CRCA CANADIAN ROOFING CONTRACTORS ASSOCIATION
Technical Bulletin
VOLUME 40 November 1993

Design of Loose-Laid Gravel Stone Ballasted Roofs

Roofing membranes have the potential for "wind uplift" if they are exposed to high pressure differentials above and below the membrane. Forces which create pressure differentials are suction from above, as wind sweeps across the roof, and high interior building pressures from underneath. For unadhered, loose-laid roofing membranes, ballast is placed on top of the membrane to prevent wind uplift. The design of mechanically fastened roofing membranes is addressed in the National Building Code which provides clear guidelines as to the forces on the roof. However, the National Building Code has no firm or clearly defined guidelines for the design of loose-laid, gravel stone ballasted roofs; rather it refers to general wind load guidelines for structural or load resisting/bearing building elements. These guidelines are outlined in Part 4 of the National Building Code (NBC) 1990 and information pertaining to their application is provided in Commentary B of the NBC Supplement. However, more detailed guidelines and specific design procedures can be found in recommendations put forward by the American National Standards Institute (ANSI) in their ANSI RP-4 document, and by Factory Mutual Research Corporation (FM) in their Loss Prevention Data Sheet 1-29. The ANSI RP-4 document was co-authored by both the US Rubber Manufacturers' Association (RMA) and the Single-Ply Roofing Institute (SPRI). These organizations are on the leading edge of testing and monitoring the performance of loose-laid, gravel stone ballasted roofs. These procedures specifically address the design considerations.

How Roofs Resist Wind Loads

Roof decks and perimeters can be described as air impermeable or air permeable. An air impermeable deck is one which does not allow air to flow through it, such as a concrete slab. An air permeable deck is one which allows air to flow through it, through joints, etc. A corrugated steel deck is air permeable. If a membrane is loose-laid over an air impermeable deck or substrate, the deck will resist the interior air pressure and the membrane will only be subjected to suction from above. If, on the other hand, a membrane is loose-laid over an air permeable deck, the membrane will be subjected to both suction and internal pressure. The amount of ballast required to resist the upward pressure may then increase.

Design in accordance to ANSI RP-4 Design Guidelines:

The approach taken here is based on wind speeds, rather than wind pressures. Wind speeds are taken from an isotech map. These are published in ANSI RP-4 and in American Society of Civil Engineers ASCE 7-85 and ANSI/ASCE 7-88 documents. It should be noted here that the F.M. 1-29 data sheets use slightly higher wind speed data and, to qualify FM approved systems, their data must be used. The ANSI publications refer to wind speeds as "Fastest mile" rather than the hourly average wind pressures used in the National Building Code of Canada. To convert hourly wind pressures in kPa to "Fastest mile" wind speeds in mph, the following formula is used:

Fastest mile speed (in miles/hour) = 113 x (Hourly wind pressure in kPa)½

Some examples:

	Hourly wind pressure (kPa)	Fastest Mile (mph)
Vancouver	0.55	84
Winnipeg	0.42	73
St. Johns	0.73	82
Coral Harbour (NWT)	1.20	124

Terrain is taken into account by the type of exposure category, but it should be noted that the ANSI RP-4 exposure categories are different to those used in the NBC. The ANSI guideline also identifies various zones on roofs which experience different wind uplift forces. These areas include: corner areas where length and width dimensions are assumed to be equal to 40% of the building height, but not less than 2.6 m (8.5 ft.); perimeter areas which measure a minimum 2.6 m (8.5 ft.) in width around roof edges; and field areas which include the central roof areas. Roof areas subjected to different wind action require varying amounts of ballast. The amount of ballast varies from 50 to 65 kg/m² (10 to 13 psf) in conventionally loose-laid, gravel stone ballasted single-ply assemblies. Ballast is assumed to be round, 38 mm (1.5 in.) or 64 mm (2.4 in.) smooth stone consisting of ballast gradation sizes #2 and #4, as specified in American Society for Testing and Materials (ASTM) D448. If crushed stone is permitted it must also follow the gradation targets described above, some manufacturers may require that a membrane protection mat be placed between the membrane and the crushed stone.

It should also be noted that the ballast specifier must consider the implications of weight on the structural capacity of the building and, if in doubt, professional advice should be sought from a structural engineer.

The recommended amount of ballast may leave the membrane visible. This is not considered a flaw in the design, as the primary function of the ballast is to provide the mass to hold the membrane down, and the membrane should have sufficient U.V. resistance.

Special consideration should be given to internal pressures generated by mechanical ventilation systems and by thermal stack effects. Normal mechanical ventilation systems are capable of generating an additional internal pressure of up to 0.1 kPa in a building. On the other hand, thermal stack effects under a 40°C internal/external temperature differential can generate 0.2 kPa of pressure per 100 meters of building height. If internal pressure exceeds 0.3 kPa, then design authorities should be consulted, as general ballast assumptions are no longer valid.

Conclusions And Recommendations

Based on the above data and from practical experience on thousands of roofs, it can be surmised that the findings and recommendations from ANSI RP-4 should be adopted as a guideline for ballasting loose-laid single-ply roof membranes. If more detailed guidelines are required, the following references should be consulted.

1. American National Standards Institute (ANSI)/Rubber Manufacturers' Association (RMA)/Single-Ply Roofing Institute (SPRI): ANSI/RMA/SPRI/RP-4 "Wind design guide for ballasted single-ply roofing systems", 1988
2. Factory Mutual Loss Prevention Data, Data Sheet 1-29, 1984
3. National Building Code of Canada, 1990

It should also be borne in mind that the designer of the system has ultimate responsibility as to the required quantity of ballast. Furthermore, detail work around the perimeter is extremely important, as well as the fixation requirements, and should be looked at carefully