar e testar**

Verificar a qualidade dos materiais e da mão de obra durante a montagem e instalação é uma recomendação, pois deve-se reconhecer as dificuldades inerentes para se ter tudo funcionando após o término dos trabalhos. Testes não destrutivos podem ser vantajosos para identificar medidas corretivas a tempo de evitar problemas.

11. **Planejar manutenção**

Após a conclusão e entrega será necessário que o proprietário assuma uma responsabilidade rotineira constante, com manutenções programadas e reparos de qualidade, sempre que necessário. Restringir o acesso a apenas aqueles que tenham real necessidade de andar no pavimento de cobertura minimizará danos corriqueiros.

12. Aprenda com a experiência

A conclusão de uma cobertura é uma oportunidade para uma análise crítica de desempenho e de enviar um relatório para os projetistas, aplicadores, fabricantes e construtores. Isto gera o desenvolvimento do produto e dos serviços. O circulo vicioso pode reduzir a repetição de erros, ao mesmo tempo em que eleva os padrões e a expectativa do proprietário da edificação, que pode confiar na impermeabilização. E é um motivador para a inovação.

PRINCIPIOS DE TECHAR FIABLE **APPENDIX A4: Spanish**

Introducción

Al llegar a ser más complejos los sistemas de techar corremos el riesgo de perder de vista el objetivo principal de un techo que es proveer refugio del viento y de la lluvia. Como industria todos aspiramos construir techos que cumplan con las necesidades del dueño del edificio de protección de los elementos. Se reconoce que a veces los techos gotean o se desconectan. El CIB Committee pretendió indentificar acciones y prioridades específicas que aumentarán la confianza. Cada orden o 'principio' no es más que sentido común. Sin embargo, cuando se leen juntos, las instrucciones aumentarán la fiabilidad de los techos que diseñamos y construimos. La necesidad de entrenamiento y experiencia es común para todos los principios.

Objetivo

Identificar colectivamente acciones y prioridades que aumentarán la fiabilidad de los sistemas de techar.

1. Retener y divulgar la base de conocimiento

Ya existe en el mundo el mucho conocimiento en centros de excelencia de como construir un techo fiable. Hay una necesidad en marcha de transferir este conocimiento por medio del entrenamiento y desarrollo profesional continuo. Hay una amenaza de la pérdida de personal experimentado por medio de la jubilación o la redundancia.

2. Preparar la documentación del contrato

Preparar diseños y especificaciones específicos para el proyecto es esencial en las etapas iniciales. Debe haber coordinación con otras disciplinas relacionadas con techar que incluyen la estructura, la calefacción, la ventilación y la plomería. Se debe tomar en cuenta el mantenimiento de larga duración del techo que incluye acceso seguro.

3. Adoptar un drenaje positivo

Los techos que se inclinen hacia desagües tienen menos problemas y menos llamadas de reparaciones al sitio para resolver goteras después de terminar el techo. Los desagües tienen que ser diseñados apropriadamente con una capacidad suficiente y ser conectados al sistema de drenaje.

4. Introducir elementos de redundancia

Un techo de doble capa es un buen ejemplo de un techo que tiene redundancia incorporada. Si la capa exterior gotea todavía hay un vía de drenaje secundario abajo para que el agua de lluvia no entre al edificio. Otro ejemplo práctico es la introducción de una tubería de rebose a través de un parapeto del techo.

5. Coordinar detalles

Muchas llamadas de reparaciones son por causa de defectos en los detalles del techo, de diseño a instalación. Se debe preparar los detalles con atención cuidadosa, adoptando detalles estándar que sean sencillos, prácticos y robustos. En los techos complejos y grandes con mucha repetición, la construcción de una maqueta a gran escala por adelantado ayuda a asegurar que los detalles si pueden ser construidos y para buscar mejoras.

6. Asegurar los recursos adecuados

Se necesitan recursos para construir un techo para poder financiar los materiales y el labor y también para proporcionar tiempo para completar el trabajo. En las estapas iniciales hay que evaluar el costo total en comparación a esquemas y métodos alternativos.

7. Sustituir con cuidado

Cambiar una parte especificada de un sistema de techo por un producto alternativo puede introducir dificultades imprevistas en el futuro, como falta de compatibilidad, aumentando el riesgo de entrada de agua. Se necesita documentación del desempeño del producto en la consideración de una alternativa. Se debe adoptar una estrategia cuidadosa en la sustitución de productos, particularmente si los cambios se proponen con rapidez, pero también reconocer el valor de la inovación en la construcción.

8. Dirigir con eficacia durante todo el proyecto

Para la construcción de un techo fiable hay una necesidad de planificación por adelantado para asegurar la sequencia adecuada del trabajo, junto con un suministro oportuno de los materiales, herramientas y equipo correctos. Al terminar un techo es importante proteger las superficies acabadas de daños por especialistas que dan seguimiento.

9. Involucrar a los aplicadores competentes

Problemas con los techos se reducen cuando hay esquemas establecidas de entrenamiento para los obreros calificados apoyados por federaciones comerciales organizados de techos. Los aplicadores deben tener experiencia en el sistema de techo eligido.

10. Inspeccionar y probar

Se recomiende revisar la calidad de los materiales y el trabajo durante el montaje del techo porque es dificil reponer un techo una vez acabado. Métodos de probar no destructivos pueden ser de beneficio para identifar acciones correctivas oportunas.

11. Planificar el mantenimiento

Después de terminar el dueño del edificio tendrá la responsibiliadad del mantenimiento planificado en forma de inspecciones rutinarias y reparaciones de calidad si son necesarios. Limitar acceso al techo a solo los que tengan que subir al techo minimiza los daños cotidianos.

12. Aprender de la experiencia

Al terminar un proyecto hay una oportunidad de una revisión crítica del trabajo y para dar retroalimentación constructiva a los diseñadores, contratistas y fabricantes. Esto conduce al desarrollo de productos. Este círculo virtuoso puede reducir la repetición de errores y elevar las normas generales y las expectativas del dueño del edificio que el techo será fiable. Este es un factor de motivación para la innovación.

GRUNDSÄTZE VERLÄSSLICHER DÄCHER — A5: German

Einleitung

Da Dachsysteme immer komplexer werden, stehen wir vor der Gefahr, den Blick auf die wesentlichen Zielvorgaben des Daches als Unterschlupf vor Wind und Regen zu verlieren. Wir streben alle als Industriezweig Dächer an, die die Forderungen der Hausbesitzer nach Schutz vor Witterungseinflüssen erfüllen. Es ist bekannt, dass Dächer gelegentlich undicht sein oder abgelöst werden können. Das CIB Gemeinschafts-Komitee hat begonnen, besondere Maßnahmen und Prioritäten festzustellen, die das Vertrauen erhöhen. Jedes Gebot oder jeder „Grundsatz“ beschreibt für sich genommen nur den gesunden Menschenverstand. Aber alles zusammen gefasst werden die Anleitungen helfen, die Verlässlichkeit der Dächer die wir planen und bauen zu erhöhen. Die Erfordernis von Training und Erfahrung ist allen Grundsätzen gemeinsam.

Zielvorgabe

Gemeinsam Maßnahmen und Prioritäten festzustellen, die die Verlässlichkeit von Dachsystemen verbessern können.

1. Wissensplattform zur Bewahrung und Verbreitung

Überall auf der Welt haben wir bereits in Kompetenzzentren das Wissen, wie man verlässliche Dächer baut. Es gibt einen andauernden Bedarf des Wissensaustauschs durch Training und kontinuierliche Berufsentwicklung. Der Verlust von ausgebildeten Mitarbeitern durch Ruhestand oder Entlassung ist eine Gefahr.

2. Anfertigen einer Vertragsdokumentation

Die Erarbeitung von projektspezifischen Zeichnungen und Baubeschreibungen ist ein wesentlicher früher Schritt. Es sollte eine gute Koordination mit anderen auf das Dach bezogene Gewerke geben, einschließlich Baugewerbe, Heizung & Lüftung und Klempner. Die Langzeitunterhaltung des Daches sollte berücksichtigt werden einschließlich sicheren Sicherheitseinrichtungen.

3. Gesicherter Ablauf von Oberflächenwasser

Dächer mit Gefälle zu Abläufen haben weniger Probleme und weniger Rückrufe zur Baustelle um Undichtheiten nach der Fertigstellung zu beseitigen. Regenwassereinläufe müssen angemessen mit entsprechender Aufnahmemenge geplant und mit dem Regenwasserabflusssystem verbunden werden.

4 Einführen von Element-Redundanz

Ein zweilagiges Dach ist ein gutes Beispiel für ein Dach mit eingebauter Redundanz. Wenn die äußere Lage leckt, ist immer noch eine zweite Entwässerungsebene darunter, so dass das Regenwasser nicht in das Gebäude eindringt. Ein anderes praktisches Beispiel ist der Einbau eines Überlaufrohres durch die Attika.

5. Detail-Koordination

Eine größere Zahl von Dachreklamationen ist das Ergebnis von Fehlern in der Detaillierung des Daches, von der Planung bis zur Ausführung. Der Detaillierung sollte besondere Aufmerksamkeit gewidmet werden, mit der Verwendung von Details, die einfach, praktisch und robust sind. Bei komplizierten und großen Dächern mit häufigen Wiederholungen kann die Verwendung eines Originalmodells vorab hilfreich sein, um zu prüfen, das das Detail tatsächlich so hergestellt werden kann oder um Verbesserungen zu finden.

6. Sicherstellen ausreichender Ressourcen

Ressourcen sind notwendig um ein Dach zu errichten, sowohl in finanzieller Hinsicht zur Zahlung der Produkte und der Arbeit, als auch in zeitlicher Hinsicht, um die Arbeiten zu erledigen. Während der Ausschreibungsphase sollten die Kosten über die Lebensdauer des Daches abgeschätzt werden, wenn alternative Schemata und Methoden verglichen werden.

7. Ersetze mit Vorsicht

Der Wechsel von einem bestimmten Teil des Dachsystems zu einem alternativen Produkt kann unvorhersehbar Schwierigkeiten für die Zukunft hervorrufen, wie Unverträglichkeit, letztlich die Erhöhung des Risikos von Wassereintritt. Die Dokumentation der Leistungsfähigkeit des Produktes bei der Überlegung zu einer Alternative ist notwendig. Ein vorsichtiges Vorgehen sollte bei dem Ersetzen eines Produktes gewählt werden, insbesondere wenn die Änderungen kurzfristig vorgeschlagen werden, während der Nutzen der Innovation in der Bauweise zu betrachten ist.

8. Effektive Leitung durch das gesamte Projekt

Für den Bau von verlässlichen Dächern ist eine Vorausplanung notwendig, um die korrekte Reihenfolge der Arbeiten sicher zu stellen, gemeinsam mit der rechtzeitigen Beistellung vom richtigen Material, Werkzeugen und Zubehör. Nach der Fertigstellung des Daches ist es wichtig, die Oberfläche vor Beschädigungen durch nachfolgende Gewerke zu schützen.

9. Beauftragung kompetenter Auftragnehmer

Ausbildungssysteme für Dachdecker unterstützt durch organisierte Dachdeckerverbände gibt. Auftragnehmer sollten Erfahrung mit dem gewählten Dachsystem haben.

10. Beaufsichtige und prüfe

Die Kontrolle der Qualität der Materialien und der Ausführung während der Bauzeit des Daches wird empfohlen; es ist zu beachten, dass es schwierig ist, Fehler im Dach nach Fertigstellung zu beheben. Zerstörungsfreie Prüfungen können vorteilhaft sein um rechtzeitige Verbesserungsmaßnahmen festzustellen.

11. Geplante Wartung

Nach der Fertigstellung gibt es ein dauerndes Erfordernis für den Hausbesitzer, Verantwortung für eine geplante Wartung in Form von regelmäßigen Überprüfungen und nötigenfalls hochwertigen Reparaturen zu übernehmen. Die Beschränkung des Zugangs zum Dach auf diejenigen, die es müssen, verringert alltägliche Schäden.

12. Aus Erfahrung lernen

Nach der Fertigstellung eines Projektes gibt es die Möglichkeit, die Leistungsanforderungen kritisch nach zu verfolgen und eine Rückmeldung an den Planer, Unternehmer und Hersteller zu geben. Die führt zur Produktweiterentwicklung. Dieser vorbildliche Kreislauf kann die Wiederholung von Fehlern reduzieren, gleichzeitig allgemeine Standards und die Erwartungen des Hausbesitzers erhöhen, dass das Dach verlässlich ist. Dies ist ein Motivator für Innovation.

"BUD" ELLER GRUNDSÆTNINGER FOR PÅLDELIGE TAGKONSTRUKTIONER A6: Danish

Introduktion

Når tagkonstruktioner bliver komplekse,er der risiko for at tabe fokus på det væsentlige, nemlig at taget skal yde beskyttelse mod vind og regn. Som industri stræber vi efter at udføre tage, som opfylder bygningsejerens krav til beskyttelse mod vejret. Det er anerkendt, at tage på et tidspunkt bliver utætte eller nedbrydes. Den fælles CIB komite har arbejdet på at identificere specifikke opgaver og forhold, som vil styrke tiltroen til tagkonstruktioner. "Budene" eller grundsætningerne er hver for sig blot almindelig sund fornuft. Hvis de anvendes i sammenhæng, vil de imidlertid hjælpe til at styrke pålideligheden af de tage vi designer og bygger. Behovet for øvelse og erfaring er fælles for alle grundsætningerne.

Formål

I fællesskab at identificere opgaver og forhold, som kan forbedre pålideligheden af tagkonstruktioner.

1. Bevare og sprede vores videns base

Fordelt over verden har vi allerede videncentre, som har kendskab til hvordan pålidelige tage bygges. Der er et konstant behov for at overføre denne viden gennem uddannelse/træning og fortsat professionel udvikling. Tabet af erfarne personer på grund af pensionering eller afskedigelse er en trussel.

2. Forberedelse af dokumentation til udbud

Udarbejdelse af projekt specifikke tegninger og beskrivelser er et væsentlig første skridt. Der bør være god koordinering med andre emner/bygningsdele relateret til taget, herunder statiske forhold, varmeisolering, ventilation og øvrige installationer. Der bør lægges vægt på vedligeholdsforhold – også over lang tid – herunder muligheden for sikker adgang.

3. Sørg for sikker afledning af vand

Tage med fald mod afløb har færre problemer og udbedringer af lækager mv. efter færdiggørelse. Afløb skal dimensioneres med tilstrækkelig kapacitet og skal forbindes med afløbssystemet.

4. Introducer dobbeltsikring

En to lags tagdækning er et godt eksempel på et tag som har indbygget dobbeltsikring. Hvis det yderste lag får en lækage, er der stadig et tæt lag neden unde, så regnvand ikke trænger ind i bygningen. Et andet praktisk eksempel er et overløb, som kan fjerne vandet, hvis afløbet stopper.

5. Koordiner detaljer

Et betydeligt antal udbedringer sker på grund af, at der er mangler ved de anvendte detaljer både stammende fra projektering og udførelse. Der skal lægges stor vægt på detaljerne. Det anbefales om muligt at anvende standard detaljer som er simple, robuste og bygbare. På komplekse tage eller store tage med mange gentagelser, kan udførelse af en fuld skala mock-up være til stor hjælp ved kontrol af, at detaljer faktisk kan udføres eller til at udarbejde forbedrede løsninger.

6. Sørg for fornødne ressourcer

Ressourcer er nødvendige ved udførelse af et tag både økonomisk, så finansiering er til rådighed, og med hensyn til arbejdskraft og tid til at udføre arbejdet. På udbudstidspunktet bør totaløkonomien for taget sammenlignet med andre alternativer vurderes.

7. Substituer med omtanke

Udskiftning af dele af et tag med et alternativt produkt, substitution, kan medføre uforudsete vanskeligheder, fx manglende kompabilitet, som i sidste ende kan øge risikoen for vandindtrængning.

Dokumentation af egenskaber er nødvendige ved anvendelse af alternative produkter. Der bør udvises forsigtighed ved anvendelse af alternative produkter, især hvis alternativerne foreslås i sidste øjeblik, fx i forbindelse med besparelser.

8. Effektiv styring gennem projektet

Udførelse af et pålideligt tag kræver planlægning for at sikre den rette arbejdsgang og de korrekte leverancer af materialer, værktøj og udstyr på de rette tidspunkter.

Ved afslutning af arbejdet skal tagfladerne beskyttes mod skade fra efterfølgende arbejder, der sker på taget.

9. Anvend kompetente håndværkere/tagdækkere

Skader reduceres, hvor der findes faglige uddannelser for tagdækkere som er anerkendt/støttet af leverandører og organisationer. Tagdækkere bør have erfaring med det valgte tagsystem.

10. Besigtigelse og prøvning

Det anbefales, at der foretages løbende kontrol af materialekvalitet og udførelse – især under henseende til, at det kan være meget vanskeligt at udbedre efter færdiggørelse. Ikke destruktiv prøvning kan anvendes med fordel, så eventuelle udbedringer kan foretages på et egnet tidspunkt.

11. Planlæg vedligehold

Efter færdiggørelse har bygningsejeren et løbende behov for planlagt vedligehold i form af løbende besigtigelser og egnede udbedringsarbejder, når der er behov. Antallet af skader kan reduceres, ved kun at tillade adgang til taget for dem, som har behov for det.

12. Lær af erfaring

Efter færdiggørelse er der mulighed for at forestage en kritisk vurdering af ydeevnen og processen og til at give konstruktiv feed-back til projekterende, entreprenører og leverandører. Dette kan bidrage til at produktudvikling. Denne proces kan reducere risikoen for fejltagelser samtidig med at den øger den generelle kvalitet og bygningsejerens forventninger til at få et pålideligt tag. Det er en motivator for udvikling.

信頼性の高い屋根を作るための基本事項

はじめに

屋根は複雑になってきており、風や雨から我々を守るシェルターでなければならないという屋根本来の役割を、ともすれば見失いがちになるというやや危機的な状況に直面している。そのような中で屋根工事に携わるものは、厳しい屋外環境から守ってほしいという建物所有者の基本的要求に応えるべく、しっかりとした屋根を作り上げようとしているが、今もって屋根からの漏水、損傷等は発生している。

これらを背景に建築研究国際協議会（CIB）と国際材料連合構造試験研究機関・専門家連合（RILEM）との連合委員会では、屋根の信頼性を高めるための諸事項について検討した。個々の項目は常識的なことばかりであるが、それらを合わせて通して読み、実行するように心がければ、我々が設計し、作り上げる屋根の信頼性向上に大いに役立つと思う。訓練とか経験が必要なことは、すべての項目に関して共通であることは言うまでもない。

目的

屋根の信頼性を高めるためになすべきこととその重要性を明確化することを目的とする。

１．知識を蓄え、活用せよ。

世界的にみても我々はすでに、信頼性の高い屋根を作るためにどうすべきかについては、かなりの知識を保有している。今後は教育訓練や自己啓発を通して、これらの知識を伝達してゆく必要がある。退職や解雇のために経験豊かなひとびとが、次々といなくなっていることは将来に対する脅威である。

２．契約時にしっかりとした文書を準備せよ。

当該建物の詳細図面と仕様書は初期の段階に整備しておく必要がある。これらは施工段階での関連分野、構造、空調、配管等と連携して仕事を進める上で不可欠だからである。その際メンテナンスのために屋根の各部に安全に接近できるといったことを含めて、長期間にわたる維持管理に係わることがらへの配慮も必要である。

３．積極的に排水せよ。

ドレンに向かって十分な勾配のつけられている屋根では、漏水トラブルが少なく、完成後漏水修理のために、現場に呼び出されることも少なくなる。また排水口は十分な排水能力を確保し、しっかりした雨水排水設備に接続する必要がある。

４．屋根部材にはゆとりをもたせよ。

屋根を二重にすることは安全性にゆとりを組み込むための好例である。万が一上側の屋

根で漏水したとしても下側の屋根が２次的な排水面となり、雨水を室内に入り込ませないからである。パラペットの一部を開けてオーバーフロー管を設けることも、実現可能なゆとり設計の例である。

５．適切な納まりとせよ。

現場に呼び出される屋根不具合のかなりのものは、納まりの部分の設計から施工にいたるまででの何等かの不備の結果である。そのため単純であるが実用的で、しかも堅牢である標準的納まりを採用するなどして、納まりを万全にしておく必要がある。複雑な形状の屋根あるいは同じ形状が繰り返されるような大面積の屋根では、事前に納まりの不備を調べ改善するための実大模型を作ることは有効である。

６．必要とされる資源量のことを考えよ。

屋根を作るためには、材料や労働に対して支払わなければならない経費、作業に要する時間といった資源量について考えておく必要がある。そのためには入札時に複数の案と方法について、屋根に要する全ライフコストを評価し検討することが大切である。

７．代替品には注意せよ。

屋根構成部材の特定部分を他の製品に切り替えることは、時として将来に予期せぬ問題を引き起こすことがある。例えば構成部材間の整合性が欠落することにより漏水の危険性が高まるといったことである。代替品を採用する際には、その製品の性能に関する文書を十分読んで理解して採用することが大事である。特に変更提案が短期間で提出された場合には、もちろんそのことにより価値が高まることは理解しつつも、慎重な取り組みが求められる。

８．プロジェクト全体を通しての作業管理を効率的にせよ。

信頼性の高い屋根を作り上げるためには、必要な材料、工具、装置などをタイミングよく準備するなど、作業を滞りなく進めるためのしっかりとした計画は大事である。さらに工事完了後も、その後に行われる他工事で損傷を受けないように仕上げられた表面を保護しておくことは重要である。

９．力量のある職人を雇用せよ。

屋根の損傷は、屋根工業連盟などの団体により組織された屋根工事作業者のため訓練プログラムが整備され、実施されている地域では減少している。そのため屋根工事に係わる作業者が、当該の屋根の仕組み、工事に習熟していることは不可欠である。

１０．検査と試験を実施せよ。

完成した後で屋根の不具合箇所を直すのは難しいことを考えると、施工中に材料品質と施工品質をチェックしておくことを強く勧める。非破壊試験方法は適正に施工されているかどうかの確認手法としては有用である。

１１．維持管理をしっかり計画せよ。

建物所有者には屋根完成後、事前に維持管理計画に従っての定期的な検査、必要に応じての修繕の責任がある。屋根には必要な人だけが立ち入ることができるように制限すると、不特定多数のひとによる損傷を抑えることができる。

１２．経験からしっかり学べ。

プロジェクトが完成した時は、出来上がったものの性能をいろいろな角度から検討できる絶好の機会であり、設計者、施工者、材料製造業者に有益な情報をもたらしてくれる。これはその後の製品の開発に大いに役立つ。この好循環は不具合の発生を抑制すると同時に、全般的な水準を向上させ、最終的には建物所有者にとっての屋根の信頼性に対する期待に応えることになる。これはさらなる開発への強い動機づけともなる。

신뢰성이 높은 지붕 공사를 위한 기본 사항

도입

지붕 시스템이 다양하게 되면서 풍압 및 강우로부터 사람을 보호하는 쉼터인 지붕의 본래 역할을 잃어가는 위기에 직면하고 있다. 이러한 가운데 건물 소유자는 가혹한 옥외 환경으로부터 보호받고 싶은 기본적 요구를 달성하기 위해 지붕 시스템은 발전하고 완벽한 지붕을 만들기 위해 노력하지만, 아직도 지붕에서 누수와 손상 등이 발생하고 있다.

이 결과, 건축연구 국제협의회(CIB)와 재료구조물 시험·연구기관 국제연합(RILEM)의 연합위원회는 지붕의 신뢰성을 높이기 위한 제반 사항에 대해 검토하였다. 개별 항목은 상식적인 것이지만, 그것들을 모아 확인 및 실행하도록 하면 설계, 시공한 지붕의 신뢰성 향상에 많은 도움이 될 것이다. 모든 항목에 대해서 기본 훈련 및 경험을 전제로 필요한 것이 공통 전제 조건이다.

목적

지붕의 신뢰성을 높이기 위해 해야 할 일 및 그 중요성을 명확하게 만든다.

1. 지식을 축적하고 활용한다.

세계적으로 이미 신뢰성이 높은 지붕을 제작하기 위해 어떻게 해야 하는가에 대해서는 상당한 지식이 축적되어 있다. 향후 교육 훈련 및 자기계발을 통해 이러한 지식을 전달할 필요가 있다. 퇴직이나 해고로 인해 경험 및 지식이 있는 사람들이 사라지고만 있는 것이 미래의 문제점이 되고 있다.

2. 계약 시 완벽한 계약서를 준비한다.

해당 건물에 관한 상세한 도면과 시방서는 초기 단계에서 관리 할 필요가 있다. 이는 시공 단계에서 관련 분야, 구조, 공조, 배관 등과 연계하여 일을 진행하는 데에 있어서 필수적이기 때문이다. 유지보수에 있어서는 지붕 부분에 대한 안전한 접근편리성을 포함하여 장기적인 유지 관리에 관련된 사항에 대한 고려도 필요하다.

3. 배수와 관련된 사항에 대하여 관심을 가진다.

드레인 쪽으로 충분한 경사가 있는 지붕은 누수문제가 적고, 완공 후 누수에 대한 수리 및 보수를 위해 현장 방문하는 일도 적어진다. 또한 배수구는 충분한 배수 능력을 확보하여 확실한 배수설비가 되어야 한다.

4. 안전성을 높이기 위한 지붕 시스템을 생각한다.

지붕을 이중으로 하는 것은 지붕의 안전성을 높이는 좋은 방안이 될수 있다. 만일 상부 지붕에서 누수가 발생하여도, 하부 지붕이 2차적 차수면으로 작용하여 빗물이 실내에 들어오지 못하게 되기 때문이다. 난간의 일부를 열어 오버플로우관을 설치하는 것도 안전적인 공간 설계의 예이다.

5. 적절한 디테일을 설계한다.

현장에서 발생하는 지붕결함의 상당부분은 설계에서 시공에 이르기까지 디테일에서 발생한 결함이다. 따라서 단순하지만 실용적인 표준 디테일을 채택하는 등 디테일에 신경을 쓸 필요가 있다. 복잡한 형상의 지붕이나 동일한 모양이 반복되는 넓은 면적의 지붕에서는 사

전에 디테일 및 설계의 결함을 찾기 위해서 시험평가(Mock-up Test) 및 지붕 모형을 만들어 보는 것이 효과적이다.

6. 필요한 자원의 양을 미리 고려한다.

지붕 시스템을 제작하기 위해서는 재료와 노동력을 활용하여야 하여야한다. 따라서 이에 대한 비용, 작업에 필요한 시간과 자원 양에 대해 생각 해 두어야 한다. 그러기 위해서는 입찰 때 여러 방안과 방법, 지붕 시스템에 필요한 소요 비용을 평가하고 검토하는 것이 중요하다.

7. 대체품 사용에 주의한다.

지붕 구성 부재중에서 특정 부분의 제품을 다른 제품으로 대체할 경우, 이후 예기치 못한 문제가 발생 할 수 있다. 예를 들어 구성 부재간의 일관성이 저하 되면서 누수 가능성이 높아지는 문제가 발생 할 수 있다. 따라서 대안을 선택 할 때에 제품의 성능과 품질설명서를 충분히 검토한 후 대안 선택을 해야 한다. 특히 변경된 제안이 단기간에 제출 된 경우에는 가치가 높아질 수 있으나 신중한 대처가 필요하다.

8. 프로젝트 전반에 걸쳐 작업관리를 효율적으로 한다.

신뢰성이 높은 지붕 시스템을 제작하기 위해서는 필요한 재료, 도구, 장비 등을 적시에 준비하는 등 작업에 차질 없이 진행하기 위한 효율적인 계획이 중요하다. 또한 공사 완료 후에도 다음 행해지는 다른 공사에 영향을 주지 않도록 마무리 면을 보호하는 것도 중요하다.

9. 역량 있는 기술자를 고용해야 한다.

지붕공업협회 등의 단체에 의해 조직화된 지붕 공사작업자를 위한 훈련 프로그램에 있어서 실시 지역에 한해서 지붕 시스템의 결함 발생률이 감소하고 있다. 따라서 지붕 시스템의 시공에 관련된 작업자가 해당 지붕 시스템 구조에 경험이 있는 것은 필수조건이다.

10. 검사 및 시험을 실시한다.

지붕 시스템이 완공 된 후 결함 부분을 고치는 것이 어려울 것이라고 판단되면, 시공 중에 재료 품질과 시공 품질을 확인하는 것이 필요하다. 비파괴 시험 방법은 적정하게 시공되고 있는지 판단하는데 유용하게 사용되는 방법이다.

11. 유지관리를 제대로 계획한다.

건물 소유자는 지붕 시스템이 완성된 후 사전에 계획된 유지 관리 계획에 따라 정기적인 검사 및 필요에 따라 보수를 해야 하는 책임이 있다. 지붕에는 필요한 사람만 들어갈 수 있도록 하면 불특정 다수의 사람에 의한 손상을 억제할 수 있다.

12. 경험에서 제대로 배운다.

프로젝트가 완료되었을 경우는 지붕 시스템에 대한 성능을 다양한 각도에서 검토 할 수 있는 좋은 기회가 되며, 설계자, 시공자, 제조자 등에게 유용한 정보가 제공된다. 이는 다음 제품을 개발하는 데에 많은 도움을 준다. 이러한 순환은 결함 발생을 억제하는 동시에 전반적인 지붕 시스템의 수준을 향상시키며 궁극적으로 건물 소유자에게 지붕 시스템의 신뢰성에 대한 기대를 충족시켜주게 된다. 또한 이러한 순환은 지붕 시스템 개발자들에겐 개발에 대한 강한 동기부여도 된다.

A9: Hebrew

עקרונות לתכנון / בניית גג אמין ומאריך ימים

מבוא

המערכות המרכיבות את הגג הופכות למורכבות יותר ויותר. המטרה העיקרית של הגג – לתת הגנה למשתמשי המבנה מפני פגעי מזג האוויר. כולנו שואפים לתכנן ולבנות גגות שימלאו את יעודם המתוכנן ביעילות, לאורך זמן ובעלות סבירה. הוועדה המשותפת RILEM/CIB הציבה לה כמטרה להגדיר ולנסח רשימת פעולות וסדרי עדיפויות שיביאו לשיפור משמעותי באמינות מערכות הגג ותפקודן. הכוונה, להנגיש את המסמך לקהל רחב של מתכננים וקבלנים מבצעים.

בדרך כלל, כל פרט / הנחיה / פעולה בודדת הוא הגיוני ומובן, אך אינו מספיק. מכלול ההנחיות, המוצגות במסמך אחד ברצף, יביאו לשיפור משמעותי באמינות הגגות שאנחנו מתכננים ובונים. הצורך בהדרכה וניסיון הוא משותף לכל העקרונות.

מטרות

לזהות ולהגדיר את שלבי התכנון והביצוע כמפורט להלן, אשר יביאו לשיפור משמעותי בתפקוד מערכות הגג והקיים שלהן.

1. שמירה והפצה של ידע

במשך הזמן נצבר ידע רב באשר לתכנון ובניית גגות אמינים וברי קיימא. בכדי להטמיע את הידע ולהפכו לנחלת הכלל, יש צורך בהרחבת בסיס הידע הנצבר ובהעברתו למספר רב ככל האפשר של מתכננים ומבצעים ולדור ההמשך. ההעברה באמצעות צבירת ניסיון מקצועי מתמשך, תיעוד והדרכה. עובדים מנוסים הפורשים מעבודתם יוצרים נתק בתהליך התפתחות והעברת הידע שנצבר. לכן, לפני פרישתם של עובדים אלה, יש לדאוג להעברת ותיעוד ניסיונם המקצועי.

2. הכנת מסמכי תכנון

הכנת מפרט מיוחד ופרטים משורטטים רלוונטיים לגג הוא שלב ראשוני והכרחי בתכנון הגג על מרכיביו. הכנת מסמכי התכנון תוך הקפדה על תיאום הולם בין דיסציפלינות תכנון אחרות הקשורות לגג, כולל קונסטרוקציה, מיזוג אוויר, תברואה, צנרת ואחרים הם תנאי להצלחת התכנון. התכנון אמור להתחשב גם בתחזוקה של הגג לטווח ארוך, לרבות תכנון אפשרות / אמצעי גישה נוחה ובטוחה לביצוע עבודות על הגג כנדרש.

3. תכנון מערכת ניקוז

כדי להימנע מקריאות לבקר באתר על מנת להתמודד עם ליקויים ו/או כשל, יש לתכנן ולבנות את הגג בשיפוע המאפשר ניקוז וסילוק מהיר של המים מהגג. כמו כן, יש לתכנן קולטני מי גשם עם קיבולת מספיקה. הקולטנים יהיו מחוברים בצורה אמינה למערכת הניקוז הכללית המתוכננת להרחקת המים מהמבנה.

4. תכנון מרכיבי גיבוי

גג הבנוי כמערכת כפולה הוא דוגמה לתכנון מערכת גיבוי מובנית. משמע, גם במקרה של כשל/דליפה דרך הגג העליון, קיים נתיב נוסף לקליטת המים ולניקוז משני. תכנון שכזה, יבטיח כי מי הגשמים לא יחדרו אל תוך בניין. תכנון של 2 קולטני ניקוז, לפחות, וצינור עודפים הם דוגמא נוספת למערכת גיבוי מומלצת.

5. תיאום פרטים

מספר רב של קריאות לתיקון גג הן נגזרת של ליקויים בתכנון ו/או ביצוע בפרטי הגג. כדי להימנע ממצב שכזה, יש להקדיש תשומת לב מרבית ולוודא, כי הפרטים המתוכננים הם פרטים אופייניים פשוטים ככל האפשר, וברי ביצוע, כאלה שיתפקדו לאורך זמן. בגגות מורכבים ובגגות גדולים עם אלמנטים רבים החוזרים על עצמם חזרה משמעותית, בנייה מראש של מודל

בקנה מידה מלא תעזור לבדוק ולוודא, כי הפרטים אכן ניתנים לביצוע. בתהליך שכזה, ייתכן ויעלו רעיונות לשיפורים אפשריים ולייעול התהליך.

6. הבטחת משאבים מספיקים

משאבים, מימון וזמן, הם תנאי לתכנון בר ביצוע של גג שיתפקד כנדרש לאורך זמן.

7. אישור "שווה איכות"

יש לנקוט גישה זהירה להחלפה של מוצרים המוגדרים ע"י המתכנן, במיוחד אם השינוי מוצע בחופזה על סף מועד הביצוע. החלפת מרכיב מתוכנן במערכת גג ואישור מוצר חלופי כשווה איכות שלא על פי אמות מידה מקצועיות עלול לגרום לבעיות וקשיים בלתי צפויים בעתיד. סביר להניח, כי חוסר התאמה של מרכיב במערכת עלול להביא להגדלת הסיכוי לחדירת מים למבנה. אישור ,"שווה איכות", יינתן על סמך דפי מידע המציגים את המוצר, מאפייניו, יעודו ודוחות בדיקה המאשרים זאת. הצגת כל המידע הרלוונטי הוא תנאי למתן האישור. יש לחזור ולוודא כי המערכת החלופית מתואמת עם דיסציפלינות התכנון האחרות הקשורות בבניין.

8. ניהול יעיל לאורך כל משך ביצוע הפרויקט

תכנון מראש של כל שלבי הביצוע, במקביל וברצף, אספקת ציוד וחומרים במועד הנדרש, הם תנאי לבניית גג אמין וביעילות. עם השלמת הגג, חשוב להגן על השטחים הגמורים מפני פגיעה ע"י בעלי מקצוע נוספים.

9. העסקת בעלי מקצוע מיומנים

מספר התקלות בגג קטן משמעותית כאשר יש מערכת מסודרת של מערכי הדרכה לבעלי המקצוע. מערכים שכאלה יעשו ביוזמת/חסות ארגונים מקצועיים רלוונטיים. בעלי המקצוע הנבחרים לביצוע העבודה יהיו עתירי ניסיון בביצוע עבודות שכאלה.

10. בחינה ובדיקה

בדיקת איכות החומרים ופיקוח על העבודה במהלך בניית הגג, נדרשת ועשויה למנוע צורך בפעילות תיקון עתידיות. שיטות בדיקה שאינן הרסניות יכולות לסייע באבחון הצורך בפעולות מתקנות בזמן אמת.

11. תכנון תחזוקה

ניהול/ביצוע הליך מסודר של תחזוקה שוטפת לגג, לרבות בדיקות תקופתיות ותיקונים כנדרש, תורם תרומה משמעותית לתפקוד הגג כמתוכנן ולאורך זמן. הגבלת הגישה לגג וביקורת על אנשי מקצוע העולים לגג תמזער את הנזק לגג.

12. לומדים מהניסיון

עם השלמת פרויקט, מומלץ לבדוק, בראיה ביקורתית, את תפקוד הגג ולדאוג למשוב בונה ולהעברת נתונים למתכננים, לקבלנים וליצרנים. המשוב הוא תנאי לתהליך ההתפתחות לשיפור המוצר. נוהל שכזה יפחית את הליקויים והטעויות בתכנון/ביצוע גגות עתידיים ויאשר ליזם שהגג יתפקד כמצופה. משוב שכזה יוצר תמריץ לחדשנות.

PRINCIPI PER UNA COPERTURA AFFIDABILE **A10: Italian**

Introduzione

Poiché i sistemi di copertura diventano sempre più complessi, si manifesta il rischio di perdere di vista il principale obiettivo di una copertura, che è quello di proteggere l'ambiente interno degli edifici dagli agenti atmosferici. Come settore industriale aspiriamo tutti a costruire coperture in grado di rispondere alla necessità dell'utenza di vivere in un ambiente protetto dalle intemperie. D'altra parte non si può non riconoscere che spesso ci si trova di fronte a infiltrazioni o a dislocamenti del sistema impermeabile. Il comitato congiunto CIB/RILEM si è proposto il fine di identificare specifiche azioni e priorità che possano incrementarne il livello di affidabilità. Ogni prescrizione o principio di per sé non costituisce nulla di più che un'indicazione di buon senso. Tuttavia, quando lette insieme, le istruzioni contribuiranno più efficacemente a potenziare l'affidabilità delle coperture che vengono progettate e realizzate. Infine, ogni principio per essere efficace ha bisogno di formazione ed esperienza

Obiettivo: Individuare insieme le azioni e priorità che possono incrementare l'affidabilità dei sistemi di copertura.

1. Serbare, fare tesoro e divulgare la conoscenza di base

La conoscenza di base su come realizzare una copertura affidabile é già patrimonio di centri di eccellenza sparsi in tutto il mondo. Si pone però una crescente necessità di trasferire questa conoscenza attraverso percorsi di formazione per una valorizzazione professionale continua. La perdita di personale con esperienza, a causa di pensionamenti o licenziamenti, rappresenta una minaccia.

2. Preparare la documentazione contrattuale

Una fase preliminare essenziale è costituita dalla predisposizione di specifici disegni e specifiche. Risulta necessario un adeguato coordinamento con altre discipline riguardanti il sistema di copertura, inclusi gli aspetti strutturali, le condizioni ambientali interne istituite dai sistemi di riscaldamento e di ventilazione, gli aspetti relativi alle lattonerie. Deve anche essere tenuta in considerazione la manutenzione della copertura a lungo termine, includendo anche le modalità di accesso in sicurezza.

3. Adottare di un adeguato sistema di drenaggio e smaltimento delle acque meteoriche

Coperture con adeguate pendenze verso i sistemi di smaltimento delle acque meteoriche hanno pochi problemi e minori richieste di intervento in situ, dedicate alla risoluzione di fenomeni di infiltrazione dopo il completamento della copertura. I bocchettoni di smaltimento delle acque meteoriche devono essere correttamente progettati, dotati di sufficiente capacità di smaltimento ed adeguatamente connessi al sistema di smaltimento delle acque.

4. Introdurre elementi ridondanti

Un' impermeabilizzazione in doppio strato rappresenta un buon esempio di sistema dotato di una intrinseca ridondanza. Se lo strato esterno presentasse un'infiltrazione, ci sarebbe ancora un secondo strato e quindi un secondo percorso di drenaggio che impedirebbe all'acqua piovana di penetrare nell'edificio. Un altro esempio pratico di ridondanza è costituito dall'introduzione di un tubo di troppo pieno nel parapetto perimetrale della copertura.

5. Dettagli coordinati

Un numero significativo di interventi effettuati dopo la realizzazione del sistema di copertura sono la conseguenza di carenze nei dettagli, attivate sia in fase di progettazione che di realizzazione. Deve essere data attenzione alla scrupolosa adozione di dettagli standardizzati per la loro semplicità, praticità, sicurezza. Nel caso di coperture caratterizzate da specifiche complessità o nel caso di coperture di grande dimensione, caratterizzate da significative ripetitività nei dettagli, risulta utile la costruzione preventiva di un modello campione in scala reale al fine di verificare la fattibilità dei dettagli ed anche per individuare eventuali miglioramenti.

6. Assicurare adeguate risorse

Per realizzare una copertura sono necessarie adeguate risorse sia di tipo finanziario, per sostenere i costi del materiale e della manodopera, sia in termini di tempo per eseguire i lavori. Quando, in fase di gara d'appalto, si comparano schemi e metodi alternativi, è necessario verificarne gli specifici impatti sui costi che attengono anche a tutta la vita utile prevista della copertura.

7. Sostituire facendo attenzione

La modifica di una parte specifica di un sistema di copertura con un prodotto alternativo può introdurre imprevedibili difficoltà in futuro, determinate ad esempio da incompatibilità, che non possono che accrescere, alla fine, il rischio di infiltrazioni d'acqua. Quando la modifica viene presentata come una alternativa è necessario disporre di una documentazione di performance del prodotto. Pur riconoscendo il valore dell'innovazione nelle costruzioni, deve essere adottato un approccio cauto nella sostituzione dei prodotti, in particolare se le modifiche sono proposte frettolosamente.

8. Gestire efficacemente il processo di progettazione.

Per la realizzazione di una copertura affidabile, è necessario prevedere una corretta sequenza delle lavorazioni basata sulla tempestiva fornitura dei materiali appropriati e l'utilizzo di adeguati attrezzi ed apparecchiature. Alla conclusione dei lavori di realizzazione di una copertura è importante proteggere le superfici completate dai danneggiamenti da parte delle attività di cantiere successive.

9. Affidare le lavorazioni ad applicatori competenti

I problemi relativi ai sistemi di copertura sono ridotti in presenza di programmi di formazione per gli addetti alla posa, istituiti e supportati da associazioni di categoria del settore delle coperture. Gli applicatori devono avere esperienza nel sistema di copertura prescelto.

10. Ispezioni e prove

Il controllo della qualità dei materiali e delle lavorazioni durante la realizzazione del sistema di copertura, è estremamente raccomandato in quanto è difficile intervenire per mettere a posto la copertura, una volta terminata la sua costruzione. Test non distruttivi possono essere utili per identificare tempestivamente le azioni correttive.

11. Piano di manutenzione

Una volta completata la copertura, sarà successivamente necessario, da parte del proprietario dell'edificio, assumersi la responsabilità di effettuare un piano di manutenzione programmata, sotto forma di ispezioni a cadenza determinata e di intervenire, qualora necessario, con riparazioni di buona qualità. La restrizione dell'accesso in copertura, solo a coloro che hanno una necessità specifica di accedervi, minimizza i rischi di danneggiamenti quotidiani.

12. Imparare dall'esperienza

Dopo la realizzazione di un progetto è importante cogliere l'opportunità di esaminare criticamente le prestazioni ottenute in modo da fornire un feedback utile ai progettisti, agli applicatori ed ai produttori. Tutto ciò non può che portare al miglioramento del prodotto. Si tratta di un circolo virtuoso che da un lato può ridurre la probabilità della ripetizione degli errori e dall'altro costituisce un valido strumento per migliorare gli standard e fare fronte alle aspettative del proprietario dell' edificio in merito all'affidabilità della copertura

Il feedback prestazionale costituisce un elemento in grado di motivare lo sviluppo dell'innovazione.

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