Improving Roof Reliability: Interim Report from CIB / RILEM Committee

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Abstract

The roof systems we design and build are tested every time it rains or the wind blows. For some building users there is a need for a high degree of confidence that their roof will pass these tests, every time. Such buildings include computer centers, civic buildings and courthouses, where there should be funding available to construct roofs that are reliable.

The paper offers an interim report from the CIB W83 / RILEM Roofing Materials and Systems Task Group that was established in 2007 to improve our understanding of the reliability of roofing. The Task Group is identifying actions and priorities that can improve the reliability of roofing systems, and specifically to collate a set of common principles or tenets of best practice. Three of the tenets are described in the paper.

Lessons learned from a reliability engineering approach used for improving vehicle manufacture could also benefit the roofing industry, such as introducing element redundancy where appropriate. One design option is the double layer roof, with a primary weathering outer face and a secondary layer underneath that drains freely out

of the building. This is not a new concept as illustrated by the details adopted in the construction of a Japanese school roof more than three centuries ago.

The late substitution of products with apparent commercial advantages can lead to unforeseen performance problems later. The approaches being adopted in different countries are explored.

In reviewing the findings of roof inspections there are often common issues that recur. When the problem is repeated for the same roof system on different projects, there is an opportunity to learn from the experience and to change practice. This can be a motivator for innovation, a key management task. By developing appropriate means to share feedback in a constructive way we can improve the reliability of the roof systems we design and build.

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Keith Roberts is the Principal of Roberts Consulting, an independent firm of consulting engineers. He is a Chartered Civil and Structural Engineer who has investigated the performance of many different roof constructions in the U.K. and Ireland since 1991. He has lectured at colleges and written more than 150 technical articles published in the *Architects' Journal*, the U.K. roofing magazine *RCI* and the U.S. roof consultants journal *Interface*. He presented a technical paper on leak testing of membrane roofs to the International Symposium on Roofing Technology held in Washington in 1997. He is chairman of the CIB / RILEM Task Group examining the reliability of roofing.

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 build up 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.

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 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 as "the probability that an item will perform a required function without failure under stated conditions for a stated period of time." (O'Connor

2002). A crude 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.

CIB / RILEM Committee

The CIB W83 / RILEM Joint Committee on Roofing Materials and Systems consists of 40 roofing specialists drawn from more than 15 countries. In 2007 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.

Ten years ago the Committee examined the topic of roof sustainability and in particular identifying key points of best practice. 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.

The Committee has set out to look for examples of reliable roofing practices from different countries, with the objective of reducing the number of call backs to sites following project completion. A set of common principles or tenets is being drafted regarding how to form more reliable roof systems. Upon completion the findings will be summarized in one page and translated into different languages for widespread circulation.

Introduce 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

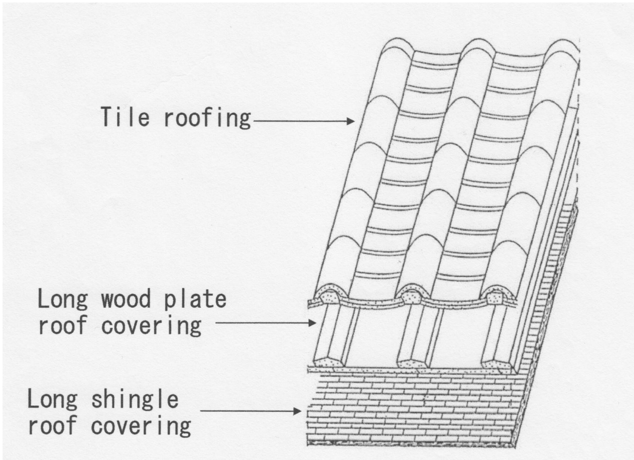

Figure 2: Roof structure of three layers

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, 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 we perhaps have forgotten. The builder recognized three centuries ago the importance of introducing element redundancy, so 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". Good examples of how element redundancy has been introduced into a modern roof construction are tile and slate roof systems 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. Introducing element redundancy should be encouraged at the design stage of the building envelope.

Substitute with care

During the CIB / RILEM Committee discussions it was found that problems 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. A balancing view is that product substitution can aid innovation, which is important for a developing industry.

When drafting project specifications the architect and building designer usually take 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 receive 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 save overall costs.

Within the Committee members shared their experiences with product substitution. An architectural practice based in the U.S. only would consider substitution at the time of bidding. In Israel it would be common practice to name three equivalent products named in a specification. In Germany often only performance requirements would be specified with product selection left to the bidder.

From Israel a series of criteria in assessing the acceptability of a substitution have been proposed. These include supplying a full set of relevant documents, referencing appropriate standards where they exist, restrictions on the number of requests for changes being limited, and a recognizing that 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 could help to improve the reliability of the completed roof.

Learn from experience

Learning from experience is another recommendation that can help prevent problems. Constructive feedback after a project is completed can result in product development and 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.

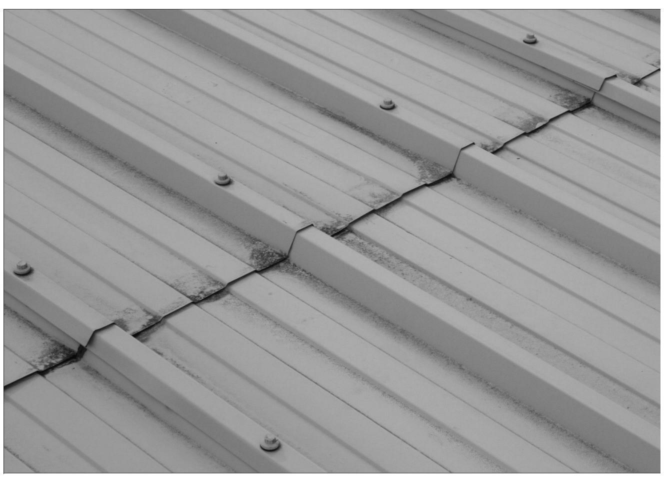

Figure 3: Typical composite panel end lap

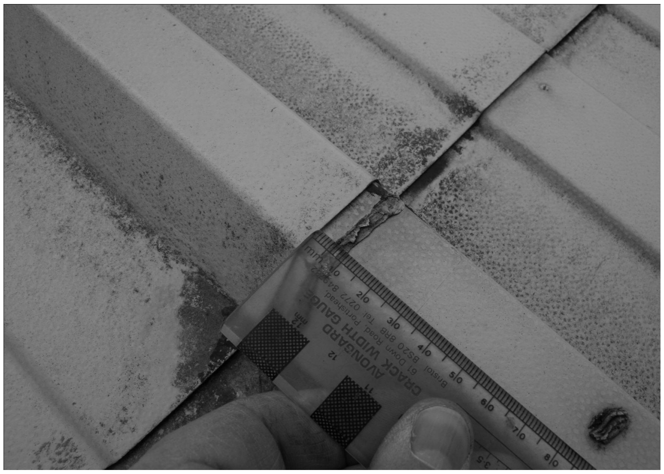

Figure 4: Sliding movement in extreme temperatures

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 as part of the ongoing 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 the reliability of the roof systems we design and build.

Conclusions

The CIB W83/ RILEM Committee on Roofing Materials and Systems has been examining the concept of roof system reliability and identifying common principles of best practice. There are likely to be a dozen tenets of reliable roofing, and three have been discussed in this paper:

- Introduce element redundancy
- Substitute with care
- Learn from experience

The committee continues to meet to complete the drafting of the tenets and the justification of their inclusion, with the expectation that the report will be published in 2012. With the translation and widespread circulation of these best practices the committee hopes the reliability of the roof systems we design and build will improve.

Acknowledgements

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