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DESIGNING RESILIENT ROOF SYSTEMS

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Recent powerful climate storms in the USA have the government discussing the need for resilient buildings: Buildings that can withstand severe storms, provide life safety and be quickly repaired. A building's roof is often the first line of defense in the changing climate conditions with its catastrophic natural disasters. The roof, if designed properly, can mitigate the impacts of these emergencies and allow a building to withstand and recover from the disruption caused. Resilience is increasingly being viewed as an important performance objective for governmental, educational, commercial and industrial construction. Interest in resiliency is high and is being actively discussed at all levels of the building industry: Governmental, Codes and Standards and Trade Organizations (ASTM, Resilient). This paper will review key resilient roof system elements that need to be considered by roof system designers: Best design and detail practices for roofing to achieve resiliency. The needed level of design and detailing will be reviewed. Recommendations to achieve resilient roof systems will be provided.

Keywords: Sustainability, Long term service life, Destructive storms, Roof deck, Construction.

1 SUSTAINABILITY TO RESILIENCE: A NATURAL PROGRESSION

For the past two decades the goal of attaining sustainable roof systems was a laudable one. Sustainable low slope roof systems were defined by the CIB W083/RILEM 166-MRS Joint Committee on Roofing Materials and System in there Publication No. 271 as: "A roof system that is designed, constructed, maintained, rehabilitated and demolished with an emphasis throughout its life cycle on using natural resources efficiently and preserving the global environment." In essence the goal was "Long Term Service Life". While new at the time, this concept is now expected by clients and no longer is a request.

The recent rash of violent and destructive storms: Hurricanes, hail, intense rain, wildfires and wind have resulted in a call for improvement in building construction: That improvement is called Resiliency.

Where sustainability calls for a building to minimize the impact of the building (roof) on the environment, resiliency requires a building (roof) to minimize the impact of the environment on the building. Thus, resiliency can be defined as: "The capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance."

Resiliency is the combination of many attributes and can be thought of as: Consisting of Durability, being Sustainability; designed for Resiliency: With the ability to: Adapt – to – Withstand – to – Recover. This concept of Resiliency, designing a roof system to weather intense storms and to be easily repaired (think of Puerto Rico and how you would repair a roof with no power, access to new materials and manpower that cannot get to your site) requires the roof system designer to:

(1) Understand that roofs are systems, only as good as their weakest link;
(2) Remove from their AutoCAD libraries old, out of date and irrelevant details;
(3) Design the roof system integration into associated barrier systems: Wall claddings, air barrier;
(4) Design the roof systems integration into the impinging building elements, such as: Roof curbs, RTU curbs, pipe penetrations, roof to wall, roof edges, roof drains and skylights;
(5) Understand how the roof will be used by the occupants: i.e. Public access, roof decks;
(6) Understand the construction sequencing and its impact on the roof;
(7) Coordinate with other impinging disciplines such as plumbing, mechanical and structural engineers; and,
(8) Develop comprehensive specifications.

1.1 Benefits of Resilient Roof Systems

Loss of property, life, productivity and inability to recover quickly were clearly evident following the severe storms the globe has experienced this year, resulting in both unlivable conditions, loss of jobs and depression. The cost of severe weather disasters in the USA in 2017 is in the billions of US dollars, a troubling trend of billion dollar events.

Resilient roof systems, the first line of a building's defense against severe weather, afford the hope of survival and the ability to be rapidly repaired. Their design doesn't rely on historical climatic events, which are clearly not the norm anymore, but anticipate climate change and repeated increasingly severe climatic events (Baskaran *et al.* 2017) (Baskaran *et al.* 2018). The Multihazard Migation Council (MMC) convened by the National Institute of Building Sciences (NIBS) in their study on mitigation efforts found that for every dollar spent on mitigation against severe weather saved an average of US$4.00. Prevention of destruction is clearly a key element and benefit of resilient roof system design.

2 ROOF SYSTEM COMPONENTS TO CONSIDER IN A RESILIENT ROOF

With resilient Roof Systems needing to be durable, sustainable, and adaptable and have the ability to recover, roof system components need to be consider in that light.

2.1 Roof Deck and Air/Vapor Retarder

The roof deck is the first component to be considered. Often outside the realm of the roof system designer, they must coordinate closely with the structural engineer. The roof deck must be able to support the roof systems anchorage and resist the anticipated forces and more. Thus it is not only the roof deck that needs to be considered, but the structure to which it is attached. Positive attachment and engagement is required. A related structural element to be considered in conjunction with the structural engineer is the roof edge, which must be tied back into the structure. As the first line of defense against wind, the roof edge structure, prior to the application of the roofing and sheet metal, needs to be robust and secure. For reroofing, this will require thorough field investigation. Often remediation of the existing roof edge condition will be required to achieve the desired result.

The air/vapor retarder should be thought of in several ways beyond the traditional value of use over humid interior conditions especially in temperate or cold climates, such as:

(1) Prevention of construction generated moisture movement into the roof system;

(2) The benefit of a temporary roof that will allow for other trades to use the temporary roof, rather than the final roof as a work surface;

(3) As a barrier to the inflow of moisture to the interior if the roof cover is physically damaged in a storm (think windblown debris in a hurricane), partially blown back or otherwise compromised roof cover. A quality vapor retarder is a valued component of most resilient systems.

2.2 Drainage

Draining water off the roof cover is a positive attribute of all roof systems not only resilient roof systems. Removing water from the roof as quickly as possible reduces the potential for that water to move inward should there be a breach in the roof cover. Draining water over a roof edge gutter or over an eave edge has the advantage of always being able to drain and not have the potential to be blocked. Interior roof drains are a predominate method of drainage in North America. For resilient systems the designer should work with the plumbing and structural engineers. Roof drains should be properly located, secured to the structural, so that they cannot be pulled up off the drainpipe if the roof membrane should blow up (see Figure 1). Consideration for when the drain might get clogged in a storm should be given in the form of overflow drainage potential in the form of scuppers or overflow drains that flow free to grade and are not connected to the drain system. Some prudent designers are looking into hidden drains; under the insulation at the vapor retarder as an emergency drain should there be partial roof blow-off that might trap water.

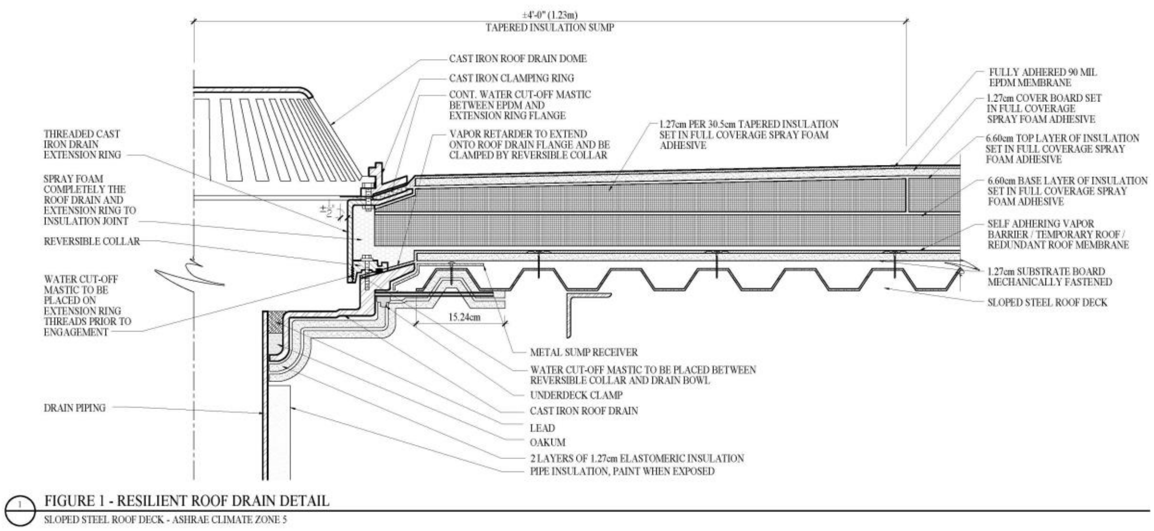

Figure 1. Drains should be properly located, secured to the structure and the vapor retarder integrated.

2.3 Roof Edge

The roof edge needs to be designed, not just be an afterthought. Taking the brunt of the initial wind loading, the roof edge components need to have strength, integrity under load and be integratable with the roof system. The roof edge should always be secured to the structure and all applied components such as wood blocking be robustly secured as well. Parapet walls can provide better wind protection than do gravel stops, but need a higher level of design.

2.4 Insulation and Cover Boards

In addition to its thermal properties, insulation provides the base for the roof cover and often provides the taper for drainage. The insulation layer though can be a weak link: Paper facers are hydroscopic and support mold growth and are susceptible to cohesive failure. Poor installation often leads to separation from the roof deck and/or each other. And low compressive strength can result in crushing of the insulation and resultant roof cover debonding. In North America the primary insulation is polyisocyanurate and this author suggests and specifies 25 psi, coated fiberglass facer (non-hydroscopic and does not support mold growth) polyisocyanurate. For adhered systems the board size should be no larger than 4'-0" x 4'-0" (1.22m x 1.22m) and when set in adhesive, the thickness should not be greater than 2.5" (6.35) so that it can be appropriately set into and bonded in adhesive. The cover board is an important component of a resilient roof system and is not an element of the system that can be value engineered out. The cover board provides a substantial substrate in which to bond the roof cover, protect the insulation from crushing under foot traffic and improved wind uplift resistance. The cover board should be compatible with the adhesives and membrane being used, and when adhered should be 4'-0" x 4'-0" (1.22m x 1.22m in size and a minimum of 1/2" thick (1.27cm). Proven cover board materials include: Cementitious, gypsum-fiber reinforced and glass mat faced gypsum.

2.5 Roof Cover

The roof cover selection should be based on parameters such as:

(1) Availability

(2) Contractor familiarity and quality of installation

(3) Ability to be easily repaired at times of storms, lack of power

(4) Past long-term performance success in the region

(5) Resistance to ultraviolet

(6) Repairable in a crisis and

(7) Redundancy capabilities.

Thicker membrane typically will perform better in harsh and violent climate conditions, especially in regard to puncture resistance.

In the Midwestern United States, EPDM has performed well for over 40 years; contractors are familiar with the product, its installation and nuances and is the only material that has a history of long-term performance. While there are numerous other materials currently available, they do not have a history of performance under the same formulations.

Resilient roof system must be looked at holistically, the sum of all its components. Viewing all the components in a drafted section of the roof system is a suggested way to visually observe how the components complement each other. Alternatively, the section might also show how some components might not work together and thus corrections can be made before moving forward with the design of the various components in the system. An example of a resilient roof system section for a sloped roof deck for drainage either to a roof edge gutter or interior roof drain, for ASHRAE climate zone 5 can be seen in Figure 2.

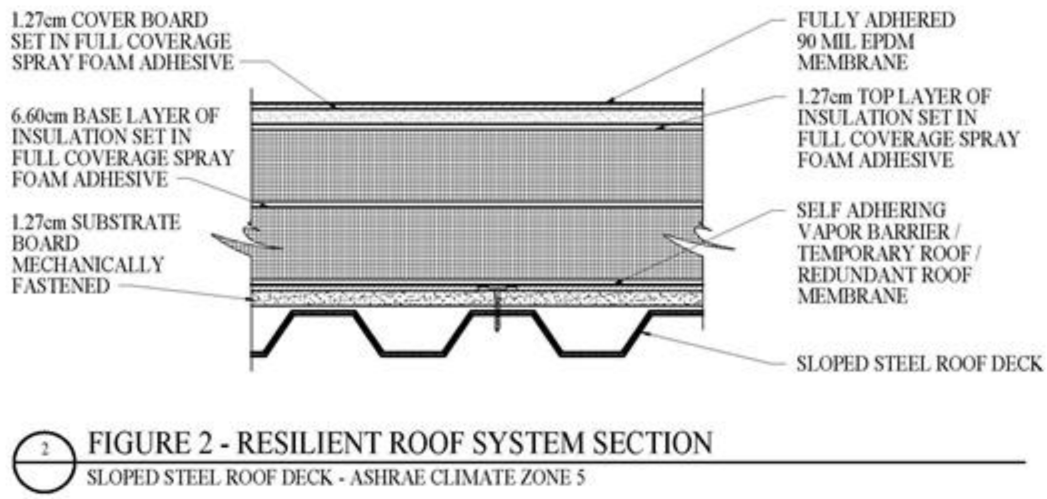

Figure 2. All roof components selected need to work holistically toward a resilient roof system.

By way of comparison, a typical non-resilient roof system is simpler in design with little thought to survivability of severe storms. Figure 3 gives an example of such a system for comparison with the resilient one in Figure 2.

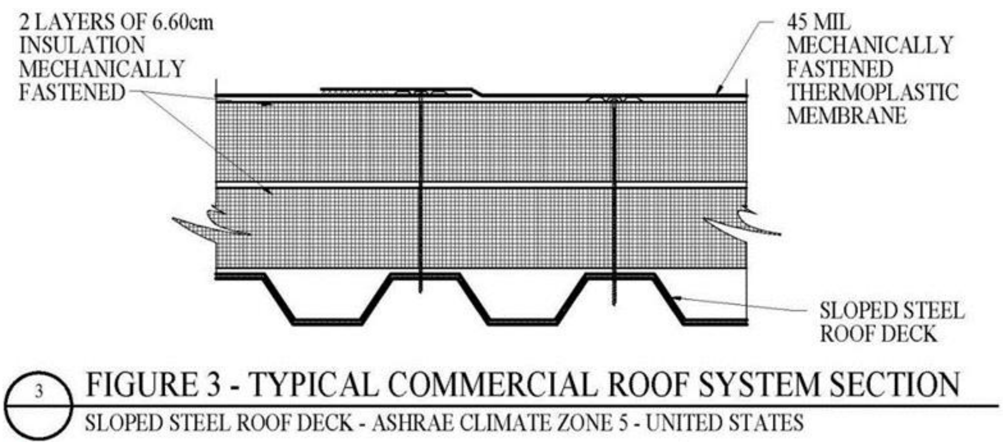

Figure 3: Roof systems that look to achieve only a roof warranty with little thought toward performance in severe are a high risk solution.

3 DESIGN RECOMMENDATIONS FOR ACHIEVING RESILIENT ROOF SYSTEMS

(1) Pre-Design: Gain an understanding of the climatic conditions in which the roof system will be installed: Storm history and 100-year events; New Construction: Work collaboratively with plumbing, mechanical and structural engineers to achieve a holistically design roof system. Reroofing: Evaluate all existing conditions that impinge on the roof and which may be a wind link in your system.

(2) Roof System Design: Think holistically; Think constructability; Select time proven materials in the climatic area of design of which contractors have expertise in installing; Provide redundancies in the roof system design, assuming that in intense climatic events,

a breach in the system will occur; Look at how each component is secured to the structure and each other; Anticipate the unexpected, and review how your design will act: Will it survive or fail?

(3) Construction Documents: Drawings and Specifications: Develop comprehensive drawing and specification that are project specific; and detail, detail, detail all conditions on the roof.

(4) Construction Observations: Be at the project to observe the installation, verify compliance with the drawings and specifications and to answer questions; and, remember you are part of a team working together to achieve a greater good.

4 CONCLUSIONS

This new design consideration, instead of relying on the hundred-year weather history, resilient design has to anticipate the now rapidly changing nature of climate. No longer can engineers and architects rely on what weather events have transpired in the past, where they have occurred or how frequently. Climate scientists and building scientists have to work together with engineers, economists, and manufacturers to determine best products and practices will work.

The concept of resiliency can be challenging when first confronted with altruistic definitions, but if one can think of it as "minimizing the impact of today's ever increasing volatile climate on the roof so that the building can function and the roof be quickly and easily repaired if damaged" the idea becomes clearer. Once crystalized, the design will be natural. Working together with clients, other disciplines and tradesman we can achieve roofs that are resilient to the effects of Mother Nature.

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