FIELD PERFORMANCE OF MECHANICALLY FASTENED ELASTOMERIC AND PLASTOMERIC MEMBRANES

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Mechanically fastened elastomeric and plastomeric membranes are a relatively new concept in roofing construction. The future for mechanically fastened membranes looks promising, but performance to date has not been totally acceptable from the perspective of high-quality roofing construction. Problems faced by the users of these membranes thus far have ranged from the quality of the fastener itself to the skill required for installation. Extensive evaluations of field performance have not been completed prior to this paper. This paper is the result of our survey to try to assess the performance of mechanically fastened membranes. Comments presented herein rate the performance from poor to good.

Major contributions to this paper on field-performance experience were made by members of the Roof Consultants Institute (RCI). Other sources of information included manufacturers of mechanically fastened membranes and fasteners, contractors, associations representing contractors and manufacturers, insulation manufacturers, recent publications, and building owners. Their input on the performance of these systems should provide the roof industry with a sound basis for the future study and evaluation.

The sources of information must be considered to accurately evaluate the overall impact of their data. As an example, a consultant who specializes in roof investigations will not likely be hired to visit good roofs. As a result, the consultant may see a disproportionate number of failures as opposed to successes. A manufacturer may evaluate its product as a success and may minimize the significance of its shortcomings. Owners and some roof consultants are often involved in the decision to select roof systems and may be reluctant to criticize their own selections.

There are several terms commonly used to describe the method of attachment of the membrane to the deck: "attached," "affixed," "anchored," and "fastened." In this paper, "fastened" will be used.

DEFINITIONS

This paper addresses single-ply membranes that are either elastomeric or plastomeric. Elastomeric and plastomeric roof membranes are single-ply roof membranes defined as follows:

Elastomeric roof membranes

An elastomeric polymer is a rubber-like synthetic polymer that will stretch when pulled and return quickly to its original shape when released. It is also referred to as vulcanized elastomer or "thermoset." A distinguishing characteristic of a vulcanized elastomer is that it can only be bonded by an adhesive because, once cured, new molecular linkages are difficult to form. Examples are:

EPDM Ethylene proplene diene monomer

CR Polychloroprene, commonly known as Neoprene (also often designated as NEO).

Plastomeric roof membranes

Plastomeric polymers are plastic-like polymers capable of being molded, extruded, or cast into various shapes or films. They are thermoplastic in nature. They soften when heated and harden when cooled. Plastomeric polymer membranes are further divided into non-vulcanized elastomers, also referred to as "uncured elastomers" and thermoplastic materials. Some non-vulcanized elastomers may cure or vulcanize upon prolonged exposure to the elements and become "thermosets." The following are plastomeric polymers:

CPE Chlorinated polyethylene (CM according to ASTM)

CSPE Chlorosulfonated polyethylene (CSM according to ASTM, also commonly referred to as Hypalon. Hypalon is a registered trademark.)

NBP Nitrite alloy with butadiene acrylonitrile copolymers

PIB Polyisobutylene

CPA Copolymer alloy.

Thermoplastic materials are distinguishable from "thermosets" in that there is no cross-linking or vulcanization. They can be welded together with heat or solvent and develop bond strengths in these welds that equal or surpass the strength of the base material. A thermoplastic may be melted so as to return to its original state while elastomerics may not. An example is:

PVC Polyvinyl chloride.

MECHANICALLY FASTENED METHODS: DEFINITIONS

Mechanically fastened systems can be divided into four types based on methods used to fasten the membrane.

The first is penetrating spot-fastened. A fastener that is inserted through a plate is installed through the final waterproofing membrane. The plate and fastener head are covered with a piece of membrane.

The second type is penetrating linear-fastened. A fastener inserted through a bar or batten strip is installed through the final waterproofing membrane. The bar or batten strip and fastener head are covered with a piece of membrane. For purposes of this paper, an "in-seam bar anchored" method is considered penetrating linear-fastening.

The third type is non-penetrating spot-fastened. While a plate with a fastener is used to fasten the membrane, the final waterproofing membrane is not penetrated by the fastener.

The last is non-penetrating linear-fastened. A bar or batten strip is used to fasten the membrane, but the final waterproofing membrane is without penetrations.

Table 1 illustrates how a group of 31 currently available systems is distributed by type of fastening technique. The 31 systems represent approximately 25 manufacturers. Figs. 1 through 4 illustrate the four types of mechanically fastening methods.

Data is not easily available regarding the actual volume of roof membrane construction that is mechanically fastened. Based on information provided by the National Roofing Contractors Association (NRCA), single-ply roofing commanded 52.5 percent of the 1985 market. EPDM was responsible for 65 percent of the single-ply market, while modified bitumen was 17 percent. Hypalon (7 percent), PVC (4 percent), CPE (2 percent), and others (5 percent) accounted for the remaining market share.

Based on our data and NRCA's figures, 52.5 percent of the 1985 single-ply market represents $4.226 billion in construction. If we were to conservatively assume that mechanically fastened systems are responsible for only one-tenth of the single-ply market, it quickly becomes apparent that mechanically fastened single-ply membranes represent a significant portion of the roofing market.

HISTORY

Single-ply membranes have been available for use in roof construction for approximately 20 years. CSPE was developed in the mid-'50s and field installations began in the mid-'60s. EPDMs were developed in the early '60s with major installations beginning in the mid '70s. One of the first mechanically fastened membrane systems was installed in 1963.[1]

The average age of the oldest U. S. installation of a single-ply (mechanically fastened, adhered, or ballasted) for a 1984 group of 32 manufacturers was almost eight years.[2] Fifty percent of the installations were five years old or less. Construction circumstances in the 1970s provided several factors that served as strong impetus for the development of the single-ply, including the mechanically fastened membranes. Such stimuli include the oil embargo, energy crisis, and built-up roof failures.

The approximate number of mechanically fastened membranes marketed in 1983, 1984, 1985 and 1986 is shown in Table 2. Sources for data shown in Table 2 include *Roofer* magazine;[3,4,5] NRCA's *Commercial, Industrial and Institutional Roofing Materials Guide;*[6,7,8,9] and the *Handbook of Commercial Roofing Systems.*[10,11] Data prior to 1982 is not easily available.

SOURCE ANALYSIS

Information on the field performances was solicited by telephone, meetings and through written correspondence. RCI members received several written invitations to provide information. RCI members responded many times with case histories of particular instances of failures. Recognizing the need for more information, contacts were made with manufacturers of mechanically fastened membranes and fasteners, associations representing contractors and manufacturers, insulation manufacturers, and building owners. Nearly all of the current mechanically fastened membrane manufacturers were contacted by telephone, with written follow-up. Lengthy meetings were held with some of the manufacturers. What follows are comments received.

Contractors

Contractor opinion ranged from, "All I ever end up doing is an autopsy" (on the failed system), to a contractor installing mechanically fastened membranes nationwide. Both of the above contractors install about the same annual volume of roofs. Mechanically fastened systems represented 65 percent of the latter firm's 1985 installations. Total volume for this contractor has included in excess of 15,000 squares of penetrating linear-fastened and in excess of 150,000 squares of penetrating spot-fastened. This contractor reports only 10 buildings with minor problems, but no failures: "The system performed, gave adequate warning, did not fail, and was easily repaired."

Fastener manufacturers

Fastener manufacturers believe that use of mechanically fastened systems will increase where use of fully adhered systems and ballasted systems will decrease. The primary reason given for the increase is ease of repair when compared with ballasted, and economics in the areas where quality ballast is not available. Adhered systems, according to fastener manufacturers, are having problems with seam failures and partial blowoffs.

Fastener manufacturers report they understand and acknowledge the concerns of the industry regarding their product. Concerns include corrosion, aesthetics, installation cost and reduction in effectiveness of vapor retarder. Fastener manufacturers are concerned about membrane manufacturers who are designing roof systems with reduced safety concerns. Examples cited include use of fewer fasteners and a wider spacing between batten strips.

Owners

An owner representing a total of 40,000 squares reported being so satisified with a mechanically fastened membrane that he will continue to have about 15,000 squares installed annually.

Several owners commented that they liked mechanically fastened systems because maintenance was minimal and, if required, easily accomplished. They felt contractors could find and repair leaks quickly without having to contend with ballast or gravel.

Other owners are taking a "wait-and-see" attitude, not only on mechanically fastened membranes, but on the membranes themselves.

Membrane manufacturers

Membrane manufacturers generally indicated mechanically fastened membrane systems are performing acceptably and are improving as modifications are being included in the system. Comments included, "We have over 180,000 squares in place and only one percent are having any problems," and, "We have thousands of squares in place and have had only one failure."

Consultants

Consultant responses varied from, "We'll probably never specify one," to, "There is a place for mechanically fastened membranes in the roofing market and I specify them often."

In the southeastern United States, a roof consultant with 28 years' experience reported he began specifying mechanically fastened membranes in 1980 and in this last construction season was involved in 20 projects ranging from 18 squares to 1,200 squares. He reports no major problems. The decks over which he has specified mechanically fastened membranes have included wood, concrete, lightweight insulating fill, gypsum, steel, and shredded wood fiber.

Another Southeast consultant reports that although he specifies mechanically fastened reinforced plastomeric membranes, he is concerned about non-reinforced elastomeric membranes that are mechanically fastened. The following workmanship problems led to premature failure of a linearly fastened non-reinforced elastomeric system on a project he investigated.

- Batten bars were omitted in some areas of the roof. Ballasting was provided through several isolated concrete masonry units in lieu of the specified bars.

- At numerous locations, there were voids beneath the membrane due to missing or misplaced (out of register) insulation board. Some voids were up to 4 inches wide. At these large voids, the membrane under foot pressure made contact with the underlying gravel (from the original roof system).
- Approximately 440 batten screws were observed bulging against the bottom of the cover strip over the battens. The screws had either "wallowed out" the hole in the metal deck or were improperly installed initially (under-torqued). Many of the fasteners were constantly abrading the bottom of the cover strip. Others made contact with the sheet only under foot pressure directly on or adjacent to the fasteners. Several of the bulging fasteners had ruptured the membrane, probably as a result of scuffing of feet or perhaps under normal foot traffic.
- At numerous locations on the roof, the end of the batten bar was bulging up and abrading the bottom side of the batten bar cover strip. The lack of reinforcement in the membrane appeared to cause stress in the membrane covering the batten bar as the membrane flexed constantly, even in minor winds.
- There were numerous locations in which the batten fasteners were apparently over-torqued, thus causing a bulging or bridging of the batten which abraded the bottom of the bar cover strip.

A Southeast consultant revealed his conviction that workmanship is the largest problem he has seen related to roof failures in his area. Another consultant echoed his comment, reporting that on a project he observed, only about one-half of the fasteners were installed correctly.

A Midwest consultant who specializes in roof forensic engineering states much of his work is on mechanically fastened systems. He reports the number of problems he is observing with mechanically fastened systems is increasing each year. He believes mechanically fastened membranes are relatively new and comprise a minority of the single-ply market, and concludes that mechanically fastened systems have some serious defects that need to be overcome.

In the northwest United States, an architect with his own firm for many years has, within the last three years, devoted 100 percent of his firm's efforts to roof consulting. He reports only success with mechanically fastened systems. To date, all experiences of his firm have been positive; however, he did express concern that the fasteners may corrode with time, ultimately causing the membrane to blow off the roof.

Some consultants indicated that they specify mechanically fastened systems for the same reasons they were attracted to plastomeric and elastomeric single-ply membranes: they are lightweight, relatively easy to repair, aesthetically pleasing and perform well on nailable decks.

A consultant reported on three buildings owned by three different owners: each building had a penetrating linear mechanically fastened system installed by three different contractors using three different EPDMs. The insulation had curled upward between the mechanically fastened strips on all of them. Heights of curling were as high as 1 foot, thus impeding drainage and stressing the membrane and seams. The only common denominator was that the urethane insulation below the membrane was less than 2 inches thick. One of the building owners used the same system on another roof, but increased the insulation thickness to 2 inches. No curling has occurred after one year, so the apparent cause of the problem was the thickness of the urethane. The consultant believes, however, the curling may have been minimized if the membrane was plastomeric.

An Eastern consultant, who investigates failures and typically does not specify single-ply roofs, made the following observations regarding two of his projects:

- On a mechanically fastened plastomeric on a sloped roof, during any level of wind, the interior noise level from the flapping of the membrane was "unbearable." The solution was to add additional fasteners.
- On a mechanically fastened plastomeric over a gypsum deck, all the toggles loosened within the first year. On some, the toggles had backed off up to 1 ½ inches below the bottom of the deck. The cause of this was not determined conclusively.

Several eastern consultants believe that mechanically fastened reinforced plastomeric membranes are more likely to succeed over non-reinforced membranes. The concern is wind uplift eventually fatiguing the components to failure. The non-reinforced membrane is more susceptible to the eccentric wind loading and flutter.

GENERAL INFORMATION

In the course of information gathering, we have been informed of approximately 12 million square feet of apparently satisfactorily performing mechanically fastened roof systems and an estimated 400,000 square feet of apparently unsatisfactorily performing systems.

Referring to Table 2, it appears that the total number of systems is decreasing. Whether this is due to market pressure or problems with systems could not be ascertained. While there are a number of manufacturers who have entered and left the market, there are a number of manufacturers who have been constantly improving systems over the last five to 10 years.

We have developed a listing in Table 3 of the concerns observed in field performance, as related to us by others. By far the greatest concern is the fastener.

CONCLUSIONS

Field performance is being critically examined as the number of in-place systems increases and a significant portion of these in-place systems age beyond the five-to 10-year mark. Of those systems in place, there have been many problems, primarily relating to the fasteners. As a result of Factory Mutual performance requirements and others, fasteners are used in many other types of systems. Solutions to fastener problems must be sought by the roof industry. As in other systems, workmanship plays a significant role in this system's performance. The mechanically fastened system has enough positive factors (i.e., it is lightweight, aesthetically pleasing and easy to repair), that there will be a promising future if current problems are overcome and if existing installations perform satisfactorily during the next five to 10 years.

REFERENCES

1 *Commercial, Industrial and Institutional Roofing Materials Guide.* Volume 9, August 1986. Section 1: Roofing Membranes, pg. 68–74. NRCA, Chicago, Ill.

2 *1984 Handbook of Single-Ply Roofing Systems.* Technical Data Listings, pg. 64–158. *Roof Design* and *RSI* magazines, Duluth, Minn.

3 *Single-Ply Systems Index '84.* Elastomers, pg. 12; Chlorinated Hydrocarbons, pg. 28; Thermoplastic Hydrocarbons, pg. 38. *Roofer Magazine,* Fort Myers, Fla.

[4] *Single-Ply Systems Index '85*. Elastomers, pg. 13-22; Chlorinated Hydrocarbons, pg. 23-28; Thermoplastic Hydrocarbons, pg. 29-31. *Roofer Magazine,* Fort Myers, Fla.

[5] *Single-Ply Systems Index '86.* Manufacturer Listings & Charts. Non-Vulcanized Elastomers, pg. 28-31; Thermoplastics, pg. 32-36; Vulcanized Elastomers, pg. 37-41. *Roofer Magazine,* Fort Myers, Fla.

[6] *NRCA Roofing Materials Reference & Guide,* Volume 1, February 1983. PVC, pg. 23-26; EPDM, pg. 33-35; Neoprene, pg. 40; CPE, pg. 42; PIB, pg. 45; Other Single-Ply, pg. 48. NRCA, Chicago, Ill.

[7] *NRCA Roofing Materials Reference & Guide,* Volume 4, February 1984. PVC, pg. 41-44; EPDM, pg. 51-60; Other Single-Ply Pre-fabricated Sheet Applied Membranes, pg. 77-80. NRCA, Chicago, Ill.

[8] *NRCA Roofing Materials Reference & Guide,* Volume 6, February 1985. Section 1: Roofing Membranes, pg. 38-67. NRCA, Chicago, Ill.

[9] *Commercial, Industrial and Institutional Roofing Materials Guide,* Volume 8, February 1986. Section 1: Roofing Membranes, pg. 50-74. NRCA, Chicago, Ill.

[10] *1985 Handbook of Commercial Roofing Systems.* Technical Data Listings for Single-Ply Roofing Systems, pg. 126-216. Published by *Roof Design* and *RSI* magazines, Duluth, Minn.

[11] *1986 Handbook of Commercial Roofing Systems.* Technical Data Listings for Single-Ply Roofing Systems, pg. 102-171. Published by *Roof Design* and *RSI* magazines, Duluth, Minn.

		SPOT FASTENED (Plate With Fastener)	LINEAR FASTENED (Bar or Batten Strip With Fastener)
PENETRATING (Final waterproof membrane is penetrated)	EPDM	4	4
	NEO	0	1
	CPE	2	1
	CSPE	3	1
	NBP	1	0
	PIB	1	0
	CPA	1	0
	PVC	1	5
	OTHER	1 (Copolymer)	
	Total	14	12
		Refer to Figure 1	Refer to Figure 2
NON-PENETRATING (Final waterproof membrane is not penetrated)	EPDM	3	1
	NEO	0	0
	CPE	0	0
	CSPE	0	0
	NBP	0	0
	PIB	0	0
	CPA	0	0
	PVC	1	0
	Total	4	1
		Refer to Figure 3	Refer to Figure 4

Table 1 Mechanically fastened systems by type of fastening technique

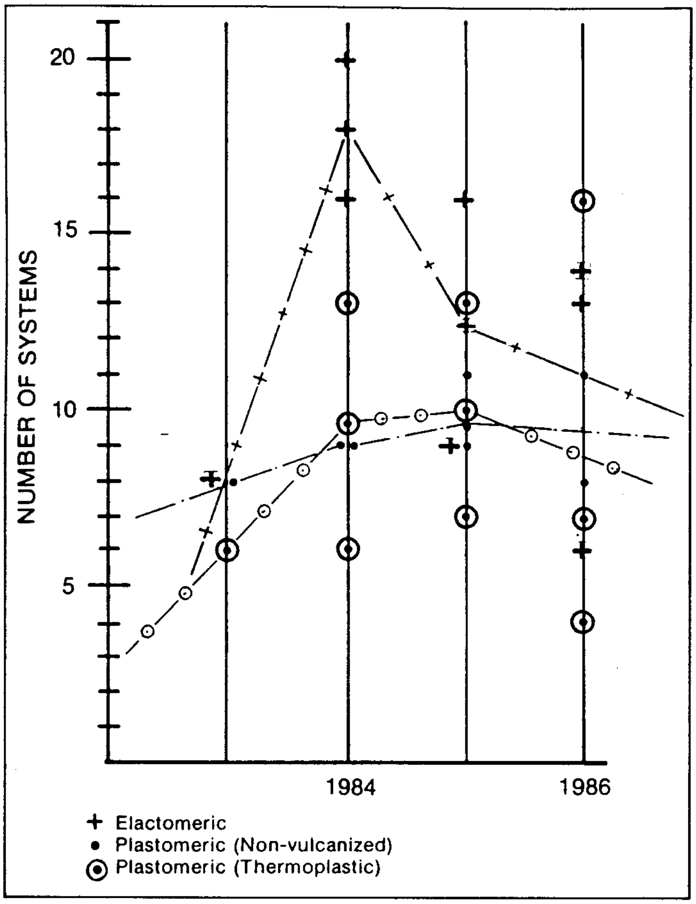

Table 2 *Historical analysis of mechanically fastened membranes*

- Fasteners

Correct length - must engage deck securely	Effect of electrolysis
Correct number	Bottoming out
Correct spacing	Backing out
Correct location (perimeter versus field)	Flexural strength
Correct type and quality	Fastener driven into the deck at an angle other than 90 degrees
Corrosion resistant	Substrate interference (old roofing coats and/or deflects fastener)
Overdriving	Heads or fasteners snapping off
Underdriving	Actually engage top flange on steel deck

- Lack of design
- Safety (trip over fastener caps or seams)
- Components often block drainage
- Limited comprehensive work has been completed on effects of dynamic wind loading
- The caps of fasteners of a non-penetrating system are targets of vandals
- A mechanically fastened system creates many more places roof has to be patched
- Batten system has some variables - batten spacing, bar size, gage, and shape
- More difficult to construct when compared to non-mechanically fastened systems
- Punching holes in membrane which is to provide waterproofing lacks some logic

Table 3 *Mechanically fastened membrane concerns*

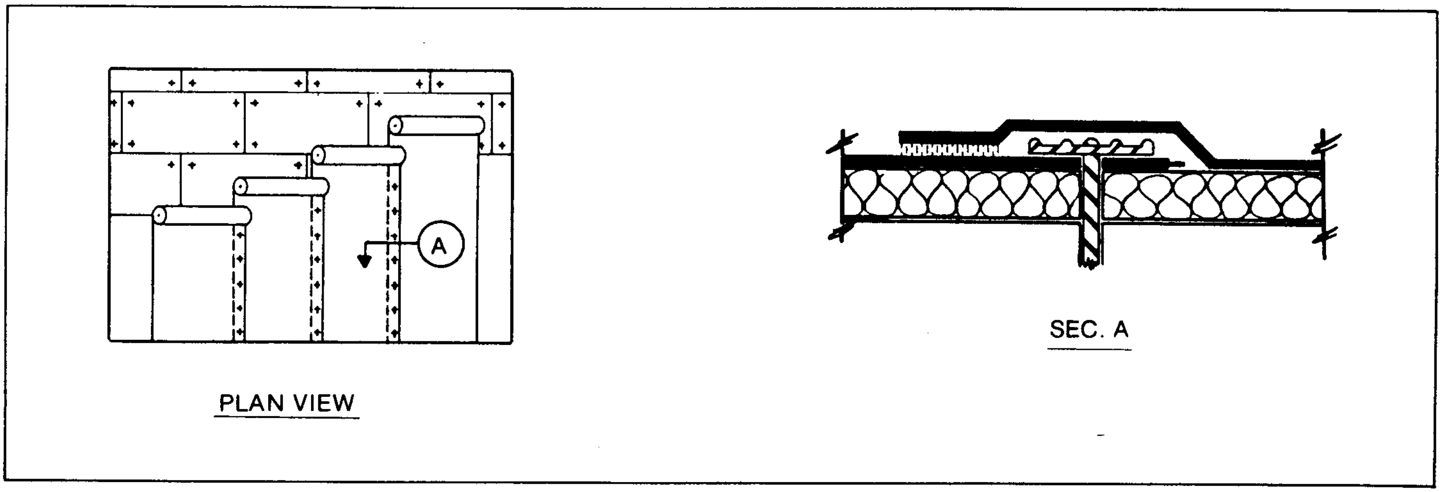

Figure 1 Penetrating spot fastened

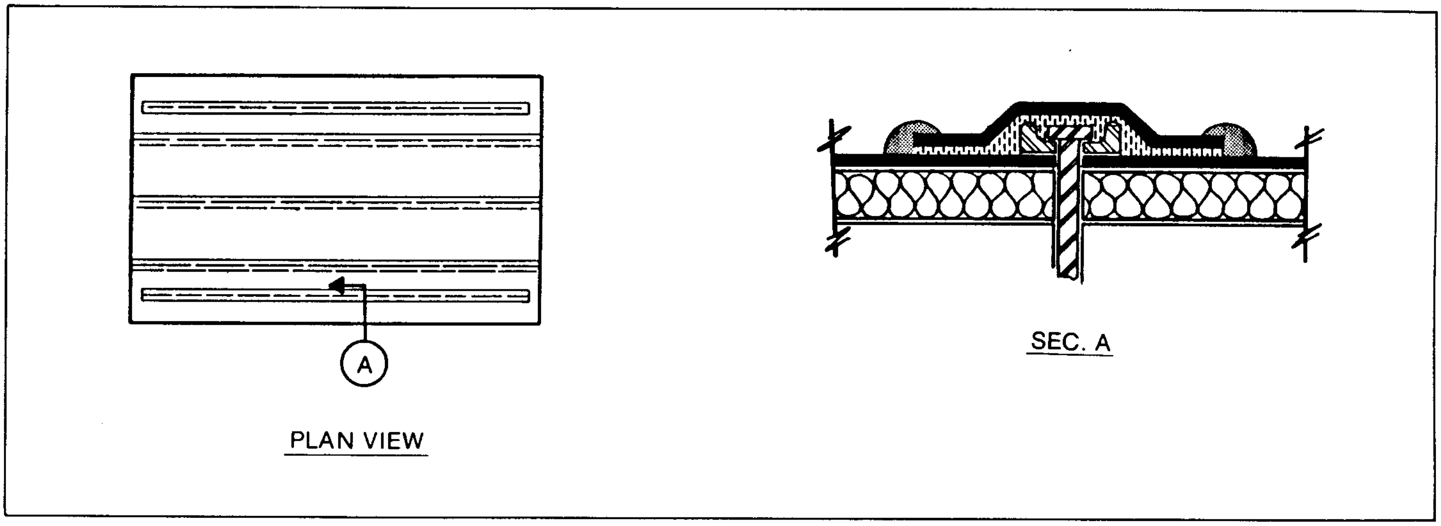

Figure 2 Penetrating linear fastened

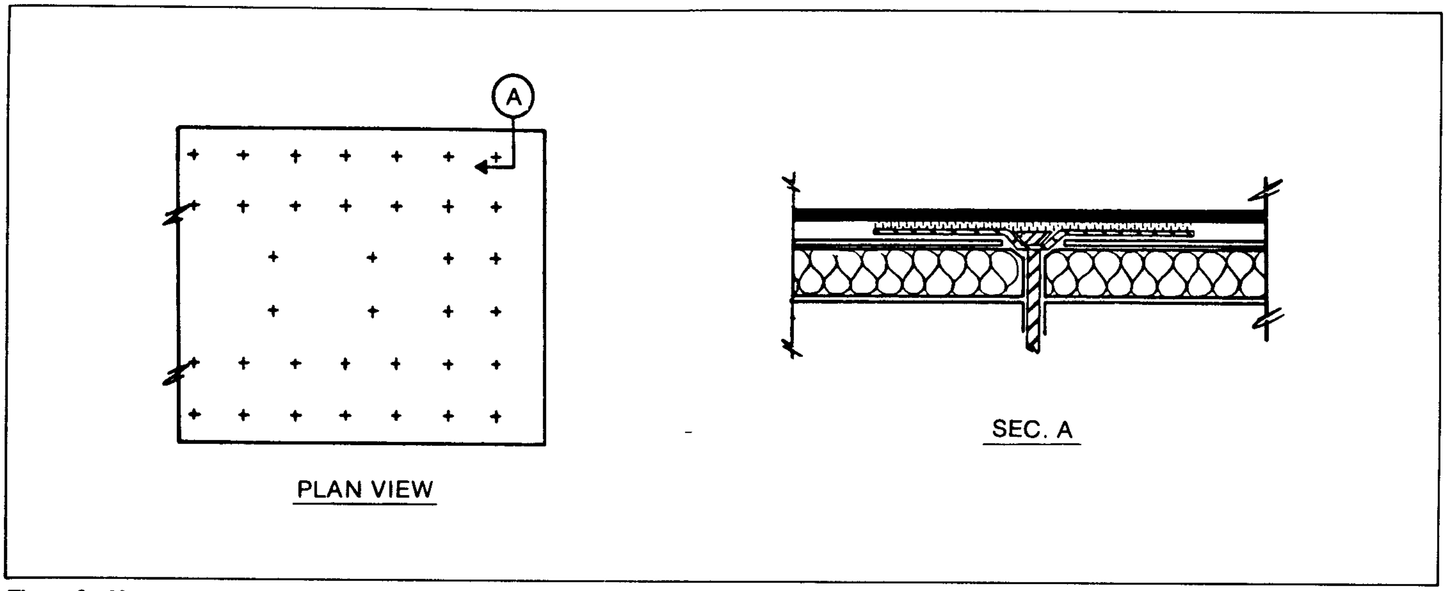

Figure 3 *Non-penetrating spot fastened*

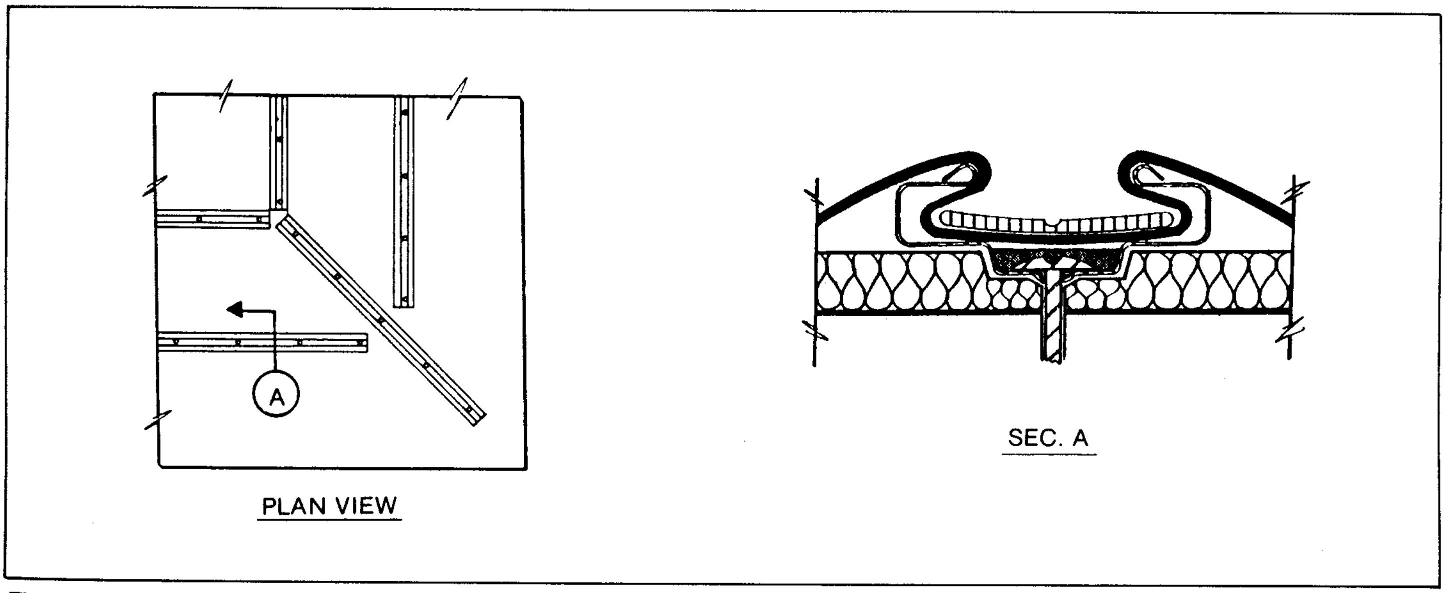

Figure 4 *Non-penetrating linear fastened*