# The development and field study of a sprayed in-situ sealing, bonding and stress absorbing asphalt interlayer.

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**Abstract**

Early failure of asphalt composite pavements can often be attributed to a number of different factors. These include, though may not be limited to: Bonding of the pavement layers, sealing of the pavement against water penetration and strain induced cracking from the pavement structure reflecting through to overlaying asphalt layers.

This paper provides information on an innovative approach to solving the above problems through the incorporation of a rapidly installed spray applied SBS polymer modified bitumen membrane as an entire interlayer in composite pavements which is being reported as beneficial against premature pavement failure resulting from the above mentioned factors.

The paper details the nature and required properties of the sprayed in situ membrane, installation experience and follow up evidence on sites in Scotland and England dating from September 2010 to the present day.

It also explains suitable test procedures and expected results of a successfully installed membrane and explores other applications for the in-situ sprayed membrane system including sophisticated surface dressings and bridge deck waterproofing installations.

**Introduction**

**Rigid composite pavements and their associated maintenance problems.**

A Rigid composite pavement is a pavement structure which has flexible and rigid layers.
These pavements usually have one or more asphalt concrete layers on top of a Portland cement concrete layer.
Flexible composite pavements are formed from cement treated and hydraulically bound aggregate layers in their base. Many Flexible composite pavements constructed in the 1960’s 70’s and 80’s were produced with sufficient cement that they act in a similar manner to rigid composite bases.
These pavement bases are also known as Lean mix or Cement Bound Material (CBM).
Maintenance of these pavements can be complex and difficult.

Signs of a failing semi rigid or composite pavement are often manifested in the surface layers as isolated patches of alligator cracking, pot holes and water penetration. Failure can be attributed to water penetration into the base from the top or the side of the carriageway and flowing into cracks formed by shrinkage of hydraulically bound cement mixes or through thermal shrinkage of existing cracks.

It is observed that the failure mechanism is related in large part to water penetrating and separating the surfacing layers from the rigid base.

It should be noted that the base can appear and test as structurally sound and intact in the main but that increasingly the pavement is moving toward rapid failure.

**Project design**

The engineer responsible for maintaining these pavements has few choices at their disposal. These could be:

a) Complete reconstruction – costly in time and investment
b) Remove the surface course and/or binder course and replace with new asphalt layers – this is likely to mask the problem in the base for a couple of years only when damage will reappear rapidly.
c) Remove all the asphalt layers, treat the base material and overlay. Treatment of the exposed base can be in the form of:

- De-stressing – which will weaken the overall structural capacity of the pavement,
- Removing individual areas of failed base and replace with concrete or asphalt
- A flexible and waterproofing sprayed in situ polymer modified bitumen membrane. This treatment is further explored below.

**Material properties**

The SBS polymer modified bitumen sprayed as an in situ interlayer is manufactured and supplied by Ooms Producten from The Netherlands through their UK and Ireland representative Material Edge Ltd. The interlayer binder is sold under the proprietary name of Sealoflex SC-4 and is one of a range of Sealoflex binders that utilise an exclusive production method for combining base binders with polymers. The pen and softening point properties of this material are shown in the Table below. The full specification of the interlayer system are proprietary and only shared with the client.

Table 1. Essential requirements of interlayer binder.

| DESCRIPTION | | TEST METHOD | SPECIFICATION | CLASS |
|---|---|---|---|---|
| **Essential requirements** | | | | |
| Penetration | at 25 °C | EN 1426 | 110-150 [mm x 0.1] | 10 |
| Softening Point R&B | | EN 1427 | ≥ 85 °C | 2 |

**Installation observations**

The laying of the hot sprayed binder is preceded by complete removal of the asphalt layers and intensive cleaning from purpose built beam sweepers to ensure the surface is as dust free and solid as possible. Where the surface continues to be friable after repeated sweeping it is considered for pre patching where practical.

The spray applied Sealoflex SC-4 is sprayed at 185 ºC by means of a specialist sprayer. The tanker used is specially adapted to heat the spraybar to higher than normal to prevent the very high SBS content bitumen binder clogging the spray jets. The vehicle is fitted with a computer controlled application system to ensure spread rates are maintained.

The construction sequence is quite simple. The Sealoflex SC-4 is applied at a rate of 2.0-2.5 litres / m2, followed almost immediately with a 4 – 6 kg m2 covering of 10mm crushed rock by a Phoenix surface dressing chipper. The chips are left on the surface to allow subsequent construction traffic to drive over during the subsequent paving operations.

It has been observed that where underlaying surfaces are not well cleaned immediate bonding of the sprayed membrane may be limited. It is therefore essential that good house keeping is set up to keep all unnecessary vehicles off the chipped surface after laying. In particular water should be sprayed onto the tyres of all incoming asphalt delivery vehicles and the paving vehicle and good observation of the membrane is essential to identify any possible picking up of the membrane on hot tyres.

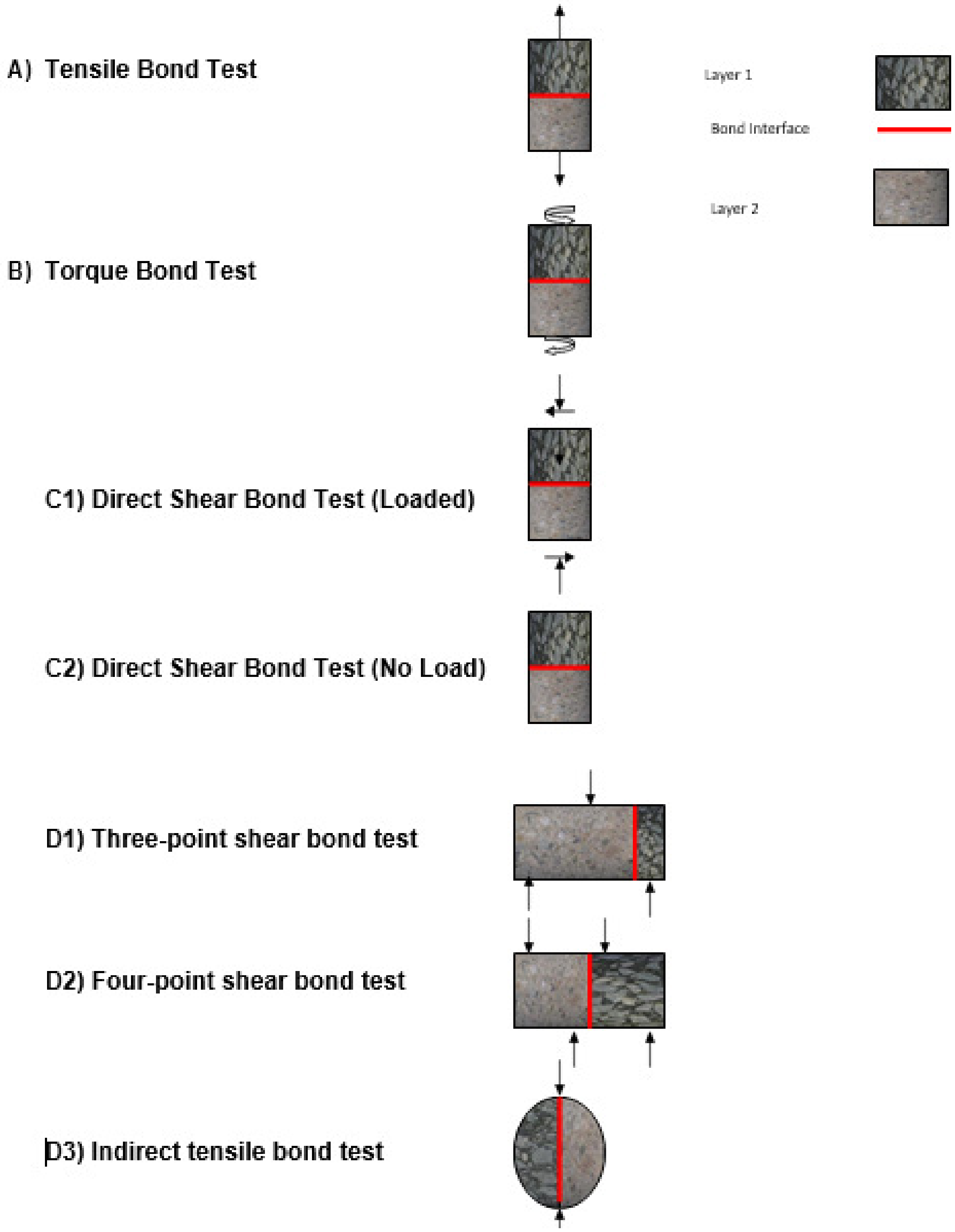
**Importance of bond**

Most, if not all pavement design and assessment methods assume the pavement to be homogenous and fully bonded. It is key that all layers within the pavement act together to be able to withstand traffic and temperature induced loadings. Under normal construction processes, either a bond or a tack coat is used to achieve this. However, and especially with semi rigid and composite structures, when this is not achieved, research has shown poor layer bonding significantly reduces the pavements capability to distribute loads. [Brown and Brunton 1984, Khweir and Fordyce 2003] This is even more important with a semi rigid or composite structure where the two materials have such contrasting properties and characteristics

**Testing**

Sutanto, in his 2009 PhD Thesis “The assessment of Bond Between Asphalt Layers” states: there have been a number of tests designed to evaluate the strength of bond between pavement layers. All of the tests are destructive and have many configurations, loadings, specimen geometry, specimen dimensions, and test equipment.

They can be classified as follows:




The tensile bond tests shown in example A and D3 are rarely employed, as, although there is the possibility that this particular type of separation mode could occur in a pavement, there have been very few known failures of this kind. In addition, results are often inconsistent and scattered.

The remainder of the tests (B, C1, C2, D1, and D2) make use of a shear force and seem to represent more closely the types of failure commonly connected with bond failure within pavements. The three and four point shear tests do provide the best and most consistent results, however, the sample specimens are complicated to manufacture and the test setup is not easy, so these test are usually only used for research.

Although the torque bond test is used by the British Board for Agreement for the assessment of bond in thin surface course systems, this test has been discounted. The preparation involves gluing a platen(s) to the specimen and the shear force is induced by twisting the sample. In most cases, the failure has occurred not at the bond interface but either within the samples themselves or the glued platens has broken off.

The direct shear tests, and moreover the unloaded in C2, seems to be the most commonly used for routine testing. Although there are some known issues with non-uniform shear the reasons for adopting this test are listed below:

- Simple setup
- Very simple test specimens – standard 150mm Ø cores
- Shear force applied accurately – so failure will not occur within the asphalt or concrete
- The test is fast
- The results are repeatable and comparable
- The test has been adopted by many European countries such as Germany, Austria, and Switzerland, UK and also in the US.

There is currently a test available that uses the direct shear method described above. The test is known as The Modified Leutner Shear test and is found in the Manual for Contract Documents for Highway Works (MCDHW) Volume 1, The Specification for Highway Works (SHW) Clause 954. This test was selected for this investigation.

**Site core sampling**

Site core sampling took place on a section of the M9/A9 Edinburgh - Stirling - Thurso Trunk Road Section 10432/60, Ch. 185-1257, a total length of 1072m involved in the project was originally constructed between 1975 and 1985. The existing pavement consists of approximately 135mm of asphalt over 180mm of lean mix cement bound material (CBM) on the night of the 18th of November 2010. This involved two coring rigs drilling a total of 27 150mm diameter cores. The decision was made to use an air flushing where high pressure air is used, in place of water. This would keep the samples dry, free from detritus and less stress would be placed on the samples. This would also allow for immediate examination of the cores on site.

The cores were marked and designated by section, either A, B or C and then local site chainage. Out of the total 27 cores taken, 8 of the cores were unsuitable for testing due to the bond failing at the interface or the concrete failing just below the bonded interface. This could be seen in Figure 4 below.

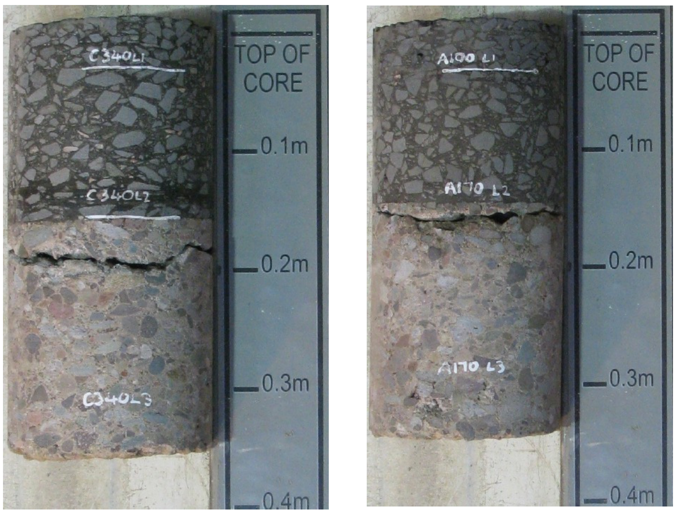



**Figure 4 - Core samples**

Out of the remaining samples left intact 8 were tested on behalf of Scotland Transerv and the remaining 9 were sent Ooms group in Holland, the manufacturer of the SAMI material. The results for the 8 tested are discussed below.

## Results

The results and a summary are given in Table 3 and Table 4 below.

| Sample ID | Diameter (mm) | Peak Load (kN) | Peak Shear Stress (MPa) | Displacement at Peak Shear Stress (mm) | Shear Modulus (MPa/mm) |
|---|---|---|---|---|---|
| B237 (NB) | 153 | 15.6 | 0.8 | 0.2 | 4.0 |
| B240 (NB) | 153 | 5.4 | 0.3 | 2.3 | 0.1 |
| B250 (NB) | 153 | 15.6 | 0.8 | 1.6 | 0.5 |
| B254 (SB) | 153 | 14.5 | 0.8 | 1.3 | 0.6 |
| | | | | | |
| C321 (SB) | 153 | 14.6 | 0.8 | 2.3 | 0.4 |
| C329 (SB) | 153 | 14.0 | 0.8 | 1.2 | 0.6 |
| C343 (NB) | 153 | 10.4 | 0.6 | 0.2 | 3.0 |
| C347 (NB) | 153 | 20.7 | 1.1 | 1.3 | 0.8 |

**Table 3 - Leutner Shear Test Results**

| Sample ID | Diameter (mm) | Peak Load (kN) | Peak Shear Stress (MPa) | Displacement at Peak Shear Stress (mm) | Shear Modulus (MPa/mm) |
|---|---|---|---|---|---|
| Area B | Max | 15.6 | 0.8 | 2.3 | 4.0 |
| | Min | 5.4 | 0.3 | 0.2 | 0.1 |
| | Average | 12.8 | 0.7 | 1.4 | 1.3 |
| | 50th%ile | 15.1 | 0.8 | 1.5 | 0.6 |
| | | | | | |
| Area C | Max | 20.7 | 1.1 | 2.3 | 3.0 |
| | Min | 10.4 | 0.6 | 0.2 | 0.4 |
| | Average | 14.9 | 0.8 | 1.3 | 1.2 |
| | 50th%ile | 14.3 | 0.8 | 1.3 | 0.7 |

**Table 4 - Summary of Results**

Area B, with the primer bond coat and the Sealoflex SC-4 Interlayer layer, has the lowest peak load values and Area C, with only the Interlayer has both the highest individual and average value also.

This is almost reflected in the peak shear stress, where again, area C has the highest value. However, on average, there is only a small margin between the two areas.

There is no noticeable difference between the displacement for both areas, with area B only marginally higher.

Area B produces both the highest and the lowest shear modulus but is again, on average, marginally higher than area C.

There appears to be no discernable difference between north or southbound cores. However, the number of samples overall is low and these observations should be viewed with a degree of caution. Also there is evidence to suggest that the Interlayer layer could have been installed under better conditions of both dryness and surface cleanliness.

**9.0 Discussion of Results.**

The test protocol for the modified Leutner Shear test is detailed below and described in SHW clause 954. The equipment can be seen in Figure 5

A core sample, conditioned to 20º C +/- 0.5º C, of 150mm Ø +/- 3mm is manually clamped in to the apparatus with the interface under test, between the two materials, located within a 5mm gap between the two shearing rings. A constant rate of displacement of 50+/- 2mm/min is applied using a standard Marshal loading frame.

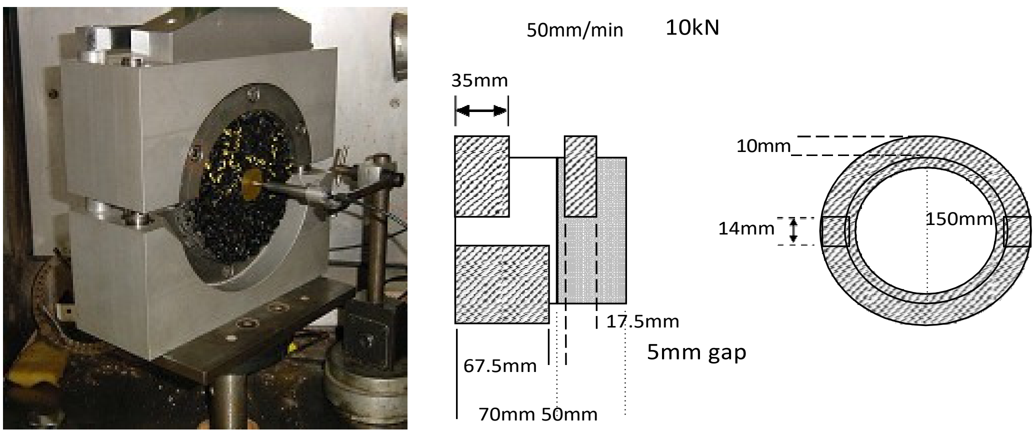



**Figure 5 - Test Equipment**

The shear strength at the interface and the displacement (slip) of both layers was measured. From these collected data the shear stiffness (k) could be determined, which is defined as the peak shear stress ($\tau_{max}$) divided by the corresponding displacement ($\delta_{max}$) as shown in Figure 6

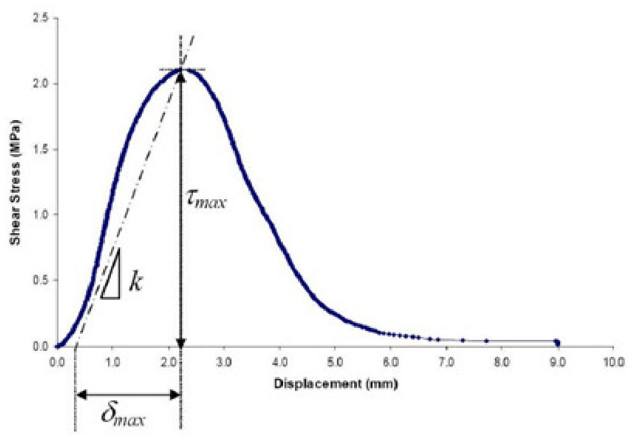



**Figure 6 - Example of shear stress vs. displacement**

Currently there is a large amount of research available on the importance of bond between layers. Further to that, some research has produced specification limits for bond strength between both surfacing to binder and binder to base. [Sutanto 2009] However, although many documents refer to the importance of this, little work has been carried out on the bond between cement bound materials and the upper bituminous layers, in a flexible composite structure. The results from this investigation will be compared only to specifications for bituminous bound pavements.

| Source | Equipment | Specimen Size | Displacement Rate | Shear Strength (MPa) Surf / Bin | | Shear Strength (MPa) Bin / Base |
|---|---|---|---|---|---|---|
| Codjia [1984] Germany | Leutner | 150mm Core | 50mm/min | 0.85 | | 0.57 |
| Partl & Rabb [1999] Switzerland | Leutner LDPS | 150mm Core | 50mm/min | | 1.3 | |
| Stöckert [2001 Germany | Leutner | 150mm Core | 50mm/min | 1.41 | | 1.13 |
| SN 640430B [VSS, 2008] Switzerland | Leutner LDPS | 150mm Core | 50mm/min | 0.85 | | 0.68 |

Table 5 - Proposed and European Limits

By applying the upper shear strength limits in the table above of 1.41, this would reject all of the samples. Conversely, if we applied the lower limits all but core (B240) would pass the  0.57MPa.

Sutanto’s 2009 research, based on the above specifications and further investigations, went further to proposed limits for use on UK roads of 1.0MPa and 0.5MPa for surfacing binder and binder and base respectively. Again, all but core B240 meet the lower specification and most almost meet or exceed the requirement of 1.0MPa as proposed for the surfacing / binder bond requirement.

All samples had a relatively low displacement at peak shear stress. Although not immediately important this may warrant further research to see if this is relevant where two materials with contrasting stiffness and differing thermal reactions are bonded together to allow for distinct differences in how they behave under thermal and traffic loading.

## Schemes completed 2010 to 2017

| Location | Scheme | Pavement | Treatment | Project size | Observations |
|---|---|---|---|---|---|
| Badachreamh | A9 Moy to Inverness | Constructed 1975 to 1985 Fatigued asphalt over fair quality concrete base Longitudinal + transverse joints | Radical sweep plus 2.0l/m2 Sealoflex SC-4 + 4-6kg/m2 10mm crushed rock | Phase 1 and 2 | |
| Ballaloi / Glen Gary | A9 Drumochtar | As above | As above | | |
| Inverness | | As above | As above | | |
| Cairnleith Moss / Bankfoot | A9 Bankfoot to Pitlochry | Transverse cracking, no bond between asphalt and cement bound layers 135mm asphalt over 180mm lean mix CBM. | Radical sweep plus 2.0l/m2 Sealoflex SC-4 + 100mm to 140mm Inlay ( 60 to 100mm AC20 dense, 40/60 bitumen and 40mm thin surfacing.) | 900 – 3,000m2 | |
| Selby | Selby By Pass | Semi rigid 270mm overlay on experimental CBM PFA + local sand mix | Radical sweep + 2.0l/m2 Sealoflex SC-4 | 37,000m2 | Main carriageway plus roundabout |

## Latest developments

The use of a rapidly applied sprayed in situ waterproofing and bonding membrane presents itself for other construction requirements not limited to the following:

### Stress absorbing surface dressing treatment.

Carriageways requiring surface treatment to improve skid resistance and water proof the surface have had an application of geosynthetic laid over a 2.0-2.5kg/m2 layer of Sealoflex SC-4 over which a conventional racked in surface dressing is subsequently overlaid.

This procedure carried out in controlled trials in Norfolk has resulted in a major improvement in the ability of a surface dressing to combat surface cracking usually seen in the dressing within a few weeks or months of application.

**Bridge deck waterproofing.**

In the Netherlands and Germany over a number of year the Sealoflex SC-4 Interlayer system described in this paper has also been utilised as a bridge deck waterproofing layer when sprayed at 3kg/m2 plus chippings as protection.

**Conclusions**

Based on this investigation the following key points can be derived from this study:

- When installing an interlayer, it is key to ensure that the cement bound substrate is both clean and dry.
- Not all failures in bond occur at the interface between the cement bound material and the asphalt overlay.
- There is no discernible difference between either profile planing or completely removing all the asphalt overlay before applying the Interlayer.
- Applying a bond or tack coat, as a primer layer, has only minimal improvement over applying the Interlayer immediately on to the concrete substrate. Although the cleanliness and dryness could have impacted on this.
- The application of an Interlayer provides a superior bond over that of a conventional bond or tack coat.
- The bond produced can almost meet or exceed that required for the interface between surface course and binders in flexible pavements of 1.0MPa.
- The displacement at peak shear stress may be more important in flexible composite structures.
- The application of a spray insitu membrane has a number of end uses which are currently being used in the Netherlands and Germany and trialled in the UK.

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