

The dirty side of slip

ZACH ARMITAGE, SATRA

Assessing slip resistance is an important aspect of the testing of footwear for reasons of both performance and safety, and is a measure of the friction between the sole and any standing surface. Slip is often given as a coefficient of friction (CoF) which expresses how difficult it is to slide one material against another. Unfortunately, the simplicity of standard friction is greatly complicated when considering polymers such as rubbers in footwear, contaminants and especially where such variable surfaces as dirt tracks, sports fields and other dirty and muddy environments are involved.

Standard slip resistance testing is conducted against a calibrated quarry tile and, while this provides a good measure of the slip resistance of a soling

material, it is only capable of distinguishing performance differences due to alternative tread pattern designs to a certain extent. The addition of contaminants, such as water and glycerol, gives a better indication of tread pattern performance, but only assess the tread's ability to direct the contaminant into its channels to allow good contact with the quarry tile below. The grip offered by studs and spikes in sports footwear, however, cannot be determined without testing on a more demanding surface.

SATRA has considerable experience of slip resistance testing of footwear and floorings, ranging from consumer complaints in the retail sector to meeting the requirements of global safety standards. It can assess slip resistance against numerous surface types and common lubricating

substances. Test Method SATRA TM144 standardises testing to a surface of known frictional properties under both dry and wet conditions. This provides a pass/fail criterion and a means of footwear comparison. Having an established range of test flooring and lubricants has helped understand the factors of sole material in relation to slip resistance. Materials selection and tread pattern are key variables in CoF behaviour.

SURFACE REQUIREMENTS

The growing demands of industry often call for the development of novel testing approaches. In this context, combinations of solid surfaces and lubricants can help represent real world situations. However, until recently, there was no deformable slip material capable of simulating unpaved or off-road surfaces (e.g. mud) in a slip

event. The properties of mud depend on environmental factors such as soil composition and the hydrological cycle. It is therefore important to consider a given shoe's potential end use and associated outdoor situations. For the wearer, mud underfoot can be highly unpredictable. Translating this to a standard test surface is experimentally challenging and has been the aim of recent SATRA research.

An ideal mud simulant must be usable more than once by being easily moulded back to shape after a slip test, withstand total fracturing and have Newtonian* behaviour. SATRA has developed a material meeting these requirements allowing it to formulate an artificial surface where both composition and properties can be precisely tailored. Unlike externally sourced test floors, this gives it full control over how the material is prepared. In keeping with current standards, the surface can be calibrated, is consistent across equivalent samples and can distinguish footwear style by slip resistance. Forming the mud simulant is simple, fast and inexpensive. This is also the case with calibration, which provides data that can be closely related to slip behaviour.

EXPERIMENTAL FACTORS

Work has been undertaken to establish a test protocol to accommodate compressible and deformable slip resistance surfaces. Calibration of the mud simulant involves a standard compression test, partly reflecting surface deformation in slip events. Minor modifications have allowed the simulant to be tested with current SATRA test methods and its STM603 slip test machine as if it were a conventional surface. Moreover, the material generates reproducible slip resistance results across multiple shoe and surface combinations.

The standard quarry tile is characterised by a CoF ranking of various materials and calibration involves dry and wet slip runs using a particular rubber specimen. On a mud-like surface, material alone is unlikely to determine slip resistance. The compressible and deformable nature of the simulant serves more as a test of tread pattern than soling material in



By testing over a range of hydration levels, the performance of a product can be assessed in greater detail. IMAGE: SATRA

terms of slip resistance. Loose material can be displaced and accumulate ahead of footwear in a mud slip event, unlike the fixed dimensions of a ceramic tile. This places unique slip resistance demands on footwear.

Shoes with good slip resistance on paved surfaces may be prone to slipping against mud and similar materials. For example, a flat sole with large contact area would not provide traction against a loose, free-flowing surface. Conversely, certain sole features act to oppose slip. The studs of a football boot will stabilise the wearer against loose underfoot mud, with the opposite effect likely on pavement. Assuming the mud simulant is a viscous solid, slip resistance can be considered a function of sole geometry

more than materials selection.

Having achieved a mud simulant surface, SATRA can help design for unpredictable slip situations. A key focus of its research was to ensure the mud simulant represents the potential range of underfoot properties yet remains reproducible for repeated testing. In particular, being able to assess soling pattern as distinct from materials may aid the design process. By isolating tread pattern as a variable, the slip resistance between footwear styles tested on mud will differ to that on paved surfaces. Preparing surfaces to a wide range of flow properties can further distinguish footwear by slip resistance.

Across the range of simulant properties achieved in testing, there



SATRA's mud simulant is able to represent the potential range of underfoot properties yet remain reusable for repeated testing. IMAGE: SATRA

Figure 1 - Slip resistance in forepart mode

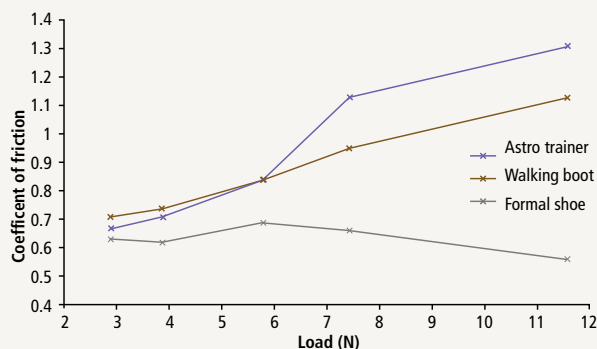
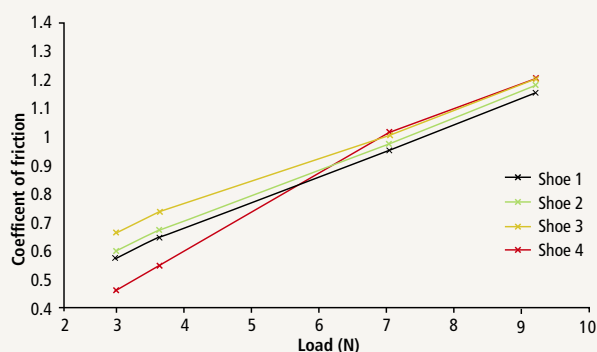


Figure 2 - Slip resistance in heel mode



are points of crossover in CoF between different shoe styles. Figures 1 & 2 highlight the effect of increasing surface compressive strength (Load, N) on the slip resistance of various footwear. Beyond this range, similar patterns may exist. Considering a mud surface of near-solid consistency or a tiled surface, the extent of deformation is either minimal or non-existent. Here, frictional properties of the soling material predominate in slip resistance. Meanwhile, free-flowing or liquid substances rely on geometric tread features for displacement which, in turn, prevents 'hydroplaning'.

By controlling the mud simulant formula, a variety of mud conditions can be obtained. Increasing hydration will produce a more liquid material (low load) while dehydration offers a firmer material (high load) although still prone to shearing. By testing over a range of hydration levels a product's performance can be assessed in greater detail. Figure 1 compares the performance of an Astro trainer, walking boot and leather soled formal shoe. In wet conditions, performance of all three is comparable, though a clear ranking still exists with the formal shoe performing the worst. As the material becomes dryer there is a much greater distinction between soling designs and, while both the Astro trainer and the walking boot perform well, their ranking changes as the material becomes drier.

As is expected, comparing such differing footwear gives a wide performance range and the ranking follows the path one would expect. The walking boot with its deep tread designed for rough terrain is ranked best in wet mud conditions, while the formal shoe performs the worst across all conditions. Figure 2 provides the performance and ranking of four items of footwear all intended for the same

purpose but featuring various design variants. Here the difference in performance is less exaggerated, but it is clear that the design of shoe No. 3 is best in wet conditions. While in dry conditions the differences in design is less pronounced and shoe No. 4 becomes the most suitable.

APPLICATIONS

Designing footwear towards a specific end use will help in testing for slip resistance in terms of potential outdoor environments. This may range from recreational activities to meeting the demands of emergency services and military roles. Extremes of weather and terrain will worsen muddy underfoot conditions. Intense rainfall or flooding combined with gravity can lead to natural displacement of land. Mud easily absorbs water, to the point of becoming saturated. Therefore, mud will realistically be inhomogeneous throughout its depth. Equally, water can rapidly evaporate from the structure of mud given the right conditions.

The introduction of water to mud will increase its tendency to flow and, in some cases, will promote adhesive behaviour. In this case, material occupying recessed regions of the sole can hinder slip resistance. This has been reflected by the mud simulant during testing. Experimentally, testing compressible surfaces is challenging due to the vertical force component acting against a fixed machine table height. With some modifications to setup, this can nevertheless be managed.

Achieving a realistic mud simulant can help identify how to 'anchor' footwear at critical slip points of the step. Naturally, exposed mud often coexists with grassland. Against the latter surface, slip resistance can be represented experimentally by artificial turf. This is a common test surface and testing can be against SATRATurf or may be conducted to customer specification. While grass can vary by length and density, mud is a continuous material of infinitely variable consistency. Given that mud and grassland frequently coexist, the ability to simulate both in testing is advantageous. For example, a given sole feature may generate high friction against turf but underperform against the mud simulant. Other sole patterns may give similar slip resistance across the two surfaces. Similarly, alternative slip resistance test methods may offer further scope for comparative testing, e.g. rotational slip resistance.

SUMMARY

As a first attempt to simulate a loose, deformable surface, the requirements of repeatability and differentiating footwear by CoF were prioritised in this work. Although the intrinsic variability of mud makes realistic testing difficult, this research has provided a good foundation for further development. Real-world characterisation and correlation testing of mud in terms of slip will contribute greatly to simulation as an experimental surface. Human factors are also an important consideration, given the higher probability of slip occurring here compared to a paved surface. For instance, modifying foot placement and contact angle might affect the ability of a sole to provide traction to the wearer.

**A Newtonian fluid is one where viscous stresses arising from its flow at every point are linearly proportional to the local strain rate (rate of change of its deformation over time).*