Sole adhesion peel strength testing

The SATRA TM411 test for assessing sole bonds has recently been revised, as MIKE GEORGE describes.

Ever since cemented and direct-moulded constructions came to dominate over stitched-on constructions, obtaining and assuring secure attachment of sole to upper has been of prime concern to shoemakers and suppliers. Achieving a good bond is a multistep process, with many opportunities for error that can lead to poor results. Sole bond failure is not just a quality issue – it can also impact upon wearer safety if a detaching sole is not at first noticed. Therefore, test methods for bond strength are long established and very widely practised.

This article focuses on peel strength testing, a significant test where sections are cut from completed whole shoes and pulled apart by a tensile testing machine. The direction of peel is nominally 180 degrees, meaning that sole and upper are pulled in diametrically opposite directions (figures 1a and 1b). This action relies on the flexibility of at least one of the adherends. The force resisting the separation is divided by the width being peeled, to give a result expressed in N/mm. While this tells us the quality of adhesion that has been obtained, it is only part of the picture. Just as important is the manner of separation, as this reveals the weakest link in the chain, which can often help to explain low results and thus point to potential remedies. These failure modes are:

- tearing of either bonded material (adherend)

A peel strength specimen cut from the sole bond of a finished shoe

- surface delamination of either adherend
- failure of either adhesive coating to stick to its adherend
- failure of the adhesive coatings on each adherend to fully coalesce together (that is, to stick to each other)
- failure of the combined adhesive coatings to set, producing cohesive failure. Set adhesive may also be subsequently softened by heat or by migrating grease/oils from an adherend, again leading to cohesive failure
- clean separation of the adherend materials (with no adhesive present – for example, on co-moulded materials).

Ideally, the strength of adhesion will be high enough to force an adherend to tear, and then it only requires the adherends to have adequate intrinsic strength to support the bond. The common peel test methods report both a numerical strength value and the mode(s) of failure. It is also worth paying attention to the area of the bonded surface because this helps to determine the total attachment strength. An overly narrow strip of adhesion could compromise an otherwise well-made bond.

Related test methods

Some of today's methods can be traced back to a 1970s British Standard BS 5131 Section 5.4. This was developed in parallel with SATRA Adhesion Method AM11, which was later renumbered as the SATRA TM411 test method. Subsequently from 1993, the European method for personal protective equipment (PPE) footwear included a very similar sole bond test – initially in EN ISO 344 which eventually became EN ISO 20344 (clause 5.3), and is now dated 2011. In 2003, EN ISO 17708 was first published, and this was most recently revised in 2018. This is also technically very close to SATRA TM411. The full names of these methods are given in box 1.

As part of its rolling programme of test method reviews, SATRA has recently produced a 2019 update of SATRA TM411. The remainder of this article will summarise this method and explain the amendments made.

Box 1: Related sole bond peel strength test methods

SATRA TM401:2000 (formerly SATRA AM1 dating from 1966) – 'Peel strength of adhesive bonds'
BS 5131 – 5.4:1978 – 'Sole bond peeling strength'
EN ISO 20344:2011 – 'Personal Protective Equipment – test methods for footwear', clause 5.3 – 'Determination of upper/outsole and sole interlayer bond strength' (originally EN ISO 344 dating from 1993)
EN ISO 17708:2018 – 'Footwear – Test methods for whole shoe – Upper sole adhesion'
SATRA TM411:2019 – 'Peel strength of footwear sole bonds'

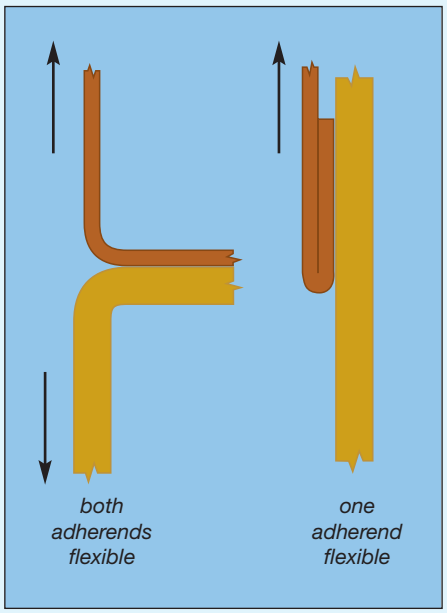

Figure 1a: Sole adhesion peel strength tests are made at 180 degrees, requiring flexibility of at least one adherend

Figure 1b: SATRA Test Method TM411

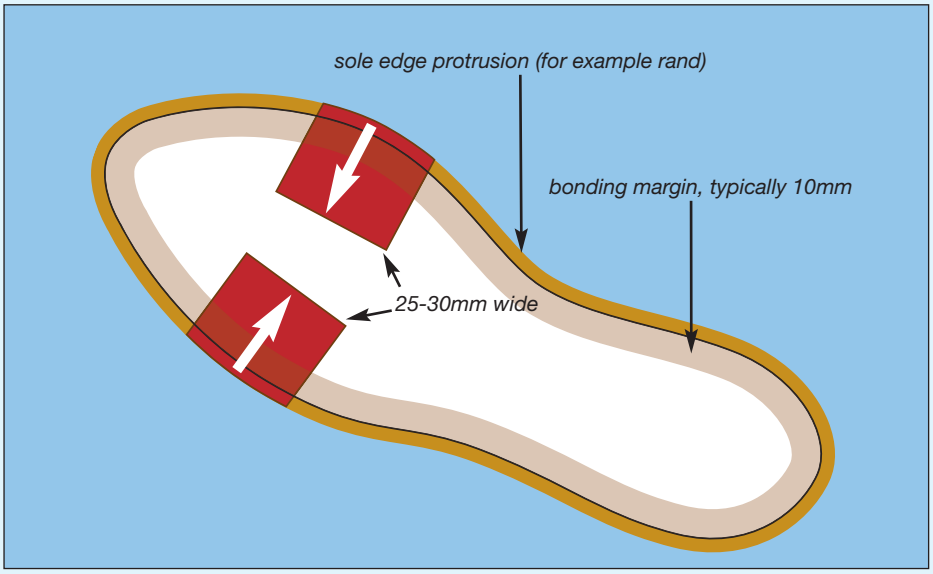

Figure 2: Sections are cut from the flexing joints. White arrows show direction of peel

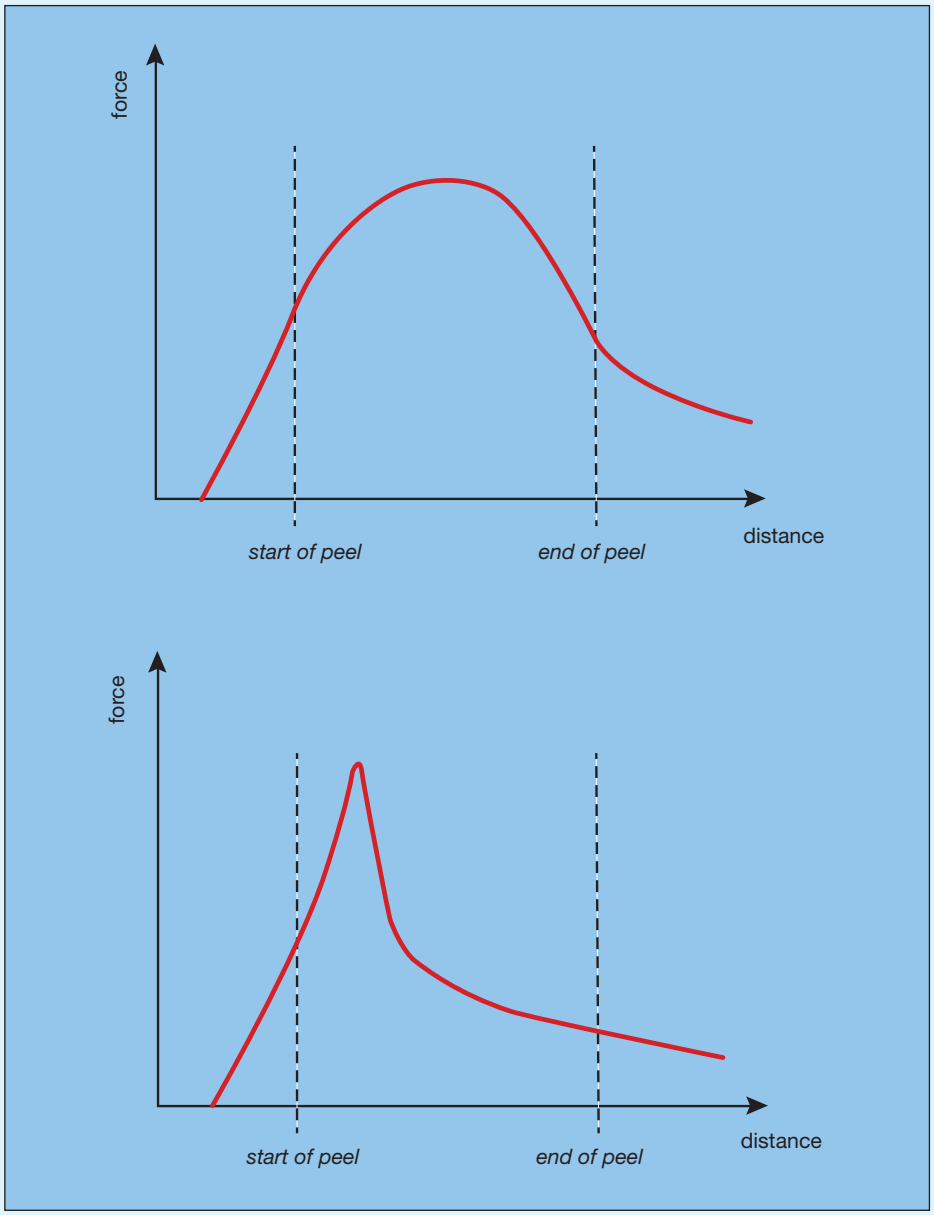

Figure 3: Typical 'across' peel trace shapes

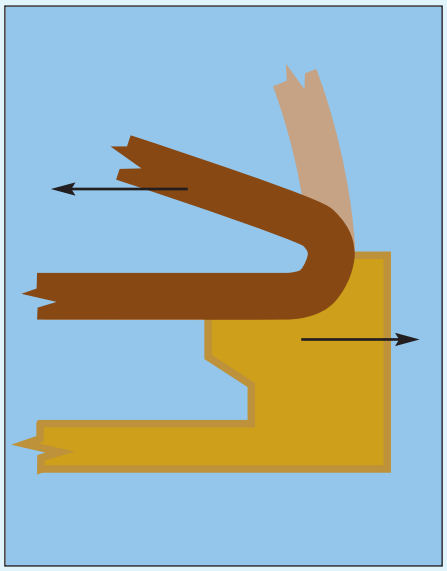

Figure 4: The peeling distance may be limited by the sole bonding margin width

Other bonds in the shoe bottom

The scope of SATRA TM411 now makes it explicitly clearer that bonds other than sole-upper may also be tested by this method. This can include midsole-outsole interlayer, veneers, platform and wedge covers, rands, overlay panels and even rubber top-pieces to heels, subject to enough flexibility in the rubber. The related but more general method SATRA TM401 (see box 1) may alternatively be used for bonds other than those involving soles in finished shoes. A good example of this is laboratory assembled bonds made from swatches of candidate shoemaking materials, which can include soles and uppers. The technical peeling action is the same.

'Along' and 'across' peeling directions

Shoes constructed with a protruding sole edge (such as with a real or mock rand) that is enough to grip, are tested in the 'across' direction, peeling inwards from the featherline towards the centre line of the shoe (figure 2). Force traces generated by such peels (figure 3) tend not to be level. They may start low because the upper preparation does not quite extend completely to the featherline, then increase over the main part of the bonded margin, finally dropping off close to the inner edge as the area remaining bonded diminishes to nothing (figure 4). Sometimes there may be an initial peak if a coating on the upper is being torn through. Depending on the

coating adhesion strength, there may then be a large reduction as the coating remains stuck to the sole but delaminates from its substrate (the main substance of the upper material – for instance, polyurethane coated textiles).

An amendment to the SATRA TM411 method instructs the user to make sure that the gripping jaws are at least as wide as the test specimen, so that it is uniformly pulled over its whole width. Some users may be in the habit of pulling 30mm specimens with 25mm jaws. If only 25mm jaws are available, the specimen width should also be 25mm. It continues to be standard to report both the initial peeling strength (closest to the featherline) and the average peeling strength (across the whole bonded margin), and computerised tensile testers will often calculate this average. The reason for the careful removal of insole board from the test specimens is explained in the amended method – to remove the clamping effect on the bond which could otherwise impede the peeling action. The test is only used to consider the quality of adhesion between two surfaces, not any mitigating effects from other components.

Many modern shoes – perhaps the majority – do not have a protruding sole edge sufficient to be gripped. In such cases, test specimens are prepared from along the edge of the sole and peeled parallel to the sole edge (figure 5). The specimens are 50mm long and 15mm wide, which is normally enough to include all of the bonded margin. Having been cut out, these pieces may then be trimmed back further if it is obvious that one material overhangs the other – for example, if the upper material extends beyond the inner edge of the raised sole margin. An important change to the SATRA TM411 method is that the width (15mm or less) is not measured at this stage, because not all of this width is necessarily bonded. This will not become completely apparent until after the specimens have been peeled apart. Any overestimate of the bonded width will cause the apparent bond strength (N/mm) to be falsely low.

Preparing specimens

Another point of emphasis is to prepare specimens of uniform width along their length, because again, unevenness will affect the N/mm result accuracy. Various specimens may have different widths, but each individual specimen must have a width that is uniform. With good specimens in hand, it is necessary to separate enough of the ends in order to grip them in the tensile tester jaws. This separation is done with a heated metal blade inserted into the bond line (figure 6). It should be hot enough to melt the adhesive (over a length of about 10mm, so leaving

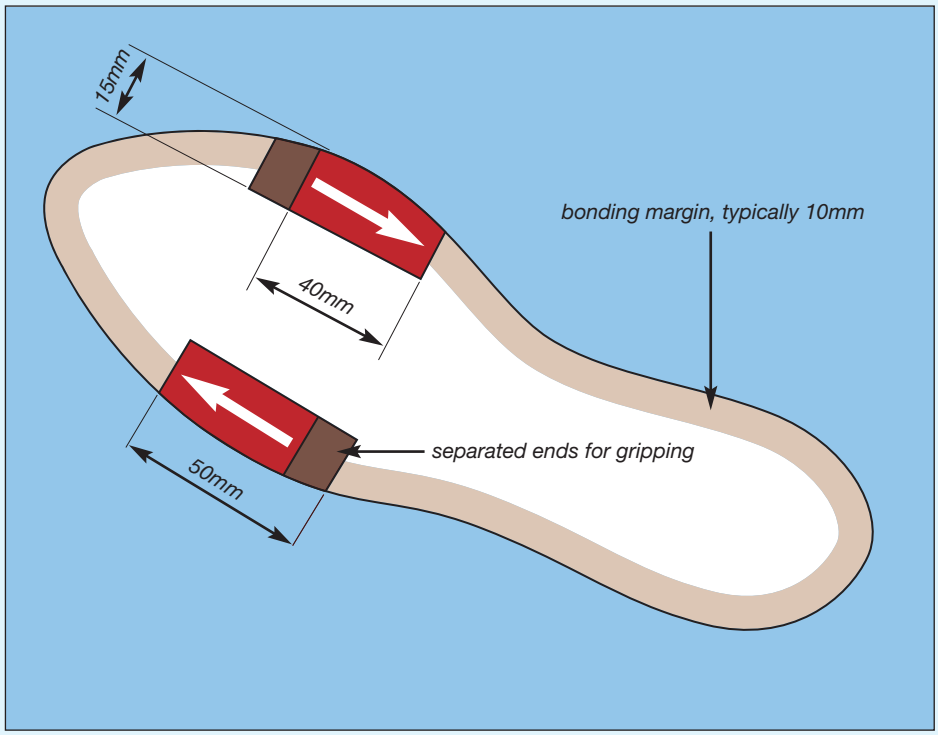

Figure 5: Sections are cut from reasonably straight areas close to the flexing joints. Arrows show the direction of peel, which may be forwards or backwards

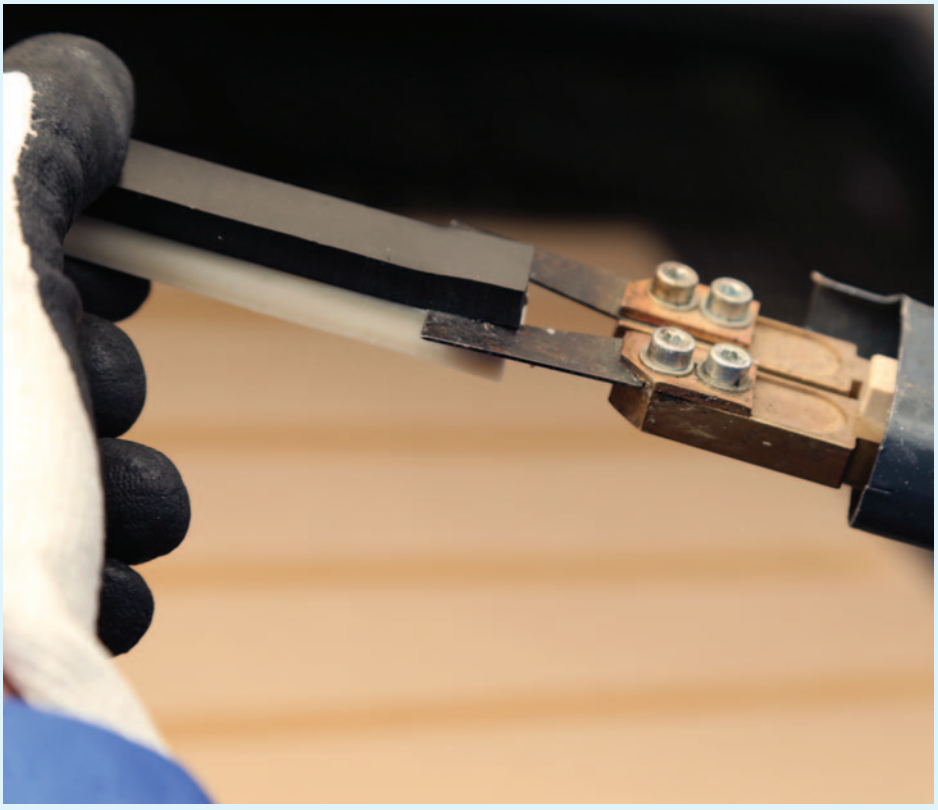

Figure 6: Preparing a specimen with a heated metal blade

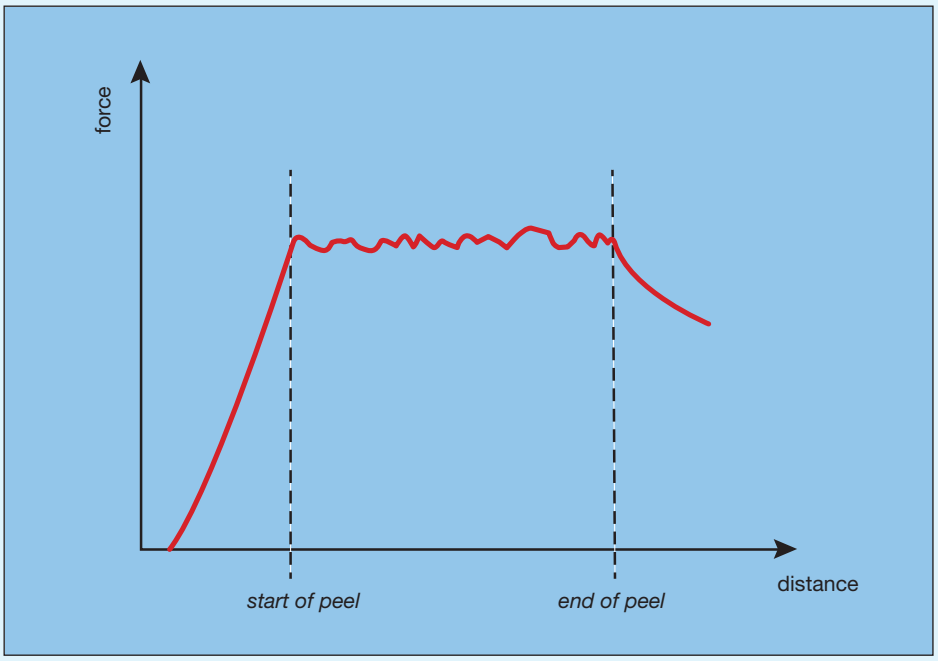

Figure 7: Typical 'along' peel trace shape

40mm to peel), but not so hot that it can melt thermoplastic sole materials. Either the front or rear end may be separated, and it does not matter if the bond is peeled forwards or backwards along the sole edge.

The gripped ends are then centred in the gripping jaws for pulling – usually the jaws are wider than the specimen in this test direction. Force traces generated by 'along' peel tests tend to be quite level once the slack is taken up and the peel commences, because the whole bond width is being peeled at the same time. This bond width remains the same as the peel progresses (figure 7). On this occasion, only the average (not initial) peel strength (N/mm) is reported, and computerised test machines will calculate this. It is important to input the correct bonded width, which is measured for each individual specimen after it has been peeled and can be seen with certainty.

The revised method now introduces the additional reporting of the average peel force (N) and the measured width (mm). Either of these may be compared to additional minimum specification levels if required, as well as the conventional N/mm value. Thus, we have a measure of both bond quality (N/mm) and quantity (N and/or mm).

Where there is a protruding sole edge, either an 'across' or an 'along' peel test can be made. Theoretically, the same average N/mm result should be obtained in both test directions. However, 'along' peels give no information about the profile of the bond strength across the width from the featherline to the inner edge. Also, the reduced width of along peels (perhaps 10mm compared with 25mm for across peels) leads to a greater measurement uncertainty in width (mm), and hence also in the final peel strength (N/mm). For example, 1mm accuracy in 10mm is potentially 10 per cent error but only a 4 per cent error over 25mm.

Responsibility for testing

The revised SATRA TM411 test method also puts more onus on the person commissioning the testing or the laboratory supervisor to establish which are the bonds needing testing in the bottom of the footwear, rather than leaving this to the testing technician who may not always be well-placed to make that decision. A simple instruction to 'test the sole bond strength' is not enough, and should be qualified with specific details. In addition, there may be more than one key bond. Cutting into the shoe will usually reveal the structural bonds to the knowledgeable shoe technologist.

Artificial (accelerated) ageing of the prepared test specimens is an option, and the revised SATRA TM411 test method now includes details of these pre-treatments rather than referring to a separate document. Heat ageing, moist ageing and wetting and drying are all included.

Assessing failure modes (the manner of separation) is a matter of subjective judgement (being stated as such in SATRA test reports), and is not always clear-cut. For instance, sometimes it is difficult to tell whether an adhesive film remains present on a surface. While such a film might become tacky as a test drop of solvent dries on its surface, so would thermoplastic rubber. Another difficulty is deciding whether torn leather fibres embedded in an adhesive layer are sufficient in number to constitute 'surface tear' as opposed to 'adhesion failure'. As ever, cohesive failure can only be judged by witnessing the peel and seeing the soft adhesive string or leg between the two surfaces. Afterwards, the adhesive residue on each surface could also potentially have been caused by non-coalescence. The revised method now gives a table of suggested codes for the various types of failure mode, which can be used in report tables which should include a key to their meanings – for example, 'SU' = surface tear of upper, or 'AS' = adhesion to sole.

Other amendments to SATRA TM411 are mainly of an editorial nature to improve clarity of meaning. All the changes are intended to tighten up on technique in order to improve the reliability of results or to increase the information reported. SATRA has aimed to provide a greater level of helpful guidance, and there remain no contradictions with the sister methods EN ISO 17708 and EN ISO 20344 (5.3).

How can we help?

Please email SATRA's footwear testing team for further information on the assessment of sole adhesion peel strength or to request testing.

footwear@satra.com