A STUDY OF PRACTICES IN THE DESIGN, DETAILING AND WATERPROOFING EXPANSION JOINTS IN NORTH AMERICA

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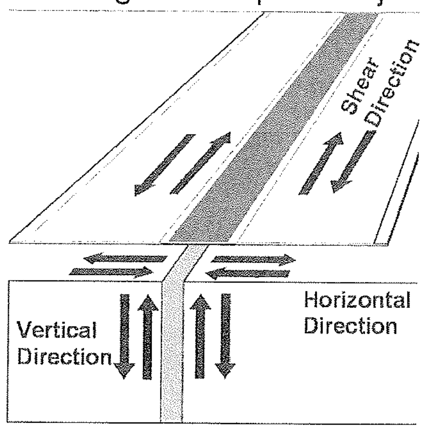
Expansion joints are periodic breaks in the structure of the building. An expansion joint is a gap in the buildings structure provided by the architect or engineer to allow for the movement of the building due to temperature changes. Waterproofing these joints is often an overlooked aspect of waterproofing design and detailing.

Typically these issues are left unresolved until the last minute or until they are encountered on site or even worse when they start to develop leaks. The generic presentation will examine the different aspects and history of expansion joint waterproofing design practices across North America (USA and Canada). The various methods of designing and detailing expansion joints in different roofing and waterproofing situations and systems will be examined and reviewed with extensive photographic documentation of encountered cases in the field.

The Problem of Movement and Water:

Expansion Joints are present in all types of building from the most simple box like designs to the most complex curvilinear buildings. Expansion joints by their own very nature are a unique feature of a building. An expansion joint is actually a gap, which allows space for a building to move in and out of. The movement of the building is caused most frequently by temperature changes, the amount of expansion and contraction of building dependant upon the type of material it is constructed out of. A steel framed building will move by a different amount then for example a concrete framed one.

Successful expansion joint design depends on two very critical factors, one is the accurate prediction of the building movement and two, the choice of a proper sealant. The latter is determined through complex calculations by a professional structural engineer, the former is achieved through proper choice of materials by a specifier. Most expansion joints in low raise buildings accommodate movements of up to 25 mm (1"), this movement can be significantly amplified if the building is tall or subjected to factors such as wind sway, seismic events, extreme variations in temperature. In all a building at an expansion joint will move in all three directions independently, that is in the vertical and horizontal planes as well as in shear along the joint itself. These are the movements, along the three principal axis of the joint. Correct determination of the building movement along these three directions is the first step in the successful design of an expansion joint.

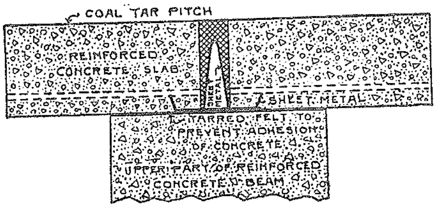


Movement at an expansion joint.

Having successfully determined the predicted movement along the three principal axis of the expansion joint gap, the designer and specifier is now faced with a more critical choice, that of choosing a material to seal the joint gap itself from the elements. This is a particularly important building envelope design consideration especially when moisture and water are present.

A Brief History of Expansion Joint Detailing in North America:

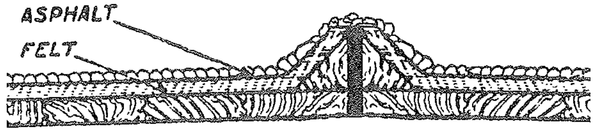
During the latter part of the 19th century, buildings and construction materials became more sophisticated with improvements in steel technology and advances in concrete construction, buildings required on a regular basis expansion joints. Designers and specifiers became increasingly creative with the design of expansion joint details, where the exercise was to introduce a detail which accommodated movement in all three principal directions and remained watertight, this proved to be a particular challenge in roofing and waterproofing. Here are examples of some of the standard details used from the 1880's through to the early 1970's in regular roofing construction.



EXPANSION JOINT IN CONCRETE ROOFING.

A typical expansion joint detail late 19th century(1)

A typical expansion joint detail in an early concrete structure circa 1890 Chicago, with a concrete roof slab waterproofed with coal tar pitch. The waterproofing of the joint relied on the coal tar pitch pour in the joint gap and a folded metal insert.



A curbed expansion joint detail early 20th century(1)

A curbed expansion joint detail in a Built-Up-Roof, typical of construction in the early part of the 20th century. The joint detail consisted of two wood cant strips back to back with and an asphalt pour and felt plys bridging the actual joint gap.

A typical raised curb expansion joint cover detail in use since the 1960's. The design of the counter flashing was detailed in a manner so as to prevent compressive buckling when a heated flashing is restrained from expanding. This details typifies the emphasis on providing a cover to the expansion joint gap, not actual waterproofing.

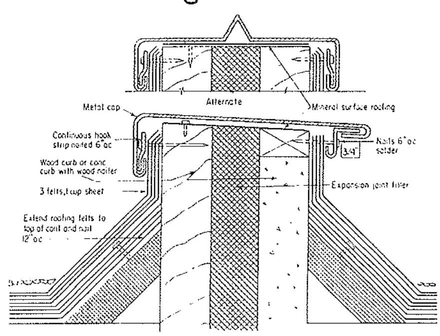
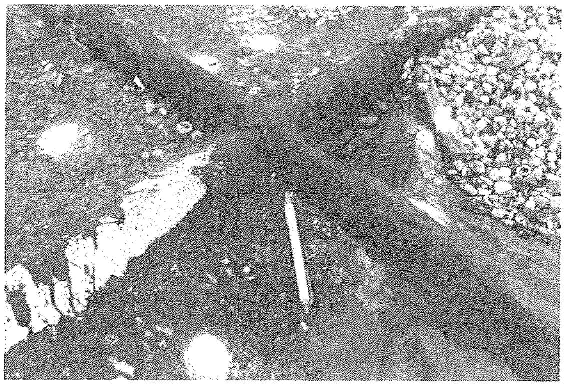


FIG. 7-10 *Typical roof expansion-joint detail.*

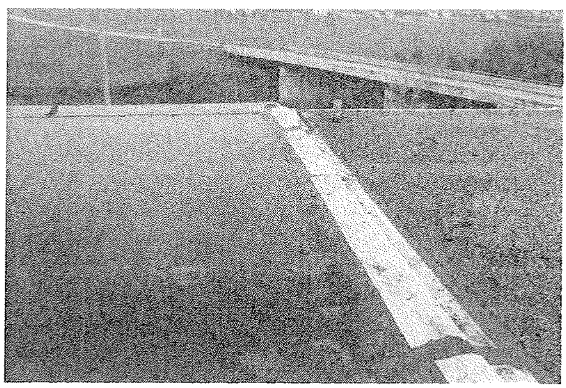
A raised curb expansion joint cover circa 1970(3)

Other types of joints included details where the roofing membrane was folded into the joint gap, frequently this type of membrane was a butyl sheet which over time succumbed to bending fatigue and weathering.

Each of the solutions was beleaguered with some form of design flaw that ultimately lead to water infiltration into the building and subsequently causing damage to the roof assembly. Below are some photographs of the more typical expansion joint failures and problems of more recent times.



A Typical failure at an expansion joint junction.



The water ponding effect of a raised expansion joint.

The photographs above depict the Achilles heel of today's expansion joints, the failure of the waterproofing membrane at the joint seams is a common cause of water infiltration into the roof assembly. The effect of ponding water on roof should not be discounted, ponded water can have an adverse effect on the long term performance of roof membranes.

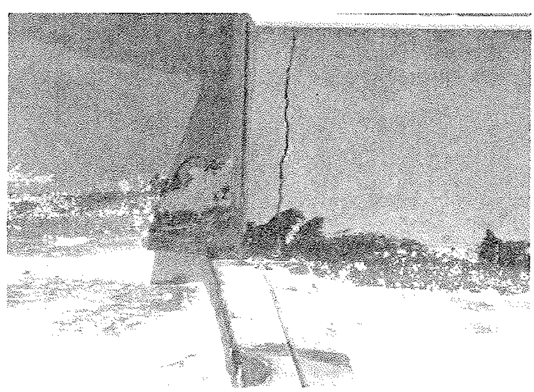
Expansion Joints in Waterproofing and Roofing Applications:

The waterproofing of expansion joints has created some very unique problems and solutions. The categories of these problems can be readily divided into two areas of application; waterproofing and roofing. Each of these areas in its own right exhibits unique approaches to the waterproofing and tie-in of the joint material. It should be remembered that expansion joints used in waterproofing are subjected to different performance requirements than roof expansion joints. The primary concern in joints used in waterproofing is their ability to perform under a pressure head and compatibility of their tie in to the waterproofing membrane. On the other hand in the case of roof expansion joints their ability to withstand long term weathering is of primary importance.

Waterproofing Applications:

Typically this form of application is confirmed to below grade installation three methods of waterproofing expansion joints exist; butyl rubber, friction fit and elastomeric joints.

Butyl Rubber Applications:



A butyl joint in a waterproofing application

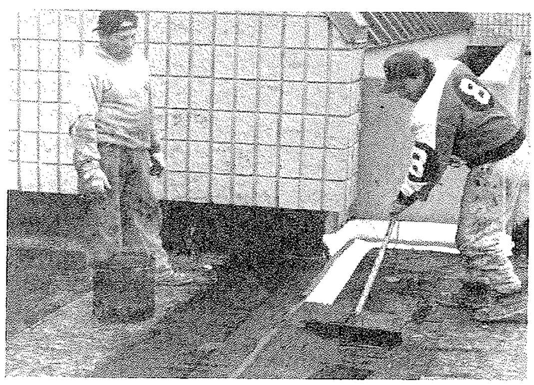
The use of butyl rubber in waterproof application arose as a result of the need to have a waterproof material which can be "looped" into an expansion joint cavity in such a manner as to allow for material movement without stressing the joint waterproof material. This is the most rudimentary of methods for joint waterproofing, problems naturally arise when certain details are encountered as they are unique and particular to a project situation. The chemistry and compatibility of these butyl rubber joints, limits the long term performance, as the material degrades under the influence of asphalt compounds and effects of heat aging. The following illustrate some typical uses of these materials.

Friction Fitted Joint Systems:

A typical friction fit joint

These joints perform well where there is no overwhelming need for watertightness rather their function is to provide a solution to traffic resistance. The reliance of friction fit to resist the infiltration of water is not entirely reliable. The seal between the actual joint material and the surrounding substrate can fail. Typically the life cycle of these joints is somewhat limited as water flows underneath the joint causing it to leak and damage the bond between the substrate and friction fit joint's sides.

Flat Elastomeric Joint Systems:



A flat elastomeric joint in a waterproofing application

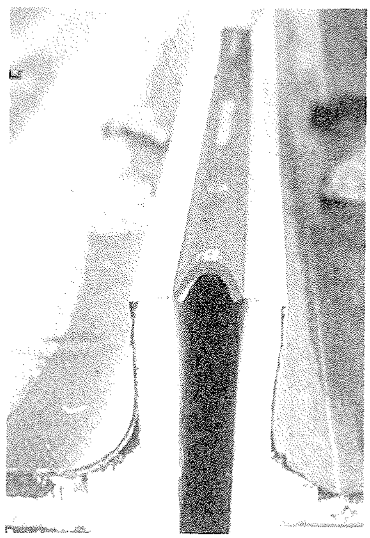
These are joints that are encapsulated in the actual waterproofing membrane and relay on the shear bond between the joint material and the waterproof membrane. Such joints typically have a central gland that allows for expansion and contraction of the joint material itself when movement is present. Joints manufactured from elastomeric materials are monolithically seamed which decreases the incidence of leaks at seams.

Roofing Applications:

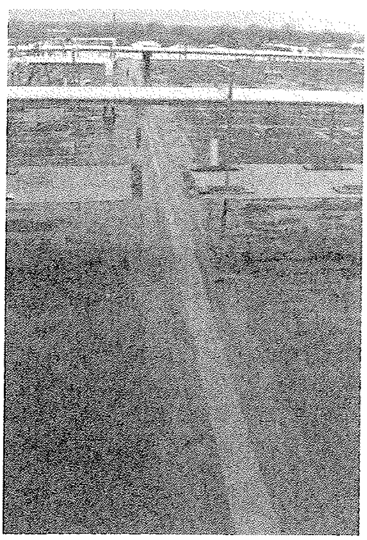
Under this application category, three distinct types of joints can be identified, namely bellow type joints, flat zero profile joints and thermoplastic and thermoset joints. Each of these joint types have gained one or another form of popularity, with bellow type joints being most the commonly used.

Bellow Type Joints:

This is the most common type of expansion joint which is used in roofing, The joint as the above historical review has described has been around for more then 50 years. The joint primarily consists of a bellows type material which is installed on a raised curb. The bellows provide the necessary material to allow for movement. Such expansion joints are typically used on asphalt roofs and perform provided they are well maintained and constructed. A common alternative or hybrid of these joints is the mopped single ply membrane which is used in lieu of the joint bellows.



A typical bellows type expansion joint



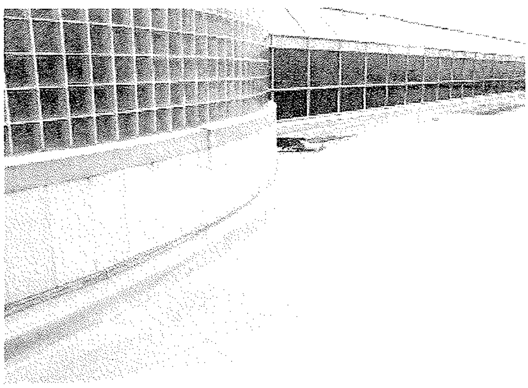
A zero profile expansion joint installed in a Built-Up-Roof

Zero Profile Joint Systems:

Zero profile joint systems are unique in the fact that they do not obstruct the flow of water and provide for the efficient drainage of water from the roof. These joints are typically installed in conjunction with an asphalt based roof membrane. The movement comes from the expansion and contraction of the joint center gland.

Thermoplastic and Thermo-set Membrane Joints:

These joints are used in thermoplastic and thermoset roof membranes and are constructed of extra material which introduced into the expansion joint cavity and are responsible for causing extra movement as a result of the excess material. The joints are waterproof and perform as well as the roof membrane materials since they are typically manufactured from these materials as the photographs shows.



A thermoplastic expansion joint.

Conclusion:

The problems posed by failures of expansion joint details stem more from the failure and material limitations of the expansion joint material itself. Advances in material chemistry in the last 20 years have brought out innovative solutions to difficult roofing and waterproofing problems. One such innovation is in the field of elastomers. Elastomeric materials are used on a large scale in today's single ply roofing applications. Chemical manipulations of elastomers at the molecular level have yielded a wide variety of materials, some with very unique properties. The use of these materials has resulted in a number of applications in the roofing industry, waterproof expansion joints being one. Excellent weathering resistance, chemical stability and non reactivity as well as the ability to be seamed monolithically, are properties that lend themselves to roofing applications.

The continual innovations in material technology and application techniques provide for better and more reliable solutions to difficult roofing problems. The issue of waterproof expansion joints is just one such challenge facing the roofing specifier and detailer today, it would be interesting to reflect on today's state-of-the-art technology in 50 years, just as we briefly reviewed the expansion joint detailing used in the roofing and waterproofing applications in North America today.

Acknowledgments:

1. Radford, William A., Portfolio of Details of Building Construction, Radford Architectural Company, 1911, pp. 73 & 78.
2. Karpati, K.K. and Sereda, P.J., Measuring the Behavior of Expansion Joints, National Research Council Canada, 1977, pp. 346 - 355.
3 Griffin, C.W., Manual of Built-up Roof Systems, McGraw Hill Book Company, 1970, pp. 117.
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About the Author

Mr. Kris Zielonka is a professional engineer who has been involved in roofing and building science since 1986. He is a specialist in joint waterproofing of above and below-grade structures. Kris has been involved in the development of test standards for PVC and Modified Bitumen roof membranes and is a member of both the American and Canadian Association of Civil Engineers. He is a permanent member of the faculty at RIEI. He is the Technical Manager for SITURA INC.