

Footwear Fundamentals

SAFETY FIRST



The global market for safety footwear is immense and, as many developing countries become more industrialised, it continues to grow. While the production of safety footwear was concentrated in Europe and North America, the implementation and policing of performance standards could be both rigorous and effective. With the global expansion of footwear manufacture, it became less easy. Furthermore, not all countries demanded the same standards in regard to safety footwear sold within their boundaries. Europe operated under EN 344 and 345 with their various amendments. The USA used ASTM standards which, although broadly similar, required a different set of tests. Some countries had scant regard for standards of any kind.

Standards worldwide are now much tighter thanks to the global nature of today's footwear industry. Those demanded by individual countries do however continue to vary. The European and International Standard for Safety footwear is ISO 20345: 2004. The USA on the other hand continues to follow ASTM, while Canada prefers its own CCA set of standards. Asia, however, has a variety of standards with Australia, China, Indonesia, Japan, Malaysia and Singapore all using different values.

The fact that the European 20345 series published in 2004 (further updated in 2007) are dual EU (CEN) and ISO methods has proved extremely positive in that countries outside the EU are adopting them. In any case, since August 2005, any safety footwear bearing a CE mark destined for EU markets should have been assessed against these requirements. New standards continue to be developed and published, so it is important for anyone involved in safety footwear to hold a full data base on all standards and to keep it up to date.

There is a wide range of separate requirements within an overall set of standards designed to cover as many eventualities as possible. The most obvious ones are for toe caps, penetration resistant inserts (sole plates) and slip resistance, the broad outlines for which are as follows.

TOE CAPS

When safety toe caps were all made from steel, establishing a suitable set of tests that could be universally applied did not present any serious difficulties. Non-metallic caps made from hard rigid polymers reinforced with textile have become increasingly popular, especially where weight is an issue or for situations where steel might cause problems as in the case of work-place environments where metal

detectors are employed for security reasons. Aluminium caps are now also more widely used for similar reasons.

Components of this type present challenges in the way they are assessed since they behave differently in both standard tests and in wear to items made from steel. For example, steel caps will usually permanently deform on impact whereas a plastic cap might spring back to shape but suffer cracking, giving the impression that it is undamaged. It could however fail badly should it suffer a second similar impact which the wearer might well not expect to happen. It has therefore proved necessary to create new tests that take these factors into consideration.

Steel caps - the classic hardened steel toe cap does however remain the most widely used and manufacturing methods have changed little over the years. A cap is blanked, formed and flanged from annealed carbon steel using deep drawing presses. It is then furnace hardened to various standard specifications followed by painting to prevent corrosion. Production is generally fully automated and the investment in tooling required to produce the diversity of shapes now required to meet all the varying performance standards is obviously considerable.

Working to fine tolerances is also important and technology now exists where special steels which accept hardening without deformation are used to produce caps with dimensional tolerances of less than 0.6mm. This results in caps that are ideal for injection moulded footwear as their precise 90° flange angle avoids production problems often encountered with traditionally made caps.

Aluminium - aluminium caps have all the strengths and properties of a steel cap but with weight savings of anything up to 50%. The main reason behind the demand for aluminium, however, is that it is non-magnetic and, as previously remarked, does not interfere with security scanning at airports and similar locations. Foot comfort is also said to be enhanced because there is less of a cold feel within the boot or shoe. An aluminium cap is more expensive and, if it is thicker than the conventional steel cap, can cause problems in footwear manufacture.

Composites - these use a special non-metallic composite material which is up to 40% lighter than steel, non-magnetic, non-corrosive, non-conductive and retains heat 50% longer. They usually have similar if not the same dimensions as a steel cap which means no sole mould modifications are needed although some alteration to lasts may be found necessary. They also recover shape after any impact and provide space to withdraw the foot more easily.

Synthetics - various materials have been tried and, of these, the most effective so far have been thermo-setting glass fibre, polycarbonate and Kevlar. Each has its own advantages and drawbacks, not the least of which is cost.

PENETRATION RESISTANT INSERTS

While more industrial foot injuries are caused by crushing from above, there is also the risk of penetration from below and, although the soles of industrial boots are generally extremely tough and substantial, they do not



Steel safety toe caps.

CREDIT: ESJOT GOLDBERG

always provide sufficient protection.

The traditional solution has been to place a shaped thin steel plate between the sole and the insole. This offers excellent protection but, for obvious reasons, is necessarily limited to the area within the inner edge of the lasted upper. It also adds yet more weight as well as reducing flexibility. It was also found to be less easy to apply to the increasingly widespread use of the sewn-in sock method of construction referred to earlier.

The answer appeared in a clever composite material produced by combining para-aramidic fibres (Kevlar) with appropriate coatings. Originally conceived for use as protective panels in body armour and chain-saw protection pads for footwear and clothing, it was but a short step to underfoot protection.

A special ceramic coating is used to compact and reinforce layers of hi-tenacity high density weave polyamide fabric (SS) and Kevlar fabric (BS). The result is a flexible board which can be used as a non-metallic insert in safety footwear. As well as performing to the required standards, it is relatively lightweight, flexible, has no thermal conductivity and is non-reactive with metal detectors. It can also be cut to shape using single layer die-cut shearing and is eminently suitable for use with sewn-in sock where it can be made to follow just inside the feather edge of the lasted upper and so provide the maximum extent of protection possible.

The increasing use of lighter weight and more fashionably styled safety footwear for men and, more

particularly, women in the workplace has been a further spur to the development of both caps and inserts made from non-metallic materials.

SLIP RESISTANCE

Soles and soling materials for safety footwear must be tested for non-cleated thickness, tear strength and resistance to abrasion, flexing, hydrolysis, chemicals and slip. The latter is, in fact, the major cause of all industrial accidents involving footwear. It has received special attention in recent years although it has proved difficult to reach a consensus on the best test method to use.

A provisional method was proposed as ENV 13287:2002 (ENVs are experimental methods for consideration by CEN countries but without the weight of a full EN) and then refined to become the current EN 13287 standard in operation today as part of the overall European EN ISO 20344 series. The procedure used is similar in many ways to the established SATRA TM144 test for slip resistance.

The method calls for two flooring surfaces (steel and a pressed ceramic tile), two contaminants (glycerol and water containing the wetting agent sodium lauryl sulphate or NaLS) and three slip modes. Other surfaces can of course be used outside the official method (ice being a good example) and test conditions varied according to the size of the footwear (a higher downwards force being used on bigger sizes).

Needless to say, because safety footwear has to comply with such strict performance standards, it must necessarily be subjected to an immense amount of testing of materials, components and the finished product. This can be an expensive process, so it is as well to have an appreciation of just what can be expected of all the materials and components involved.

UPPER LEATHERS

Increasingly tough safety standards have also made the selection and testing of upper leathers a vital consideration for safety footwear producers. An important factor to bear in mind is that differences can exist between the properties of a leather when it leaves the tannery and when it is taken from completed footwear where it has become part of a three-dimensional construction, possibly involving several materials. In this instance, leather properties may be influenced by conditions imposed during construction by the other materials involved or the design itself.

While upper, tongue and lining leathers have different requirements, they share essentially the same test methods. These are tensile strength, tear strength, breathability, water vapour permeability (WVP), water vapour absorption (WVA), water vapour coefficient (WVC) and pH value to determine acidity (too low and it can cause skin irritation).

Testing for water resistance is optional for safety footwear but mandatory for specialist applications. A further option for water resistant footwear is the trough test which determines the degree of water penetration after walking 1,000 paces in a trough with the top of the shoes' soles 5mm below the surface of the water and upper seams



Assessing slip resistance on a ceramic tile.

CREDIT: SATRA



Testing resistance to chainsaws.

CREDIT: SATRA

suitably sealed.

These tests set a base level for leathers used in general safety, protective and occupational footwear for professional use. There are other more specialised areas of high risk that demand additional protection to the upper part of the foot and lower leg areas. These call for more brutal tests involving the complete boot or shoe.

Cut resistance for occupations such as glass manufacture and where additional reinforcement such as ballistic nylon, rubber strip, thin wire mesh or heavy substance leather is part of the overall construction is one such example.

Chainsaw resistance speaks for itself and, once again, the footwear will normally incorporate protective materials such as ballistic nylon or rubber.

In addition to mandatory safety requirements, two additional tests are set for upper leathers in regard to thermal behaviour as experienced by fire fighters. Radiant heat measures serious heat damage extending from the outer surface of the upper to the inner surface of the boot and the flame test assesses the actual flammability of the upper leather. Foundry boots also require a molten metal test in addition to mandatory upper material standards in order to check resistance to penetration should any molten metal be accidentally poured over a wearer's foot.

FOOTBEDS

These are often included in safety footwear to help improve underfoot comfort and come in varying types, thicknesses and densities. They also have the potential to adversely affect the performance of the footwear concerned. Potential problem areas include compromising the internal clearance under a safety toecap enough to cause the footwear to fail impact and compression resistance tests, energy absorption of the seat region and the optional electrical resistance tests for antistatic and conductive footwear. Indeed, footbeds fitted in shoes with specific electrical resistance requirements must be strictly controlled by the manufacturer during production.

Thermal behaviour is a further optional test that can be affected by the removal of a footbed, as are tests for both heat and cold insulation. Removing the footbed from a thermally-insulated boot or shoe can seriously reduce its thermal insulating properties and possibly create an increased risk of injury. For these reasons all footwear must be tested in an 'as-supplied' condition. Furthermore, to ensure correct protection is maintained throughout the life of the footwear, footbeds should never be removed or replaced without first consulting the supplier or manufacturer.

The whole subject of standards for safety footwear and the testing necessary to achieve compliance is extremely complex. Any organisation involved with either the sourcing or manufacturing of safety footwear is well advised to employ a manager with specialist knowledge to oversee this vital aspect of its business. If it cannot afford such a person, it must seek the advice of a recognised testing such as SATRA which will be able to offer the correct advice as well as conduct all necessary testing organisation. 

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