New Test Method To Assess The Walkability Of Roof Insulation Boards

Nico A. Hendriks

KEY WORDS: Insulation boards, roofing, walkability, test method and dynamic loading

ABSTRACT

For many years problems and failures with roof systems on insulation have occurred, caused by more or less frequent pedestrian traffic, mostly during the installation period. These problems relate specifically to mineral wool though frequent loading also can damage other insulation boards. The new European Standard, EN 12430:1998 "Determination of behaviour under point load", is totally inadequate though the objective is to determine whether a product has sufficient strength to withstand forces caused by pedestrian traffic. The result of a test according to this standard is more or less the compression strength of the tested insulation board. In actual practice, repeated loading can damage certain materials with good compression strength. Therefore, a new test method has been developed using an apparatus called 'The BDA Marathon Man' to simulate the repeated dynamic loading caused by a walking person. This paper describes the research program that has been carried out. The result is a new draft test method that provides for the classification of insulation boards with respect to walkability. Also, a comparison is given with observations on relevant roof failures in actual practice.

AUTHOR BIOGRAPHY

Nico A. Hendriks is professor in Building Materials and Sustainable Construction at the Technische Universiteit Eindhoven. He is also president of the BDA Test Institute, Gorinchem, The Netherlands.

INTRODUCTION

Problems and failures with roof systems on insulation occur caused by more or less frequent pedestrian traffic. These problems relate specifically to mineral wool though frequent loading also can damage other insulation boards. In actual practice, repeated loading can damage certain materials with good compression strength. The new European Standard, EN 12430:1998 "Determination of behaviour under point load", is totally inadequate though the objective is to determine whether a product has sufficient strength to withstand forces caused by pedestrian traffic. The result of a test according this standard is more or less the compression strength of the tested insulation board. By order of BING, the European Organization of Polyurethane Foam Manufacturers, an extensive research program has been carried out to establish a test method that simulates the dynamic loading by pedestrian traffic.

ROOF DAMAGE BY PEDESTRIAN TRAFFIC

During the installation period frequent pedestrian traffic on a low-slope roof can occur specifically with new construction projects and involving other building activities. This dynamic form of loading can cause severe damage to the insulation material and, subsequently, to the roofing material. The damage may happen despite specified measures to protect insulation boards and roofing materials during the construction phase. An example of such damage is shown in Photo 1.

Photo 1. Damage to roofing material caused by destruction of insulation material by frequent pedestrian traffic

OBJECTIVE OF THE RESEARCH

The objective of the research program was to draft a reproducible test to predict whether a roof insulation product is suitable to withstand repetitive walking on a roof especially during application but furthermore during maintenance. Linked to this test method, a classification system had to be set up to be able to rank roof insulation products with regard to the use of a roof.

Starting points

For the development of the test it has been based on the principle that the insulation shall withstand the pressure of the foot of a person weighing 70 kg and carrying a load of 30 kg, for instance a roll of roofing membrane. This load corresponds with a vertical load of 980 N on a die with an 80-mm diameter.

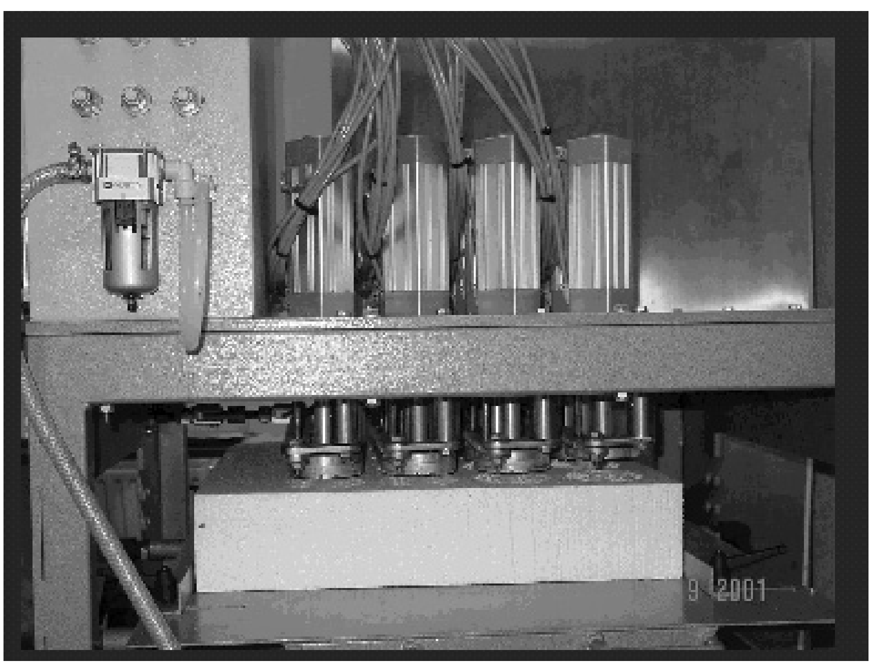
The test apparatus was designed to simulate repetitive walking by applying a dynamic and repeated force onto the insulation through a battery connecting 16 cylinders conducting 16 dies placed above the product to be tested. During one subcycle, each die is loading the test specimen subsequently. To load the product in the most equally distributed manner, after each subcycle, the test specimen is moved over half the center to center distance of the dies. These movements are executed from front to back and from left to right (or reverse).

To translate the real forces transmitted to a roof by a pedestrian, a radial force is applied onto the insulation to simulate the friction that occurs between a shoe sole and substrate. According to information supplied by a research center for the shoe manufacturing industry, this radial load is about one-third of the axial load. Therefore, this load is set at 390 N.

To apply a realistic load on the insulation, the underside of each die has been rounded and provided with a profile. To prevent the die from slipping when the radial force is applied, the underside of the die is made of a material comparable with the sole of a workman's shoe. According to the information of a research center for the shoe manufacturing industry, the most suitable material for the underside is polyurethane with a 60 Shore A hardness.

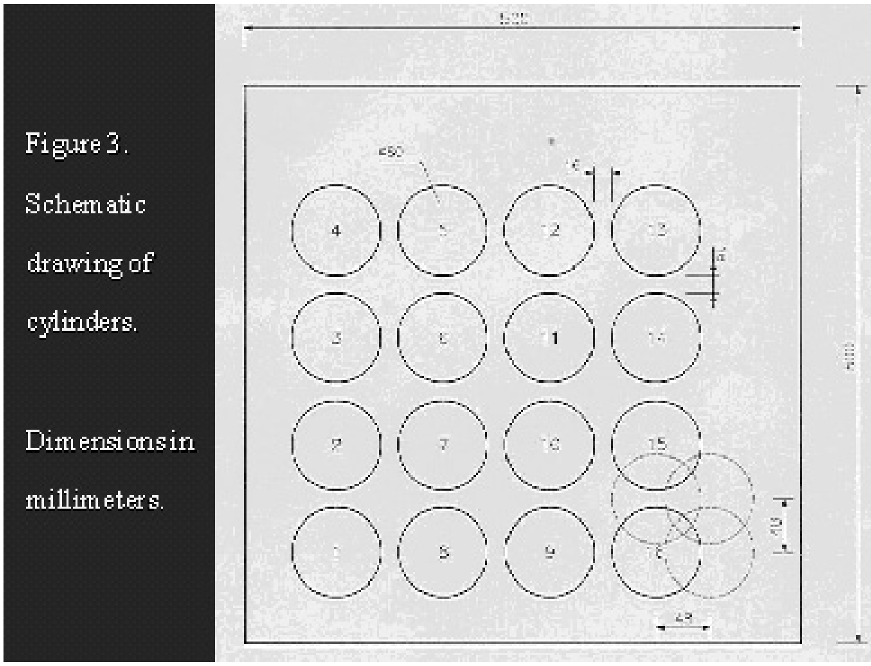
Photo 2 shows the test apparatus. Shortly after the construction of the first prototype it was called the BDA Marathon Man.

Photo 2. Test apparatus: the BDA Marathon Man



The schematic principle of the test apparatus is given in Photo 3.

Photo 3. Schematic principle



TEST PROGRAM

Samples

The samples to be tested were all purchased at one company that was chosen at random. The following insulation products have been used:

- PUR (rigid polyurethane foam)
- MWR (pressed mineral wool)
- EPS (expanded polystyrene)
- XPS (extruded polystyrene foam)

For the correlation between the different products, it was decided all the samples should have approximately the same thermal resistance (R = approx. 3.2 $m^2 \cdot K \cdot W^{-1}$). This resulted in the samples as given in Table 1.

Table 1. Tested samples

Product	Thickness [mm]	Density [kg·m^{-3}]	Facing
PUR	90	30	Two sided with bituminized glass mat
MWR	130	160	None
EPS	120	20	One sided with bituminized glass mat
XPS	120	25	None

Test procedure

The test procedure covers the testing of insulation products without any waterproofing and without any other cycling (with an ageing effect) than the repetitive loading (mechanical cycling) applied on the test specimens by the BDA Marathon Man. This was decided to prevent having too many parameters at this stage of development.

The mechanical cycling was applied on the test specimens subsequently for 10, 30 and 100 cycles. The number of cycles has been determined from the frequency of pedestrian traffic on different categories of roofs. Following the draft description of the test method, the thickness and the compressive strength were determined before and after testing.

Four consultants and inspectors of BDA, independently of each other, judged the test specimens. These experts were asked to give their opinions about the appearance of the test specimen after various test cycles and relate them to known actual damage.

Results

The results of the tests and the judgments are given in Tables 2, 3 and 4.

Table 2. Thickness [mm]

Product	Initial thickness	After 10 cycles	After 30 cycles	After 100 cycles
PUR	90	88	88	85
MWR	129	127	not measured [1)]	not measured [1)]
EPS	120	117	115	110
XPS	120	120	not measured [2)]	120

Table 3. Compressive strength [kPa]

Product	Initial compressive strength	After 10 Cycles	After 30 cycles	After 100 cycles
PUR	119	120	104	104
MWR	74	6	not measured [1)]	not measured [1)]
EPS	90	94	83	78
XPS	> 800 [3)] at 3%	> 800 [3)] at 2%	not measured [2)]	> 800 [3)] at 3%

1) Not measured because the test specimens had been destroyed; this is caused for reason because vertically applied forces develop transverse forces inside the test specimen.
2) Not measured because based on the result after 100 cycles, no changes were to be expected.
3) Strength at maximum reach of the test equipment; the deformation at that moment is given.

Table 4. Judgement on appearance

Product	After 10 cycles	After 30 cycles	After 100 cycles
PUR	realistic	realistic [3)]	not realistic [4)]
MWR	realistic [1)]	not realistic	not realistic
EPS	realistic	realistic [3)]	not realistic [4)]
XPS	realistic	not measured [2)]	realistic

1) Some experts stated that in actual practice damage could even be worse.
2) Not measured because based on the result after 100 cycles, no changes were to be expected.
3) At locations where much pedestrian traffic occurs, such as the entrance to a roof.
4) Only occasionally at locations where, for instance, tools have been dropped on a roof.

Photos 4 and 5 show examples of some test specimen after testing.

Photo 4. Mineral wool test specimen after 10 cycles

Photo 5. Polyurethane board test specimen after 30 cycles

EVALUATION AND DRAFT CLASSIFICATION

Based on the results found at the development of this test method and the experience of the experts of BDA, the following criteria for the properties of the insulation boards after testing have been drafted.

Thickness: - Maximum allowable decrease of thickness: 10 percent, but not more than 10 mm
Compressive strength: - maximum allowable decrease: 25 percent

Classification

To classify roof insulation boards with respect to their intended use, a classification system has been drafted as given in Table 5.

Table 5. Draft classification system

Class	Number of cycles	Intended use of the roof
1	10	Only accessible for purpose of maintenance; may be used without any restrictions
2	30	Accessible to pedestrian traffic; may be used where frequent maintenance of equipment is envisaged
3	100	Accessible to lightweight vehicles; only to be used where the waterproofing is protected by concrete pavers or similar protection

FURTHER RESEARCH

Laboratory tests, though always meant to predict the behaviour of products in practice, can never exactly simulate practice. To make results clear, it is recommended to exaggerate practice to obtain a wider scale and be able to interpret the results easier. However, a test must never be so severe that the results lead to the other extreme, such as in the case of 30 cycles and more, the total damaging of the MWR insulation product. Also, in that case, no interpretation is possible.

The appearance of the MWR insulation after 30 cycles and 100 cycles was judged to be not realistic. This appearance is caused, among other reasons, because the vertically applied forces develop transverse forces inside the test specimen. This results in the falling apart of the specimen first at the edges and, subsequently, over the entire specimen.

In further research, a supporting framework around test specimens will be applied. This can be compared with the actual situation in the roof where the insulation boards are also sideways supported. This will, no doubt, give more realistic results for mineral wool. Furthermore, the absence of a waterproofing membrane during the test is only representative for the first part of the roof installation. In case this classification is only meant for products not covered during application, this way of testing is correct. In case this test method shall also be used to predict the behaviour during lifetime, it is necessary to investigate the effect of the addition of a reproducible membrane simulating roofing felt. This could be, for instance, a nonreinforced EPDM roof membrane fixed at the edges. This will be investigated in further research.

CONCLUSIONS

1. The drafted new test method to assess the walkability of roof insulation gives realistic results for certain combinations of insulation materials and cyclic loading.
2. However, specifically for mineral wool, it is necessary to apply a supporting framework to prevent transverse forces and get a more realistic loading. This is to be investigated in further research.
3. It seems to be possible with the (adapted) test method to classify roof insulation boards with respect to the intended use of a roof.
4. It is also needed to further investigate the effect of the addition of a reproducible membrane simulating roofing felt.

ACKNOWLEDGEMENT

The author wishes to acknowledge the co-operation of the Dutch Association of Polyurethane Manufacturers (NVPU) and Koert van Zee, Albert Hameete and Pieter Dorresteijn of the BDA Test Institute.

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