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PROJECT REPORT 21

Einar M. Paulsen

Roofing fasteners

Field survey 1985 of roofs with mechanically attached bituminous or polymeric membranes

Recomended corrosion protection of metallic fasteners

Trondheim/Oslo 1987

NORWEGIAN BUILDING RESEARCH INSTITUTE

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Preface

The Trondheim Division of the Norwegian Building Research Institute (NBI) has a specialised and trained staff. They act as advisers and consultants for manufacturers as well as users of building materials and components. A special feature of the division is the development of specialised test methods and laboratory testing equipment. Another important aspect is obtaining practical experience by investigating of damage and doing systematic field surveys.

This report gives the results from a field survey carried out in 1985 as a project sponsored by the Norwegian Roofing Research Group (TPF).

Because of wide international interest and focus on the durability of roofing fasteners, the Institute has decided to print a report in English.

Trygve Isaksen and Helge Juul, NBI, are aknowledged for taking part in the survey and Tor Gunnar Eggen, SINTEF, Corrosion Laboratory for analysing fastener coatings.

Trondheim, February 1987

Jarle R. Herje

Contents:

INTRODUCTION

Mechanical attachment of roof membranes has been in use for many years and is best known from bituminous felts nailed to wooden decks.

Because of the many examples of roofing material being blown off steel roofs, and problems connected with asphalt bonding on to polystyrene in the middle of the '70's, mechanical fasteners began to be employed much more frequently. In 1980, the Norwegian Roofing Research Group (TPF) completed a project concerned with testing and evaluation of fastening systems, by publishing TPF Information Pamphlet No.2 "Mekaniske festemidler for taktekking" (Mechanical fasteners for roofing).

In 1985, TPF resumed its work on mechanical fasteners with the following programme formulation:

"TPF has previously carried out pioneer work with respect to testing and evaluating the strength of fastening assemblies.

There is now a need to continue this work by, in addition, finding out what on the whole are the most decisive factors when a fastening system is being chosen. We will initially examine the short-term effect during installation and long-term effects on the construction.

The work will consist of tests in the laboratory and field surveys of existing buildings.

Manufacturers of fasteners will be invited to participate in the project."

In March 1985, a planning seminar was held at the Trondheim Division of the Norwegian Building Research Institute, wich considered

- plastic in mechanical fasteners
- corrosion protection of metallic fasteners
- capacity of fasteners in wood
- insurance cover for wind-damage to roofs
- laboratory testing of fastening systems

The project has been directly supported by 22 firms that were registered as participants. These entered the following numbers of "products" in the form of membranes and fastening systems:

- 25 membrane systems using bituminous felts or polymeric sheets
- 14 systems for fastening to steel plates
- 13 systems for fastening to concrete
- 7 systems for fastening to aerated concrete
- 5 systems for fastening to lightweight aggregate concrete
- 10 stress distribution plates

ROOFS INVESTIGATED

The roofs investigated were selected from ca. 290 references provided by the participants.

A very large number of variants of membranes and fasteners were offered. As limited finance was available there had to be a fairly severe reduction of objects for investigation during the selection process. An attempt was made to achieve a balance based on the following criteria:

Geographical distribution:	Eastern Norway (Oslo region)	
	Western Norway (Bergen, Stavanger)	
	Central Norway (Trondheim)	
	Northern Norway (Narvik, Bardu)	
Type of membrane	Bituminous felt	
	Polymeric sheets	
Deck	In situ cast concrete	Fig. 1 (page 28)
	Concrete elements	Fig. 2 "
	Aerated concrete	Fig. 3 "
	Steel plate	Fig.4 "
Fastener	At least one of each type	

The investigation comprised 48 roofs, distributed as follows:

Geographical

16 roofs from Eastern Norway (E 1 - 16)
10 roofs from Central Norway (T 1 - 10)
14 roofs from Western Norway (W 1 - 14)
8 roofs from Northern Norway (N 1 - 8)

Supporting deck

10 roofs made of concrete elements
9 roofs made of in situ cast concrete
3 roofs made of aerated concrete
1 roof made of wood
25 roofs made of steel

Membranes

25 roofs of polymeric sheets
23 roofs of bituminous felt

Fasteners used for concrete

5 roofs using Pin-Plug (diam. 8 mm)

4 roofs using Hardo WD (diam. 8 mm)

4 roofs using KV system (diam. 6 mm)

3 roofs using Bifit (diam. 5.5 mm)

2 roofs using Teleskop (diam. 6 mm)

1 roof using Mungo concrete nails (diam. 8 mm)

1 roof using SK Tuote (diam. 8 mm)

Fasteners for aerated concrete

2 roofs using Loden anchors

1 roof using Teleskop (diam. 15 mm)

Fasteners for steel decks

13 roofs using Insuscrew self-drilling screws

3 roofs using SFS-Isofast self-drilling screws

2 roofs using Knipping self-drilling screws

1 roof using JVC self-drilling screws

1 roof using M-screw self-drilling screws

1 roof using Mustad self-drilling screws

2 roofs using Hardo Al expansion bolts (diam. 8 mm)

METHODS OF INVESTIGATION

The investigation took place as follows:

1) NBI selected test roofs from the reference roofs provided.

2) Those responsible for carrying out the roofing job took part in the inspection to provide information about materials and the construction, and to repair the roofing after holes had been made.

3) Visual inspection and photographing of the roof.

4) The membrane was opened at the fastener, inspection took place and a pullout shoe was fitted (Photo 1, page 31).

5) The fastener was pulled out using an NBI Plug-Jack (Photo 2, page 31).

6) All fasteners were photographed.

7) The corrosion protection was determined and the thickness of coating on the fastener was measured at the SINTEF Corrosion Laboratory.

RESULTS

A separate report was written for each roof inspected, and this was sent to the roofing contractor responsible.

Information from these reports has been compiled in Tables 1 - 9 (page 11-16).

For some fastener systems results from laboratory testing of strength are given in Table 10 - 12 (page 17-18).

In Tables 1 - 6 the following abbreviations have been used for the various columns.

Roof number

E =	Eastern Norway	(Oslo region)
W =	Western Norway	(Bergen, Stavanger)
T =	Central Norway	(Trondheim)
N =	Northern Norway	(Narvik, Bardu)

Use of building

Age in years from instalment to inspection

Vapour barrier

PE = Polyethylene film usually 0.2 mm thick

BF = Bituminous felt

EX = Existing membrane in cases of re-roofing

Insulation

EPS = Expanded polystyrene

MW = Mineral wool

150 = Thickness in mm

D = Dry insulation

M = Moisture in insulation recorded

Roof membrane

PVC = Single-ply polyvinyl chloride

CPE = Single-ply chlorinated polyethylene

ECB = Single-ply ethylene copolymer bitumen

APP = Single-ply APP polymer modified bitumen

SBS* = Single-ply SBS modified bitumen

OX = Two-ply oxidised bitumen
SBS = Two-ply SBS polymer modified bitumen
G = Membrane in good condition
F = Uneven surface with folds
X = Uneven surface with wrinkles
P = Ponding water
S = Slack in membrane at parapets

Stress plate, screw or bolt

D = Dry at time of inspection
L = Liquid water on top of fastener or underside of membrane
R = Red rust (2 R = Two out of five fasteners had red rust
WR = White rust records incomplete; white rust is usually present on fasteners that have red rust)
O = No visible rust
Zn = Zinc
ElZn = Electrozinc plating
+k = Chromatising on top of ElZn
AlZn = Aluzinc plating
Al = Aluminium
SS = Stainless steel
Bit = Stress plate embedded in bitumen
μ m = Thickness of coating in micrometers = 10^{-6} m = 1/1000 mm

The thickness of coating on screws and bolts proved difficult to measure exactly, but in most cases it was found to be 10 - 15 μ m.

Table 1.
Fasteners in concrete elements

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane			Stress plate			Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	µ m	Rust	Protection
E3	Shop	1		120 EPS + 30 MW	D	G	PVC	D	0	Plastic		0	SS
E4	Store	3	PE	100 EPS	D	F	PVC	D	0	Plastic		WR	ElZn
E7	Office/school	0			D	F	PVC	D	0	Zn + plastic	450/30	WR	ElZn
W5	Industry	1	BF	100 EPS	D	G	PVC	L	0	Plastic		WR	ElZn
E1	Gymnasium	3		150 MW	D	G	SBS	D	0	Plastic		4R	ElZn
W7	Shop	1	BF	160 EPS	D	G	SBS	D	0	Plastic		0	SS
W8	Shop	5			D	G	OX	D	0	Bit		1R	ElZn
W11	Office	2		100 EPS	D	G	SBS	D	0	Plastic		5R	ElZn
T1	Shop	3		EPS	M	G	SBS	L	0	Plastic		O R	Plastic ElZn
T4	Garage	2		MW	D	G	OX	L	0	Bit		4R	ElZn

Table 2.
Fasteners in in situ cast concrete deck

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane			Stress plate			Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	µ m	Rust	Protection
T2	School	4		EPS	M	G	SBS	D	0	Plastic		0 1R	Plastic ElZn
T9	Cold store	5		Inside	D	G	SBS	D	0	Plastic		0	Plastic ElZn
W13	Industry	1	Ex	+ 100 EPS	M	G	APP	L	0	Zn	20	0	Plastic ElZn
T5	Housing	2	Ex	+ EPS	D	G	OX	L	0	Bit		5R	ElZn
T10	Industry	3	Ex	+ EPS	M	G	APP	L	2R	Zn	ca.20	2R	ElZn
E15	Housing	2	Ex	+ EPS	D	G	OX	D	0	Bit		1WR	ElZn
N8	Shop	1	Ex	+ 100 EPS	M	G	PVC	L	0	Plastic		1WR	ElZn
W2	Shop	3		100 EPS	M	S	PVC	L	0	Plastic		1R	ElZn
E11	Office	2			D	F	CPE	D	0	Plastic		0	Plastic ElZn

Table 3.
Fasteners for aerated concrete and wood

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane		Stress plate				Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	μm	Rust	Protection
Aerated concrete													
E14	Warehouse	1			D	G	OX	D	0	Bit		0	ElZn
E5	Office	5			D	F	PVC	D	0	AlZn AlZn+laquer	30 70/30	4R	ElZn
N5	Garage	0		+ 50 EPS	D	G	PVC	D	0	Plastic		0	Plastic
Wood													
W14	Industry	1	Ex	+ 50 MW	D	G	APP	D	0	Zn	20	0	ElZn

Table 4.
Fasteners in steel decks without vapour barrier

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane		Stress plate				Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	μm	Rust	Protection
E6	Warehouse	4		150 MW	D	F	PVC	D	0	AlZn AlZn+laquer	17/35 40-60	0	ElZn + k
E8	Water treatment plant	1		150 MW	D	F	PVC	D	0	Zn+plastic	450/30	0	ElZn + k
W1	Restaurant	2		160 MW	D	G	PVC	D	2WR	Zn	25	0	ElZn + k
W3	Restaurant	4		100 EPS	D	G	PVC	D	1WR	Zn	25	0	ElZn + k
E9	Slaughter house	6		100 MW	D	G	OX	D	0	Bit		0	ElZn + k
W9	School			100 MW	D	G	OX	D	0	Bit		0	ElZn + k
W10	Shop	6		100 EPS	D	G	OX	L	1R 4-0	Zn Bit	25	0	ElZn + k
T3	Shop	7		EPS	D	G	SBS	D	0	Al		0	Al
T6	Warehouse	0		100 EPS	D	G	SBS*	D	0	Bit		0	ElZn + k

Table 5.
Fasteners in steel decks with vapour barrier (0.2 mm PE)

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane		Stress plate				Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	μ m	Rust	Protection
E2	Office	2	PE	200 MW	D	G	PVC	D	5R	Zn + k	2	2R	ElZn + k
E13	Industry	2	PE	100 MW	M	P	PVC	L	1WR 4-0	AlZn AlZn+ coating	20 30/40	5R	ElZn + k
N1	Gymnasium	7	PE	100 MW	M	G	PVC	L	3R	Zn	20	5R	ElZn
N2	Gymnasium	9	PE	60 EPS	D	G	PVC	D	3R	Zn + k	2	3R	ElZn + k
N3	Garage	8	PE	100 MW	D	S	PVC	D	0	Al		0	Al
N4	Shop	6	PE	100 MW	M	G	PVC	D	5R	Zn	30	5R	ElZn
N6	Conference hall	10	PE	100 EPS	D	S	PVC	D	5R	Zn + k	2	2R	ElZn + k
N7	Swimming hall	6	PE	100 MW	M	F	PVC	L	4WR	Zn	20	3R	ElZn
W4	Swimming hall	2	PE	200 MW	D	G	PVC	D	0	Zn	12/25	1R	ElZn + k

Table 6.
Fasteners in steel decks after reroofing on existing bituminous felt

Roof No.	Use of building	Age yrs	Vapour barrier	Insulation		Roof membrane		Stress plate				Screw or bolt	
				Type and thickness	H_2O	Cond	Type	H_2O	Rust	Protection	μ m	Rust	Protection
E10	Shop	4	BF	+ 50 EPS	D	G	ECB	D	0	Zn	20	0	ElZn + k
E12	Garage	2	"	+ 50 MW	M	F	CPE	L	1R	Zn	20	5R	ElZn + k
E16	Industry	4	"	+ EPS	D	F	PVC	D		Zn	20		ElZn + k
W6	Shop	1	"	+ 50 EPS	D	G	SBS	D	0	Bit		1R	ElZn + k
W12	School	2	"	+ Tapered EPS	D	G	SBS	D	0	Al		0	Al
T7	School	5	"	50 EPS + 50 RW	D	G	SBS	D	0	Bit		0	ElZn + k
T8	Industry	5	"	EPS + EPS	D	G	SBS	D	0	Bit		0	ElZn + k

Table 7.
Capacity of fasteners in concrete found in field survey

Fastener	Roof No.	Capacity at break/ Standard deviation N
Pin-Plug	E1	2500
	E4	2270/800
	N8	2262/441
	W2	2590/776
	W5	2832/508
Hardo WD	E11	1360/300
	T1	1608/652
	T2	1640/524
	T9	1670/147
KV system 3,8 mm diam.screw and 6 mm diam. plug	W8	2827/279
	W11	3226/1902
	T5	3298/437
	T10	2278/1073
Bifit	E7	2100/400
	E15	3640/1070
	T4	2073/1190
Teleskop Betong	E3	2670/100
	W7	2468/328
Mungo concrete nail	W13	3035/336
SK - Tuote	E 1	700

Table 8.
Capacity of fasteners in aerated concrete found in field survey

Fastener	Roof No.	Capacity at break/ Standard deviation N
Loden	E5	930/250
	E14	1730/100
Teleskop	N 5	1903/153

Table 9
Capacity of fasteners in steel deck found in field survey

Fastener	Roof No.	Capacity at break/ Standard deviation N
Insuscrew	E6	2660/20
	E8	2320/200
	E9	2310/70
	E10	2270/170
	E12	1490/100
	E13	2280/140
	W1	2156/31
	W3	2560/113
	W4	2401/310
	W9	1921/55
	W10	2827/152
	T7	1906/147
	T8	1878/33
SFS Isofast screw	N1	1840/110
	N4	1870/193
	N7	1662/193
Knipping screw	N2	1700/130
	N6	2054/199
Roofscrew 724	W12	1494/103
M-screw	E2	3080/520
Mustad screw	W6	1697/348
Hardo Al plug	N3	1358/466
	T 3	1158/79

Table 10.
Capacity of fasteners in concrete found by laboratory testing

Fastener	Capacity at break/ Standard deviation Static load N	Capacity at break/ Standard deviation Pulsating load N	Dimensional capacity N
Pin-Plug	2809/369	2391/762	970
Hardo WD I	1046/150	805/172	471
II	2220/597	2297/540	1241
KV system	2457/459	2508/278	1834
Bifit	2224/475	2550/686	1265
Teleskop	2421/91	1962/566	915
SK-Tuote I	758/218	589/207	219
II	1018/104	805/62	631

Table 11.
Capacity of fastener in aerated concrete found by laboratory testing

Fastener	Density of aerated concrete kg/m	Cap. at break/ Standard deviation Static load N	Cap. at break/ Standard deviation. Pulsating load N	Dimensional capacity N
Loden I	450	975/192	647/278	239
Loden II	450	875/85	1020/63	823
	500	1570/320	1295/206	714
Teleskop	450	696/109	760/126	500
	500	1218/127	933/100	690

Table 12.
Capacity of fastener in steel deck found by laboratory testing

Fastener	Capacity at break/ Standard deviation Static load		Capacity at break/ Standard deviation Pulsating load		Dimensional capacity	
	0.65 mm N	1.0 mm N	0.65 mm N	1.0 mm N	0.65 mm N	1.0 mm N
Insuscrew	1600/76 1483/83	2195/91 2818/85	1247/116 1140/26	2073/174 2220/290	958 837	1620 1562
SFS-Isofast	1424/102	2023/168	1235/103	1648/206	966	1185
Knipping	1299/263	1661/124	1186/708	1308/155	762	954
Roofscrew 724	1472/78	2682/118	1354/152	2305/237	990	1718
Mustad	1353/90	2655/112	1170/000	1453/000	1059	2208
Hardo Al	1174/43	1543/174	957/120	1354/152	690	1000

DISCUSSION OF RESULTS

Bituminous roofing felts

On the whole, the visual inspection gave a very good impression. This agrees with the results from a separate survey of roofs with bituminous roofing felts described in NBI project report no.15.

The following variants of fastener attachments to membrane were recorded.

a) Three-ply membrane with the fastener through the first layer and subsequent felts fully bonded.
(Fig. 5, page 29, roof E 1).

b) Two-ply membrane with the fastener through the first layer, separate cover over the stress-plate and the cap sheet fully bonded.
(Fig. 6, page 29, roofs T 3, T 7, T 8, T 9, W 6, W 7, W 12).

c) Two-ply membrane with the fastener in the overlap joint and the cap sheet fully bonded.
(Fig. 7, page 29, roofs T 1, T 2, W 11).

d) Two-ply membrane with the fastener in the joint between the felts, separate cover over the joint and the cap sheet fully bonded.
(Fig. 8, page 29, roofs E 9, E 14, E 15, T 4, T 5, W 8, W 9 and W 10).

e) Single-ply membrane with the fastener in the joint between the felts and a separate cover over the joint.
(Fig. 9, page 29, roof T 6).

f) Single-ply membrane with the fastener in the middle of the fully bonded overlap joint.
(Fig. 10, page 29, roofs W 13 and W 14).

g) Singl- ply membrane with the fastener at the edge of the felt and full bonding outside the edge of the stress plate.
(Fig. 11, page 29, roof T 10).

Comments:

With three-ply roofing (a) it is not necessary to provide the fastener with an extra cover in the form of a patch or strip. The distance between fastening points can be varied freely in both directions.

Two-ply membranes require two layers above the stress plate (b). If the fastener is not placed in the overlap (c), it must be covered by a patch or strip identical in quality with the first layer. The distance between fastening points can be freely varied in both directions in (b), whereas in (c) and (d) it is limited by the joint in the one direction. A fastener in a bonded overlap (c) may give a good result, but its strength is more sensitive to variations in workmanship than (b) and (d).

Single-ply membranes were used in three ways, - e, f and g - on four roofs (T 6, T 10, W 13, W 14).

Excessive loss of slate flakes was recorded on two roofs where the membrane had oxidised asphalt.

Wrinkles were recorded in the top layer, on one roof where the cap sheet had a core of light fibreglass felt.

Footprints were recorded in the membrane of one roof where the cap sheet was of SBS polymer bitumen.

Polymeric sheets

The membrane was in order and characterised as being in good condition on all the roofs inspected. The oldest roof was 10 years old, but most were relatively new. Our comments are aimed at those conditions which seem to result from poor practice and which are therefore potentially weak points in the future.

The following ways of attachment to the membrane were recorded:

a) Fastener placed at the edge of the membrane in the overlap joint. Fig. 12, page 30, (roofs E 2, E 3, E 10, E 11, E 12, E 13, E 16, W 1, N 5).

b) Plate or bar attached to the lower side of the membrane. Fig. 13, page 30, (roofs E 7, E 8).

c) Fastener through the membrane with a separate cover over the plate or bar. Fig. 14, page 30, (roof E 16).

d) Fastener mounted through a piece of material which is attached to the lower side of the roofing membrane. Fig 15, page 30 (roof W 5).

e) Fastener mounted in a separate flap attached to lower side of the membrane. Fig. 16, page 30.
   - Flaps in the machine direction (roofs W 2, W 3, W 4, E 6, N 7).
   - Flaps across the machine direction (roofs, N 1, N 2, N 3, N 4, N 6, E 4, E 5).
   - Flaps across the 2 m wide membrane (roof N 8).

Comments:

Spot fastening at the edge of reinforced sheets (a) seems to give the smoothest membrane, even though folds are recorded here, too.

Preassembled sheets with flaps in the machine direction (e) give a variable result as regards folds, whereas flaps attached across the machine direction result in a smoother membrane.

Homogeneous PVC welded longitudinal ly to steel profiles (b) results in an extremely uneven surface, especially when the welding is carried out in cold weather, because the plastic material expands when the temperature increases (Photo 6, page 33).

Ponded water was recorded on several roofs although it had not led to noticeable damage to the roofing.

Screws sticking up and pressing against the membrane were recorded as follows:

a) screw placed between ribs

b) too long screw with the threaded part extending beneath the steel deck

c) overdriving of screw during installation.

Fasteners for concrete

a) PIN-PLUG (roofs E 1, E 4, N 8, W 2, W 5)

This fastening assembly has three components:

- 80 mm diam. plastic stress plate
- 6 mm diam. steel nails with ElZn 10 - 15μm
- 8 mm diam. plastic expansion plug

Pullout values from the field test vary from 2262 N to 2832 N with a standard deviation of 441 N to 800 N and an average of 2491 N/631 N.

Compared with laboratory tests which were carried out for static loads (2809 N/363 N) the pullout capacity is lower and the spread larger (11 % reduction).

b) HARDO WD (roofs E 11, T 1, T 2, T 9)

This fastening assembly has two components:

- 80 mm diam. stress plate and 8 mm diam. sleeve of plastic, cast in one piece. The sleeve may be extended by having a pipe welded on.

- 5 mm diam. expansion nails with 10 - 15 μm ElZn. There are two varieties of nails, with and without heads.

(I) headless nails under static tests gave a tensile failure capacity of 1046 N/150 N with a dimensional capacity of 470 N.

(II) nails with heads gave corresponding results of 2220 N/597 N and 1240 N.

The field tests revealed both varieties on roof T 1. This explains the large scatter in the fastening capacity with 700 and 830 N along with 2360, 2050, 2200 and 1510 N. 10 mm diam. plugs with headless nails were found on roof E 11. This type of plug has been tested for use in aerated concrete and lightweight aggregate concrete. Nails with heads had been used on roofs T 2 and T 9, and measurements of these showed capacities of 1640 N/524 N and 1670 N/147 N, with an average of 1655 N/336 N.

In the laboratory test, a result of 2220 N/597 N with dimensional a capacity of 1214 N was achieved. The reduction from laboratory testing to field testing is marked (24 % reduction).

c) KV system (roofs W 8, W 11, T 5, T 10).

This fastening assembly has three components:

- metal stress plate
- 3.8 mm diam. screw
- 6 mm diam. plastic plug

Prior to installation the screw must first be put through the hole in the plate after which the plastic plug is put on. Installation involves pre-drilling using a 6 mm diam. drill, after which the fastening assembly is inserted and screwed fast.

The field test achieved a static failure capacity varying from 2278 N to 3298 N with a standard deviation from 279 N to 1902 N, and averaging 2907 N/923 N.

The laboratory test gave 2457 N/459 N. Exact and careful installation gives good grip, but a standard deviation of up to 1900 N shows too much scatter.

d) BIFIT (roofs E 7, E 15, E 4).

This fastening assembly has two components:

- metal stress plate
- 4.8 mm diam. steel pin with a pre-moulded plastic plug for a 6.5 mm diam. drill bit

Under installation the pins are driven into a 6.5 mm diam. pre-drilled hole using a sledgehammer. The field test gave static pullout from 2073 N to 2640 N and a standard deviation of 400 to 1190 with averages of 2604 N/887 N. The laboratory test gave 2224 N/475 N. The field test gave better pullout results than the laboratory test, but with a greater scatter.

e) TELESKOP BETONG (roofs E 3 and W 7).

This fastening assembly has two components:

- stress plate and sleeve moulded in one piece of plastic
- 5.5 mm diam. stainless steel pin.

After pre-drilling using a 5 mm diam. drill bit, the pin is driven in with a sledgehammer.

Results from the field test show good agreement with the laboratory test.

Up to 10 mm of slack was found on fasteners on roof W 7, i.e. the pin was not driven sufficiently far into the concrete. There may be several reasons for this, but the most likely one is that a greater degree of accuracy than is obtainable in practic is required to avoid drilling right through the 50 mm deck.

f) MUNGO concrete nails (roof W 13)

This fastening assembly has three components:

- metal stress plate
- plastic sleeve passing from the plate down into the concrete
- stem of steel which at the same time is an expansion plug

Results from the field test show a good grip in the concrete, but no report on type-testing is available. Hence, no comparison can be made with the laboratory test.

g) SK-TUOTE BSK 308 (roof E 1)

This fastening assembly has two components:

- stress plate, stem and expansion plug moulded in one piece in plastic
- 6 mm diam. steel expansion bolt

Two types of plugs were found in roof E 1.
The capacity was low (700 N), but this corresponds with laboratory tests showing 758 N/218 N. A re-test using a new expansion plug achieved 1018 N/104 N.

Comments:

The number of variants relative to roofs investigated is really too large to allow definite conclusions to be drawn.

Type-testing in the laboratory enables many conditions to be taken into account that may have significance for the usefulness of a fastening system.

When making an overall appraisal it may also be in place to look at such factors as the need for training, leeway during installation, availablility and total price per installed fastener.

Acceptable systems are to be found for fastening to in situ cast concrete where it is possible to drill deep enough, or when concrete elements can be drilled through.

On 50 mm concrete elements which cannot be drilled right through, the demands on precision will be greater than present-day systems can meet with a reasonble safety margin.

Fasteners for aerated concrete

a) LODEN anchor (roofs E 5, E 14).

This fastening assembly has three components:

- metal stress plate
- 6.5 mm diam. steel sleeve
- 3.5 mm diam. expansion pin with a conical expansion to 6.5 mm diam. lowermost

When installation takes place a special installation tool must be used which is removed during the final driving-in stage, to achieve expansion. This operation has proved extremely critical since it demands accurate work and even resistance from the aerated concrete. When such concrete is wet, resistance is reduced and a greater expansion length is required.

The results of the field test suggest that a density of 450 kg/m^3 has been used on roof E 5 and one of 500 kg/m^3 on roof E 14. If so, there is good agreement with laboratory tests using a static load.

Two laboratory tests using 450 kg/m^3 aerated concrete have given dimensional capacities varying from 240 N to 820 N. The main reason for the large difference is that the fitters were, respectively, inexperienced and experienced, but density variation may also have had some bearing.

b) TELESKOP LETTBETONG (roof N 5).

This fastening assembly has two components:

- stress plate and 15 mm diam. sleeve with an expansion piece moulded altogether in one piece
- plastic expansion plug

Results from pullout tests show reasonably good agreement between field and laboratory tests.

A fastening assembly incorporating an 80 mm diam. plate was used on roof N 5. This is rounded and specially intended for mounting directly on to mineral wool. When it was installed against a hard surface, like sheet on EPS, several examples were seen where the plate had cracked because of strain from blows during fitting. The present model, TELESKOP 45, has been improved with respect to impact brittleness.

Fasteners for steel decks

Self-drilling screws which consist of two parts:

- metal stress plate
- self-drilling screw

Under installation the screw is inserted through a hole in the plate and drilled fast into the steel deck.

a) INSUSCREW (roofs E 6, E 8, E 9, E 10, E 12, E 13, W 1, W 3, W 4, W 9, W 10, T 7, T 8).

The capacities found during field tests vary from 1490 N to 2827 N. This agrees with laboratory tests using 0.65 to 1.0 mm thick steel plates (Table 12, page 18).

b) SFS - ISOFAST (roofs N 1, N 4, N 7)

The capacities found during field tests vary from 1662 N to 1870 N. This lies within the limits found during laboratory tests.

c) KNIPPING (roofs N 2 and N 6)

The capacities during field tests vary from 1700 N to 2054 N. This exceeds the values found during laboratory tests.

d) ROOFSCREW 724 (roof W 12)

The capacity of 2490 N found during field testing lies within that found during laboratory tests.

e) M-Screw (roof E 2).

The field test gave a capacity of 3080 N and a standard deviation of 520 N. Comparable laboratory tests are not available.

f) MUSTAD SUPER INSUL (roof W 6)

The capacity found in the field test was 1697 N/348 N, which lies within values from laboratory tests.

g) HARDO AL (roofs N 3 and T 3)

This fastening assembly has two components:

- 75 mm diam. steel plate with a 7 mm diam. Al sleeve
- 5 mm diam. steel expansion pin

When installing, pre-drilling must take place using an 8 mm diam. drill. The plug is then inserted and the expansion pin driven in.

Capacity under field testing varied from 1158 N/79 N to 1358 N/426 N. This is within the limits for values from laboratory tests.

Comments:

Self-drilling screws offer a simple and good fastening method. Since it has proved difficult to obtain information about the plate thickness in the steel decks on the reference roofs concerned, an exact correlation between capacity and plate thickness has not been calculated.

Improperly installed fasteners must be removed to ensure that they do not work up and damage the membrane. The greatest risk for damage arises when the fastener has a separate plate and stem, and when re-roofing takes place using polymeric sheets on top of existing bituminous membrane. Loose screws are drawn up by windloads on the membrane, whilst the friction is too high in the existing membrane for it to go completely down.

SUMMARY AND RECOMMENDATIONS

General conclusions

On the whole, the membranes are good and fulfil their function today, and no serious defects have been recorded.

The study has shown that there are a great many variants of fasteners and fastening systems in use. When these are combined with different types of decks and membranes it becomes difficult to maintain perspective. Small changes in the installation and use of the fastening assembly can determine whether the result will be good or bad. A fastener that has good pullout values under given conditions can, when every aspect is considered, be unsatisfactory for use.

Because of the many variants, there is a clear need for a coordinated plan for substantiating the usefulness and dimensional capacities of the fasteners under the various combinations of membrane attachment and types of decks.

In the case of some fasteners the number of roofs investigated is too small to give reliable information.

Test programmes, including an ageing test, for fasteners made of plastic should be developed.

Many cases of corrosion on metallic fasteners were found, sometimes on new roofs.

Corrosion protection of metallic fasteners and components must be improved where there is a risk for prolonged periods of damp from condensation, alone or in combination with corrosion-promoting substances.

Testing of protective coatings

Corrosion protection is tested by a DIN 50018 Kesternich apparatus using 2.0 l SO_2 according to procedure described in Factory Mutual Standard 4470 where maximum 15 % of the surface may be attacked by red rust when the sample is subjected to the stated number of cycles.

The temperature stability of organic coatings is tested for 300 hours at 90°C and 100 % RH and the coatings should not peel off or show any blistering.

Categorising corrosion risk

The risk of corrosion on metallic fasteners may be grouped into three categories:

Category K — Moisture caused by condensation may occur on the underside of the membrane only for short periods.
Good opportunities for drying out to room climate.

Examples: steel deck roof without vapour barrier
stress plate on fastener covered, or embedded in bitumen

Category KL — A great risk for moisture coming to lie on the fastener for long periodes, the moisture beeing caused by high relative humidity in the air between the roof membrane and an impermeable substratum.
Poor opportunities for drying out.

Examples: steel deck roof with vapour barrier
concrete deck roof
re-roofing
stress plate on fastener exposed at edge of membrane

Category KLA — Like KL, but with aggressive substances in insulation or on existing membrane when re-roofing takes place

Examples: phenol in insulation
re-roofing in an industrial area where corrosion-promoting pollution is present

Required corrosion resistance

Category	Roof constructions	Required minimum corrosion protection stated in Kesternich cycles	Types of coating and materials of interest for mechanical fasteners		
			Stem	Stress plate: Covered or embedded	Stress plate: Exposed
K	Steel deck roof without vapour barrier	2	10-15 µm ElZn	20 µmZn	As for KL
KL	Roofs with vapour barrier Concrete deck roofs Re-roofing	8	Special coating *Stainless steel *Al Plastic	As for K	20 mAlZn *Stainless steel *Al Plastic
KLA	As for Kl, but stem of fastener exposed to aggressive substances	>15	As for KL	As for K	As for KL

* Galvanic corrosion may occur in combination with certain other materials.

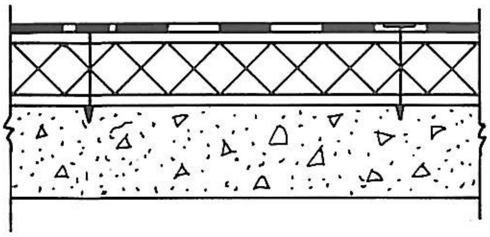

Fig. 1. Roofs with in situ cast concrete decks

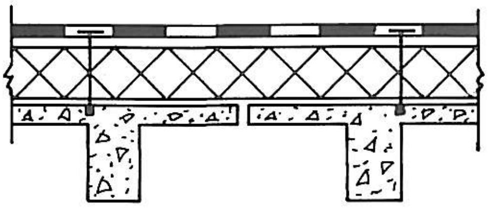

Fig. 2. Roofs with concrete element decks

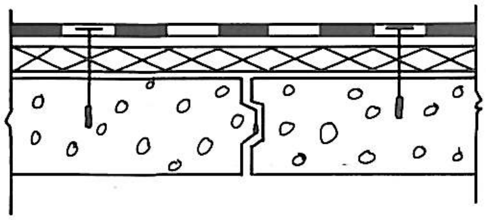

Fig. 3. Roofs with aerated concrete decks

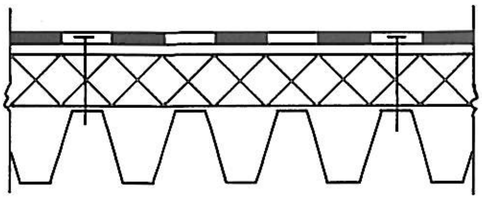

Fig. 4. Roofs with corrugated steel decks

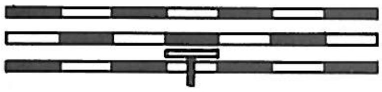

Fig. 5. Three-ply membrane with fastener through first layer and subsequent felts fully bonded

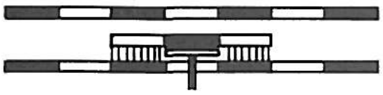

Fig. 6. Two-ply membrane with fastener through first layer, separate cover over stress plate and cap sheet fully bonded

Fig. 7. Two-ply membrane with fastener in overlap joint and cap sheet fully bonded

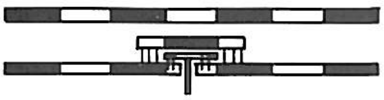

Fig. 8. Two-ply membrane with fastener in joint between felts, separate cover over joint and cap sheet fully bonded

Fig. 9. Single-ply membrane with fastener in joint between felts and separate cover the joint

Fig. 10. Single-ply membrane with fastener in middle of fully bonded overlap joint

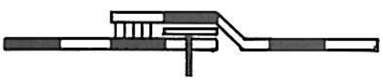

Fig. 11. Single-ply membrane with fastener at edge of felt and full bonding outside edge of stress plate

Fig. 12. Fastener placed at edge of membrane in overlap joint

Fig. 13. Plate or bar attached to lower side of membrane

Fig. 14. Fastener through membrane with separate cover over plate or bar

Fig. 15. Fastener mounted through a piece of material attached to lower side of roofing membrane

Fig. 16. Fastener mounted in separate flap attached to lower side of membrane

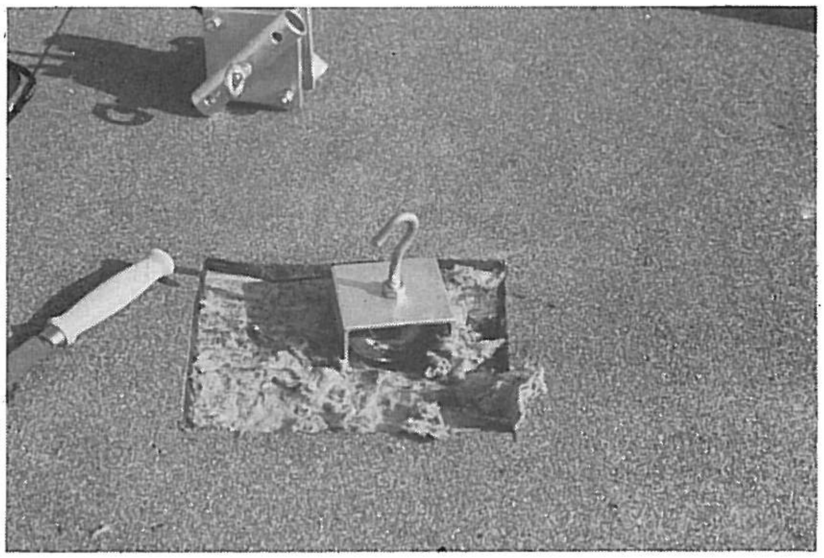

Photo 1.
Membrane is cut open at fastener and shoe for pullout test is mounted.

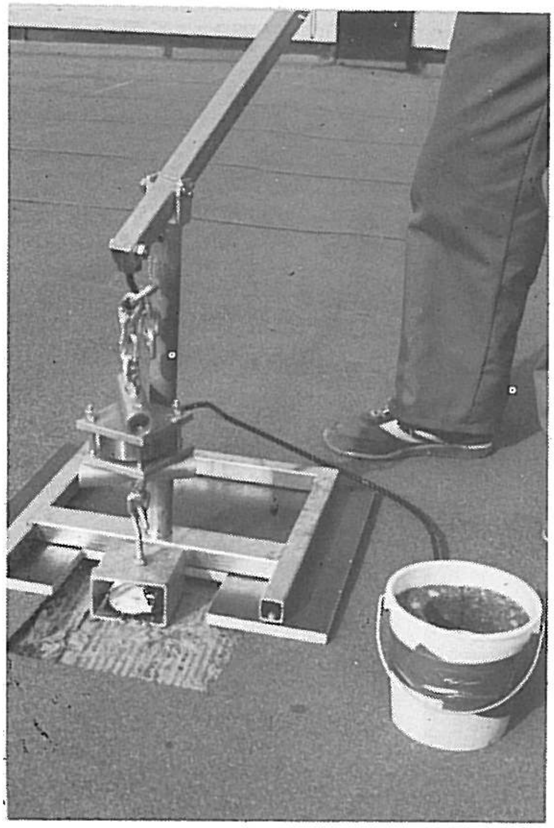

Photo 2.
NBI Plug-Jack used for pullout test.

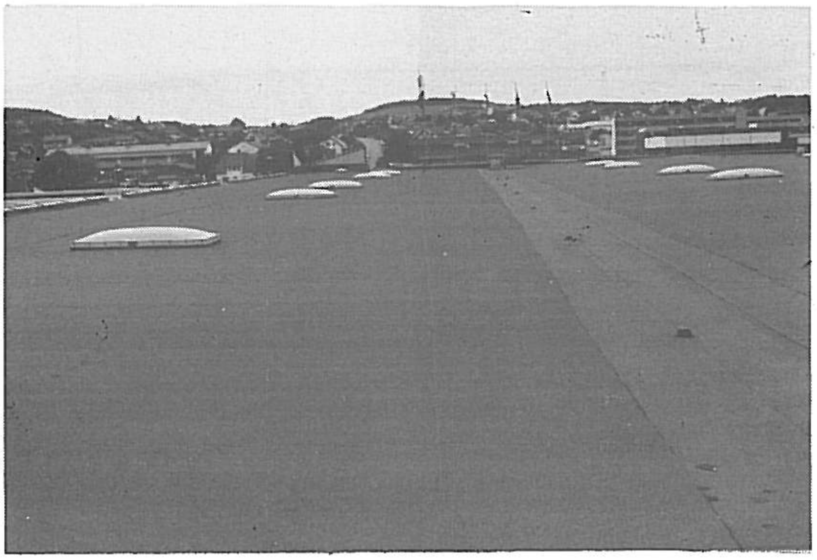

Photo 3.
Bituminous membrane in good condition.

Photo 4.
Examples of wrinkles in fibreglass cap sheets.

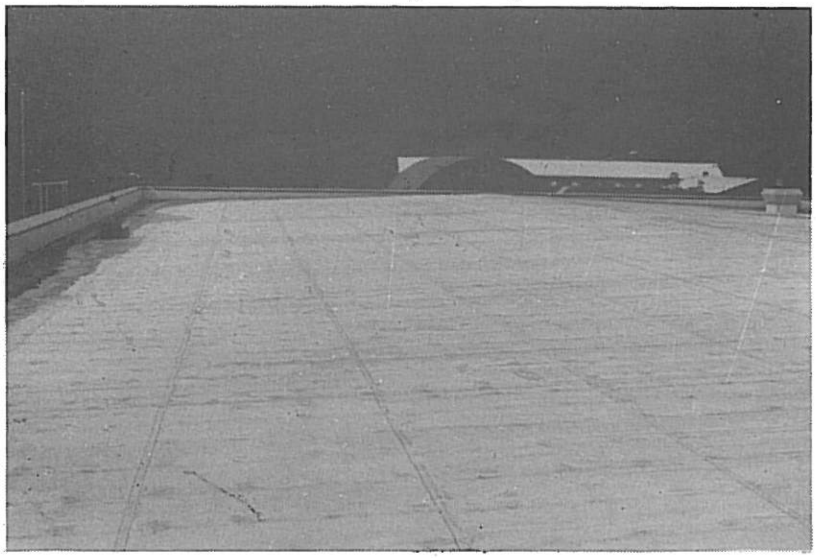

Photo 5.
PVC membrane with polyester fabric reinforcement in good condition.

Photo 6.
Homogeneous PVC membrane with folds over the whole surface.

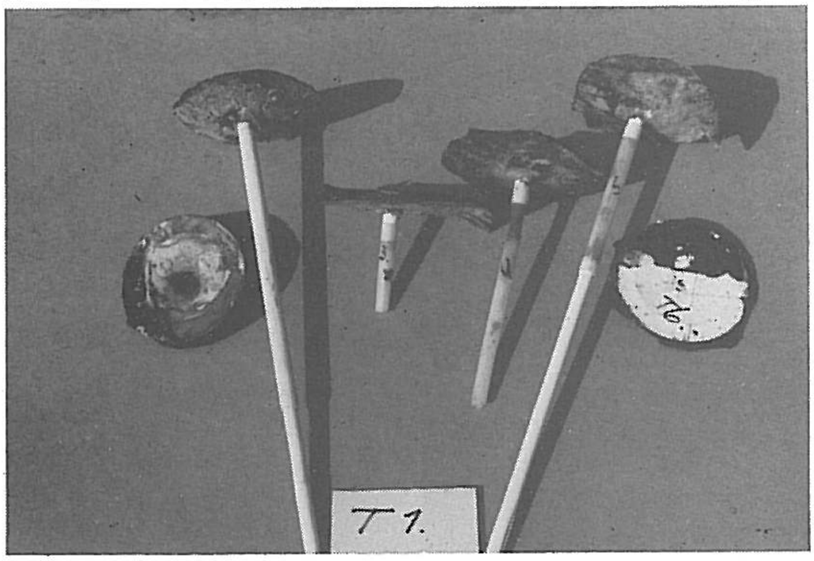

Photo 7.
Plastic fastener for concrete with metal expansion pin. Corrosion on metal parts.

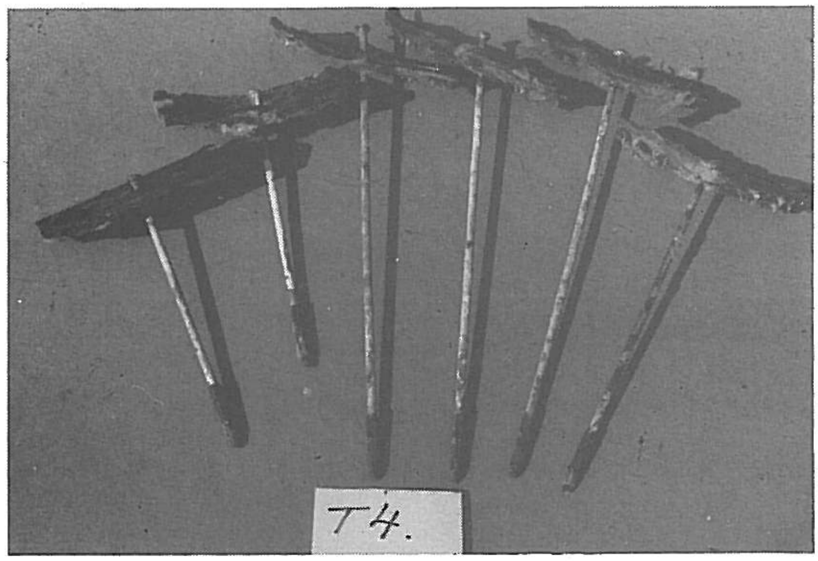

Photo 8.
Metal stress plate and bolt with fixed plastic friction plug. Corrosion on bolt.

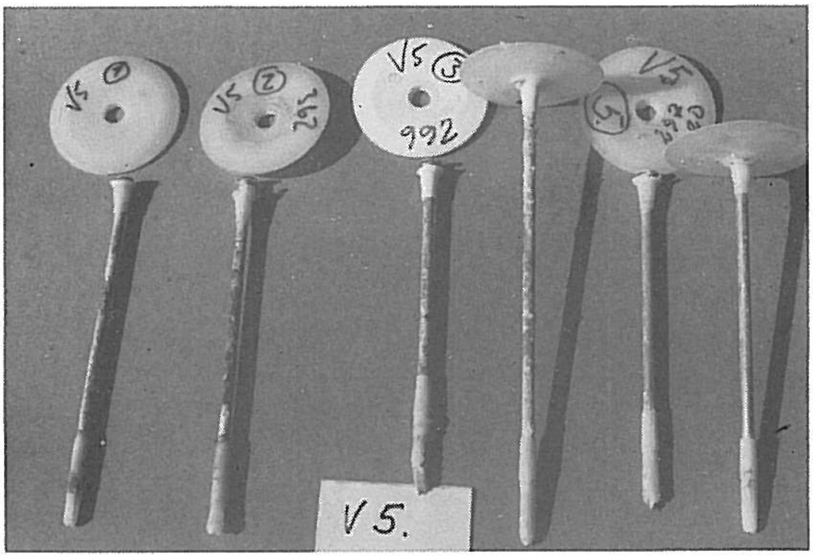

Photo 9.
Fastener for concrete with plastic stress plate, metal bolt and plastic plug.
Corrosion on bolt.

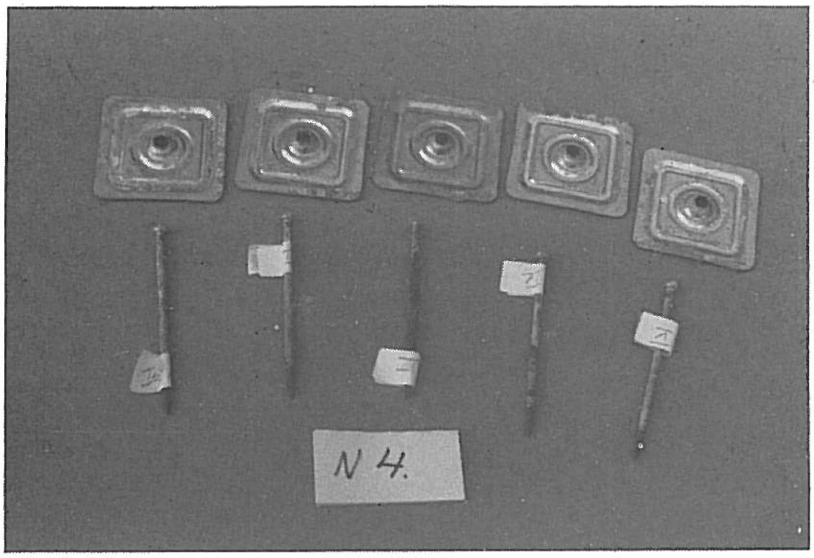

Photo 10.
Fastener for steel decks. Corrosion on screw.

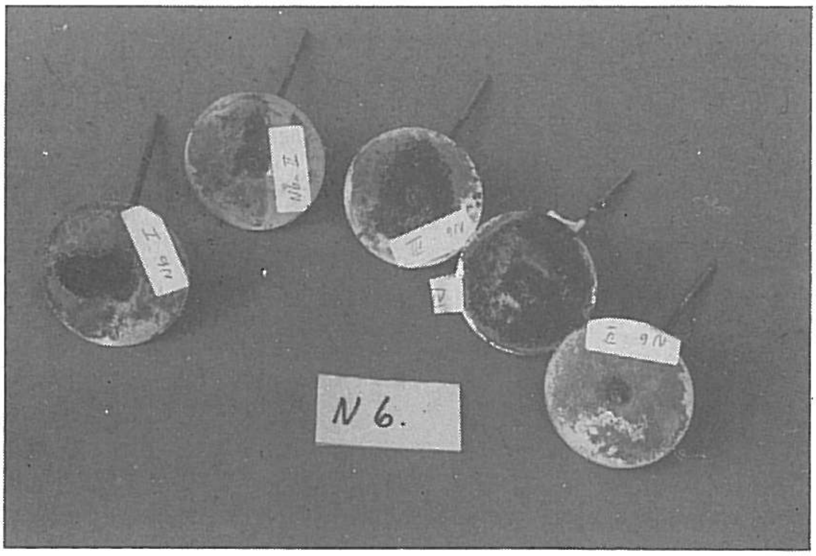

Photo 11.
Fastener for steel decks. Corrosion on stress plate.

Photo 12.
Example of loose screw mounted wrongly between ribs in steel deck.
In time the membrane will be punctured.