NEW RESEARCH INTO THE BEHAVIOR OF COLD SELF-ADHERING MODIFIED BITUMEN ROOFING SHEETS AND BITUMINOUS COLD ADHESIVE COMPOUNDS UNDER SIMULATED AND ACTUAL WIND CONDITIONS

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In early 1990, Europe suffered a succession of five vicious typhoons. Although not yet scientifically ascertained, it is feared that more will follow, caused by environmental changes which man has imposed on this planet. Against this background, a closer look into the subject of bonding strengths and wind uplift forces in conjunction with relatively new cold-adhered roof systems seems not only justifiable but also necessary. Before mentioning additional detailed facts and figures, it can be said that, in general, flat roofs have been more resistant to heavy wind forces than pitched roofs. This fact was reported by the insurance companies in Germany who have had to pay out almost $2.2 billion for storm damages. In the area of housing alone, the damages exceeded $1.3 billion.

After examining roofs that were waterproofed with the cold self-adhesive method, the author found that practically no damages had occurred, which confirmed the opinion that cold-adhered roof systems will withstand severe wind forces.

Cold bonding application on flat roofs is to be divided into two categories; the first being a cold self-adhesive polymer modified bitumen roof sheet, which was introduced in Germany about 15 years ago. The other being a stripewise applied bituminous cold-adhesive compound, which has been in use for more than 20 years. Over the past few years, polyurethane based cold-applied adhesives have also come into use.

The cold self-adhesive polymer modified bitumen roofing sheet being discussed here is a sturdy, heavy duty cap sheet of 4.5mm thickness, covered with mineral chips on the surface. Compared to the more traditional methods of torching or hot mopping, self-adhering sheets are laid faster. Also, the danger of causing fires is excluded. This fact is an important consideration for chemical factories or other industries, where torching flames and/or bitumen kettles on the roof are regarded as potential hazards.

KEYWORDS

Bitumen-based cold-adhesive compounds, cold-adhered roofing systems, overlap bonding strength, wind uplift forces.

The percentages were measured by VEDAG Central Laboratories and correspond to literature in standards, e.g., "Bitumen," by Dr. E. Braun, 1987.

AREA ADHESION

First, the sheet is rolled out and aligned. Then, an approximate 1.5m part of the plastic release film is removed to enable full bond adhesion and anchoring of the sheet on to an adhesive system-prepared surface. This surface can be a suitable base sheet or a primed old roof. Dirt/dust/moisture should be removed and the temperature of the roll should not be less than 5°C. The remainder of the release film is pulled off, walking the opposite direction of the anchored part. This process is then repeated with the next roll.

On uneven surfaces, a high percentage of adhesion can be expected. Experience has shown that a vast majority of the surface is cold bonded instantly. The remaining unbonded area is securely adhered by what is termed as "after bonding," which comprises the effect of direct sunlight, the sheet's own weight and the vapor diffusion properties of the material composition. (Vapor diffusion is an important factor to deter bubbling in a roof.) The vapor diffusion values* of this sheet are approximately 15 percent less than those of a normal SBS-modified sheet, but 240 percent better than those of an APP-modified sheet and 400 percent better than those of an oxidized bitumen sheet, both of comparable thickness. The vapor diffusion properties of the self-adhered sheet can be formulated as follows:

^{s}D = approximately 100m

This means that the vapor diffusion ability of the sheet equals approximately 100m of air layer. This ability has a positive effect on the contour adjusting behavior which therefore maximizes continuous adhesion, resulting in increased wind resistance. Although some blistering has occurred in the first few weeks after laying, these have disappeared by themselves and did not occur again. The diffusion properties of the sheet were instrumentative in this respect.

The "after bonding" can be observed easily, as shown in Figure 1. To this end, a test piece made of rough profile glass is prepared and the cold self-adhesive sheet positioned onto it. The dynamic development of the bonding process can be verified here. The difference between the highest and the lowest point is 50 percent. Because of the surface profile geometry, there is an immediate adhesion of the elevated parts in the test piece with the cold-adhesive zone of the sheet.

To simulate the "after bonding" effect, the cold-applied test pieces are subjected to intensive temperature variations, from 20°C up to 40, 60 and 80°C. These conditions are similar to those which can be expected on the roof. With temperature rises from 20°C to 80°C, it can be observed that within a short time no parts remain which are not adhered.

OVERLAP BONDING STRENGTH OF SELF-ADHERING SHEETS

The sheet is rolled out and aligned. Then, the overlap release film of the adjacent sheet, already in position, is removed and overlapped with 8 cm of the sheet now to be applied. By applying immediate seam roller pressure (15 kgs), the cold bonded overlap is closed watertight (see Figure 2).

In order to obtain comparable values, the cold self-adhered overlap was tested against overlaps done with the traditional hot bitumen and torch-on method. It was established that the cold self-adhered overlap bonding strength, tested with the peeling method, was superior compared to the traditional overlapping techniques (see Figure 3). Bonding strength values of approximately 250 Newtons/5 cm were obtained. The peeling length was 80mm, the peeling angle 180° and the peeling speed 40mm per minute. The test was done at a temperature of around 5°C (see Figure 4).

PRACTICAL EXPERIENCE

Experiences with cold self-adhering cap sheets are now available. An examination of the roof surface on the premises of the Main Postal Administration in Hannover, Germany, which was carried out three years ago, confirmed unchanged characteristics after laying there for 10 years (see Figure 5). The roof area was free of blisters and absolutely waterproof. The examination was done by a government test institute and included laboratory testing, which confirmed that 'the aging of the sheet progresses only slowly and the functional capacity of the cap sheet is guaranteed for years to come.' (Translated from the German text in the test certificate.) At the Ford automobile factory in Cologne, roof areas in excess of 100,000 square meters have been laying there for more than 10 years. Both waterproofing properties and wind uplift resistance were unimpeded.

RESEARCH INTO BITUMEN-BASED COLD-ADHESIVE COMPOUNDS

As stated previously, bitumen-based cold-adhesive compounds have a proven record of workability for more than 20 years. They also have the advantage of not only being suitable for adhesion of single layers, such as insulation boards, but have a waterproofing effect in the overlap area, also. The same compound, with a lower viscosity, is available to adhere mineral fiberboards.

In the past, the question was asked more than once if cold-applied adhesives would provide sufficient security against wind uplift forces on high-rise buildings. A series of tests pertaining to the positional stability of a roof system fastened with bituminous cold-applied adhesives under simulated wind uplift conditions were conducted by the independent institute "Ingenieurgemeinschaft WSP" in Aachen, (consulting engineers for thermal, aerodynamic and process techniques) under the supervision of Professor Gerhardt one-year ago. The roof assembly was chosen according to the design prescribed by UEAtc regulations and consisted of the following components:

- Profile metal deck with a span of 6m.
- 100mm polystyrene insulation with a 4mm SBS base sheet laminated onto it (rollform insulation).
- 5mm SBS-modified sheet with mineral chips on the surface.
- The rollform insulation was fastened to the metal deck with 3 X 4 cm strips of bituminous cold-applied adhesive.

This test object withstood an uplift load of 5,000 N per square meter without any visible negative effects.

When observing the wind uplift factor assumptions in the DIN 1055 norm, Part 4, as well as the additional strain caused by pressure inside the building, and observing a 1.5 security factor against roof cover lift-off, the roof system subjected to this test is positionally stable in the middle and perimeter area of the roof surface on rectangular buildings up to a height of 100m. Only in the corner area, additional mechanical fastening will be required.

For buildings up to 20m in height, no mechanical fastening is necessary, when observing a security factor of 1.5. (See Table 1 for more detailed information on the DIN 1055 norm, Part 4.)

SUMMARY

If until now only partial areas of the roof waterproofing systems were adhered with the cold self-adhesive technique, the newest development is that whole roof systems are being applied with this method. This includes the vapor retarder, the insulation, base and cap sheet, as well as detail work.

The application technique is comparable to those two-ply polymer bitumen systems which are already known to the roofer. However, the roofer should be trained in the use of cold self-adhesive material.

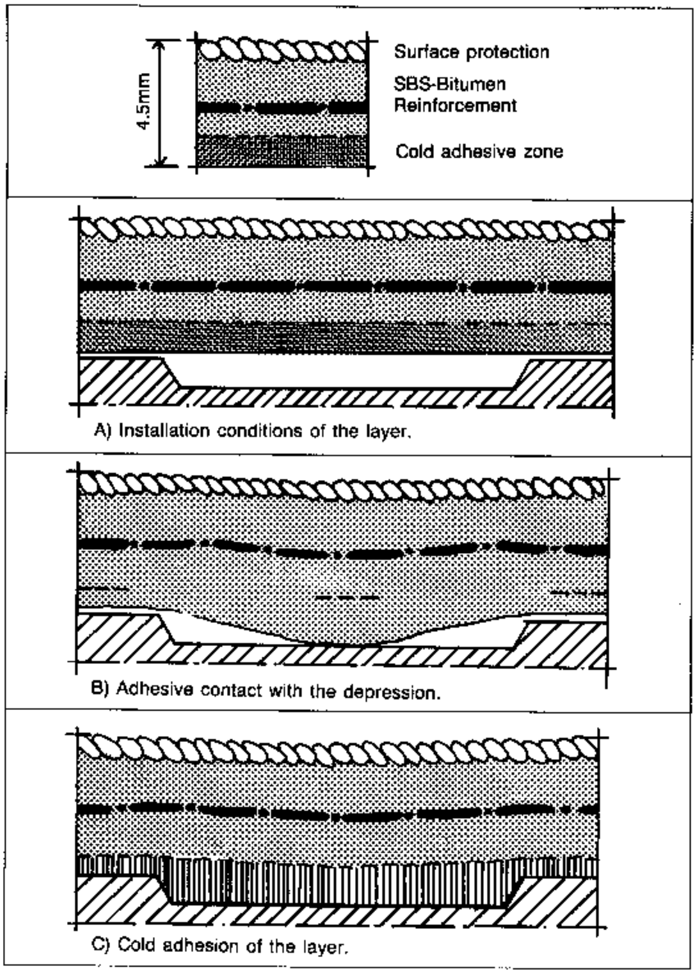

Figure 1 *Function of the cold adhesive zone or uneven surfaces (schematic).*

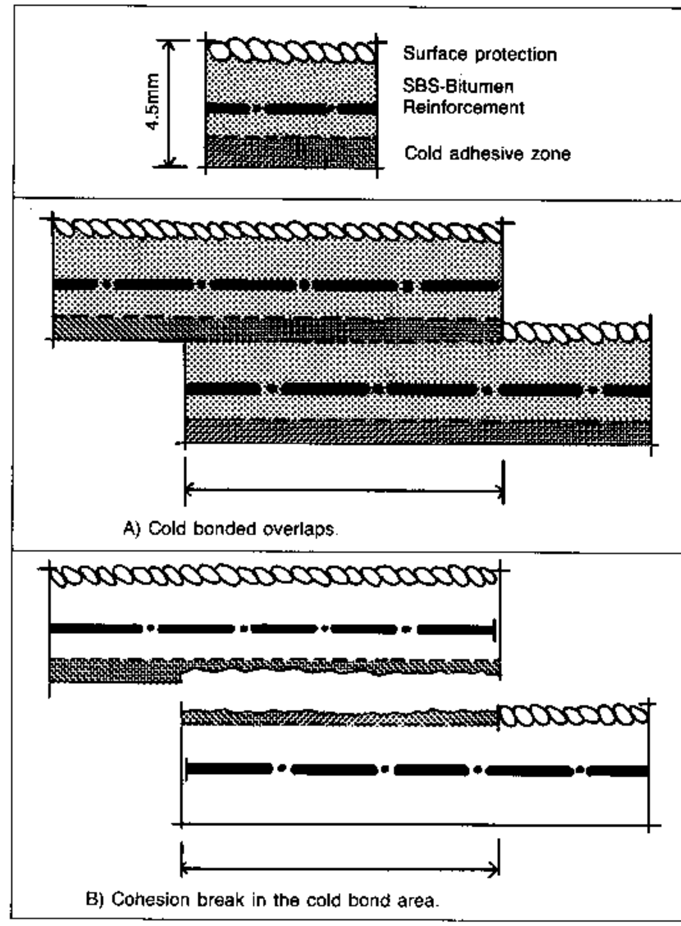

Figure 2 *Effectiveness of lap joints - peeling method elastomeric bitumen cold self-adhesive membrane.*

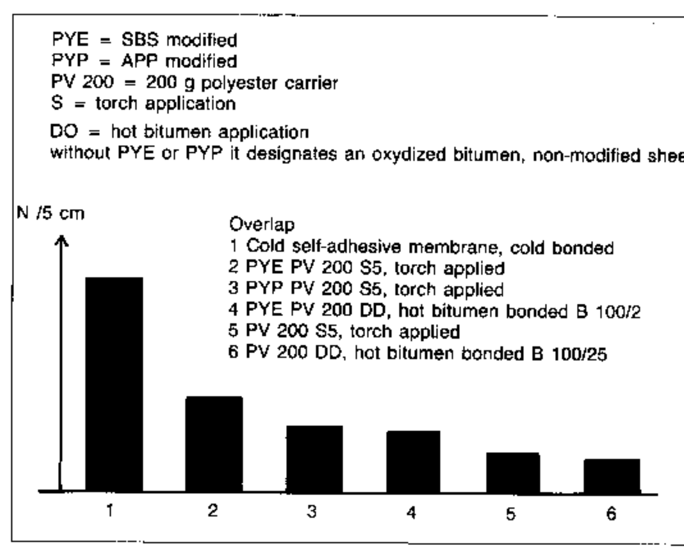

Figure 3 *Bonding strength of adhered overlaps (peeling method).*

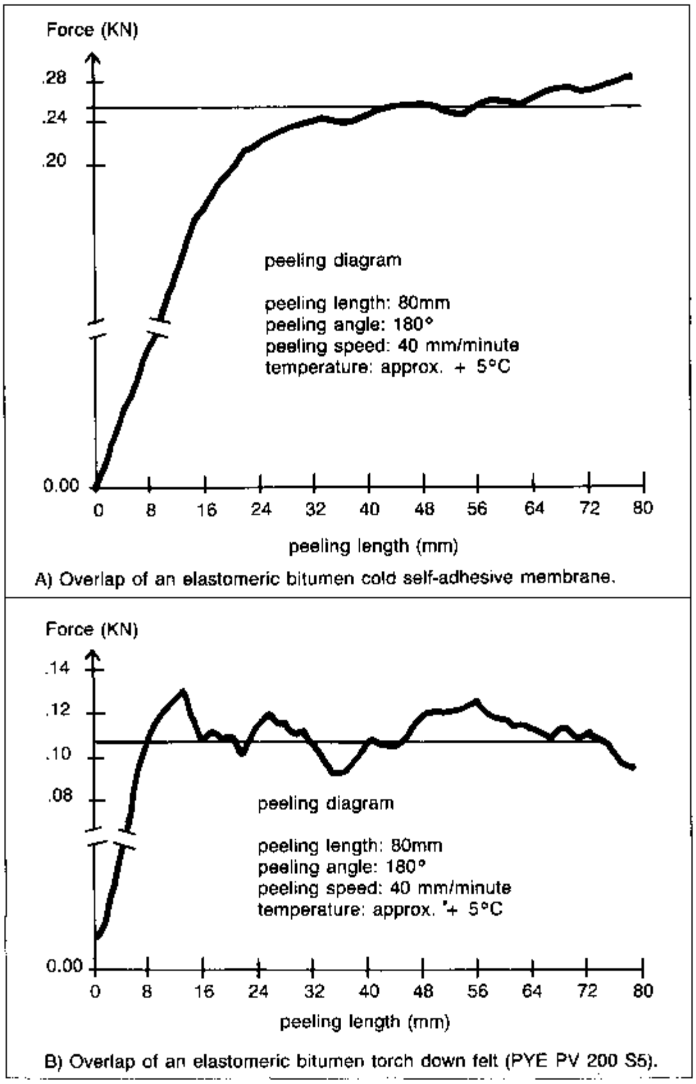

Figure 4 *Peeling diagrams of overlap joints.*

Our Reference Date	V 87 4176 Mo/m 26.05.1987
Applicant	GmbH Postfach 60 05 40
Nature of the Test:	Testing of the roof waterproofing which was done 10 years ago with cold self-adhesive roofing sheets. The building is the Main Postal Administration in Hannover. Your order of 01.04.87 Sample taken on 30.04.87 in Hannover

Figure 5 *The first page of the test certificate.*

1. The basis for measurements is the air pressure.
   It is to be assumed to be

0.5 kN/m² (10 lbs/sq.ft.)	at height of 0-8m (0-26.24 ft.)
0.8 kN/m² (16 lbs/sq.ft.)	at height of 8-20m (26.24-65.6 ft.)
1.1 kN/m² (23 lbs/sq.ft.)	at height of 20-100m (65.6-328 ft.)
1.3 kN/m² (27 lbs/sq.ft.)	at height of over 100m (over 328 ft.)

Calculation of suction force with the coefficient cp for various ranges for flat roofs with protrusions.

	Roof area	Edge area 2.0m (6.56 ft.)	Corner area 2.0 X 2.0m (43.05 sq.ft.)
Height 0-8m (0-.26.24 ft.) c X p =	0.40 X 0.50 = 0.20 kN/m² (4 lbs/sq.ft.)	2.2 X 0.80 = 1.10 kN/m² (23 lbs/sq.ft.)	3.6 X 0.50 = 1.80 kN/m² (37 lbs/sq.ft.)
Height 8-20m (26.24-65.5 ft.)	0.40 X 0.80 = 0.32 kN/m² (7 lbs/sq.ft.)	2.2 X 0.80 = 1.76 kN/m² (36 lbs/sq.ft.)	3.6 X 0.80 = 2.88 kN/m² (59 lbs/sq.ft.)
Height 20-100m (65.6-328 ft.)	0.40 X 1.10 = 0.44 kN/m² (9 lbs/sq.ft.)	2.2 X 1.10 = 2.42 kN/m² (50 lbs/sq.ft.)	3.6 X 1.10 = 3.96 kN/m² (81 lbs/sq.ft.)
Height above 100m (328 ft.)	0.40 X 1.30 = 0.52 kN/m² (11 lbs/sq.ft.)	2.2 X 1.30 = 2.86 kN/m² (60 lbs/sq.ft.)	3.6 X 1.30 = 4.68 kN/m² (96 lbs/sq.ft.)
Free standing buildings on raised ground up to 100m (328 ft.) in height	0.80 X 1.10 = 0.88 kN/m² (18 lbs/sq.ft.)	2.6 X 1.10 = 2.86 kN/m² (59 lbs/sq.ft.)	4.0 X 1.10 = 4.40 kN/m² (90 lbs/sq.ft.)
Height above 100m (328 ft.)	0.80 X 1.30 = 1.04 kN/m² (21 lbs/sq.ft.)	2.6 X 1.30 = 3.38 kN/m² (69 lbs/sq.ft.)	4.0 X 1.30 = 5.20 kN/m² (107 lbs.sq.ft.)

2. Measured values for bonds with author's proprietary cold-adhesive force
   at right angles to bonded area (comparable to wind suction force).

(Government authorized test station for bituminous building materials TU Munich.)

Bonded materials		Average shearing force at right angles to bonded surface
Polystyrol hard foam	-painted steel plate	18 kN/m² (369 lbs/sq.ft.) bonded surface = 0.72 kN/m (48 lbs/ft.) adhesive strip at 4cm (1.57 in.) width
Polystyrol hard foam	-galvanized steel plate	16 kN/m² (328 lbs/sq.ft.) bonded surface = 0.64 kN/m (48 lbs/ft.) adhesive strip at 4cm (1.57 in.) width
Polystyrol	-weld	48 kN/m² (984 lbs/sq.ft.) bonded surface = 1.92 kN/m (129 lbs/ft.) adhesive strip at 4cm (1.57 in.) width
Dry concrete	-weld	34 kN/m² (697 lbs/sq.ft.) bonded surface = 1.36 kN/m (91 lbs/ft.) adhesive strip at 4cm 1.57 in.) width
Slightly damp concrete	-weld	23 kN/m² (472 lbs/sq.ft.) bonded surface = 0.92 kN/m (62 lbs/ft.) adhesive strip at 4cm (1.57 in.) width
Steel plate, galvanized	-weld	40 kN/m² (820 lbs/sq.ft.) bonded surface = 1.60 kN/m (107 lbs/ft.) adhesive strip at 4cm (1.57 in.) width

Table 1 *Measurement basis for wind suction force on roofs DIN 1055, Part 4, May 1977 edition.*