CREDIT: V12 FOOTWEAR

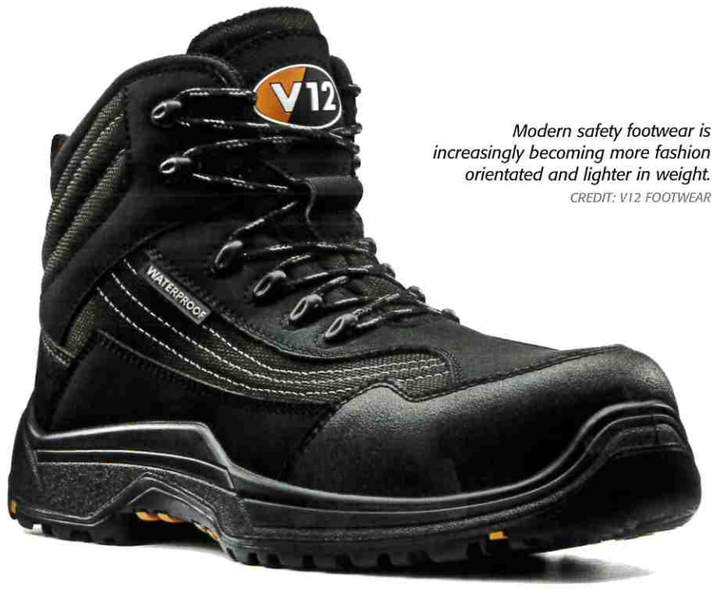
Steel or composite?

An awareness of the importance of safety footwear continues to grow. The global market was estimated by Research & Markets at $2.37 billion in 2012, since when it has been rising at an annual CAGR, compound annual growth rate, of 8.5% and is expected to reach some $4.3 billion next year. In terms of the number of pairs being produced, total output this year is expected to approach 400 million of which Asia will have made around 58%. It is therefore a significant sector in the footwear market.

There is, however, still no single global safety footwear standard. Instead, there are three main sets which, between them, are accepted by a majority of countries. EN ISO 20344 produced by the Comité Européen de Normalisation /International Organisation for Standardisation (CEN/ISO) is probably the foremost of these. They are recognised by the European Commission as possessing the presumption of conformity to the Personal Protective Equipment (PPE) 89/686/EEC Directive and are the most commonly used method of demonstrating a product's compliance with it.

These standards have either been wholly adopted or used as a basis from which countries have developed their own standards, as is the case of Australia and New Zealand. Countries adopting EN ISO, although outside the European Union, may still be able to demonstrate that their footwear meets the same standards as those supplied within it. They would not, however, be able to obtain the CE mark which forms a part of the certification process against the PPE Directive.

America and Canada have their own standards. The American Society for Testing and Materials (ASTM) and Canadian Standards Association (CSA) have both produced safety footwear standards which, while not quite the same, do share similarities. These standards take a less comprehensive approach than EN ISO which contains assessments of key safety features as well as performance requirements for the complete shoe and its components.



Modern safety footwear is increasingly becoming more fashion orientated and lighter in weight.
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In view of the global nature of the supply chain and differing the standards involved, consumers can be confused as to how effective some safety footwear actually is. This applies especially to the different safety toe caps available, with the main question being "are composite caps as safe as steel?" The simple fact is that both metal and non-metal caps, including thermoplastic and fibreglass, can all meet required standards when made to the right specification. Unfortunately, there can be instances where they do not offer the level of protection claimed on the certificate due to inconsistency and poor quality control.

SAFETY TOECAPS

When safety toecaps 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 popular, especially where weight is an issue or for situations where steel might cause problems in regard to metal detectors. Components of this type are more difficult to assess as they behave differently in both standard tests and wear to those made from steel. For example, on impact steel caps will usually permanently deform. A synthetic cap, on the other hand, may spring back to shape but suffer cracking, giving the impression 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.

METALLIC TOE CAPS

The classic hardened steel cap remains the most widely used globally and is produced from strip rolls of high quality carbon steel of around 1.8mm in thickness. Blanks are fed into a deep drawing press which applies around 80 tonnes of pressure to create a dome which is then cut in half producing one pair of toecaps, left and right. A flange is normally then formed around the lower edge of the cap to provide support under impact.

To provide extra hardness, the caps are fed through a high temperature furnace and then rapidly cooled, before finally being tumbled to remove any remaining roughness and then given an anti-corrosion coating. Production is generally fully automated and the investment in tooling needed to produce the diversity of shapes now required to meet all the varying performance standards is therefore considerable. *Figure 1* demonstrates their advantages and disadvantages.

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.

Figure 1: Advantages and disadvantages of steel caps.

Figure 2: Advantages and disadvantages of thermoplastic caps.

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NON-METALLIC TOECAPS

These are becoming increasingly popular due to the benefits they offer. They can be made from a number of materials including fibreglass, polycarbonate, thermoplastic and composite reinforced thermoplastics. Their main drawback is that they usually require a greater 'wall thickness' in order to provide the same impact and compression resistance as steel and, as a result, look more bulky in the shoe. Their big advantage, however, is that they are the most lightweight form of cap and help reduce fatigue in the workplace. There are two main types: thermoplastic and composite.

Thermoplastic caps – these are injection moulded in PC/PBT (polycarbonate/polybutylene terephthalate) that is often used for vehicle bumpers and similar mouldings due to its high impact strength. The manufacturing process is simple and themoplastic caps perform well *(Figure 2)*.

Composite caps – these are designed to flex under impact, spreading the load to the front and side walls. They quickly regain up to 80% of their original height after impact, making it easier to remove the foot in the event of an accident. They are good in environments where steel is less suitable, such as where metal detecting and security equipment is in use, explosive or flammable areas where there is a sparking risk from an exposed toe cap and hot or cold temperatures due to their superior thermal insulation compared to steel.

Figure 3: Advantages and disadvantages of composite caps.

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They are also more complex to manufacture and consequently more expensive. They can be composed of a variety of materials but fibreglass is considered by many to be the best. They are made by impregnating sheets of fibreglass with resins that have been softened in an oven. The material is then sliced into four pieces which are placed on top of each other and folded into an S shape of 12 layers. The resulting material is placed in a hydraulic press which reduces its thickness down to 2-3mm. Blanks are then cut out, formed into shape and cured at 200°C before being trimmed to produce the finished cap *(Figure 3)*.

TESTING

All toecap protection works on the 'defended space' principle where the cap provides a shell in which the toes are protected from damage. Safety cap testing is carried out in accordance with standard EN 20345:2011 using test method EN 12568:2010. Although caps may be tested alone, it is important that the whole shoe is assessed as the effectiveness of the cap will greatly depend on satisfactory positioning and the degree of support provided by the sole. Safety caps need support and poor soling materials, pattern design and/or shoemaking can greatly reduce the effectiveness of even the strongest ones.

First, the dimensions of the caps are checked before two main tests are carried out: impact and compression. These are performed in exactly the same way for both metallic and non-metallic caps with the only difference being that non-metallic ones undergo chemical and thermal ageing prior to the test and metal ones require a corrosion test. For impact, a wedge-shaped striker is dropped onto the cap under which a soft cylinder of modelling clay has been placed. The height of the clay after the impact is then measured to assess whether the clearance meets the criteria set out. The compression test is similar and creates a crushing effect using a calibrated machine, again using a clay cylinder to measure the result *(Figure 4)*.

EN ISO, ASTM and CSA standards all contain methods and requirements for impact resistance of footwear incorporating toecap protection which may be produced from either metallic or non-metallic materials. The principle of these tests is the same, with a toe section test sample of the complete shoe being assessed for its resistance to impact by a falling mass. EN ISO and ASTM standards contain test

Figure 4: Impact and compression test values for EN 12568:2010

Impact resistance	200 Joules
Compression resistance	15,000 Newtons

methods to assess compression resistance in footwear containing safety caps against accidental compression damage; the CSA standard does not. In this case, a section of the shoe comprising the whole toe region is cut away just behind the cap and compressed between two flat horizontal plates until a pre-set load is reached.

Accordingly, the most appropriate series of standards for a manufacturer or distributor to test against and be in accordance with, will depend on where in the world the footwear is intended to be sold. The range of requirements it needs to meet will depend on the claims being made about it, so both manufacturers and distributors need to test the safety caps in their shoes thoroughly and regularly to ensure they are up to the mark and that they are not risking potentially costly claims for faulty products.

In conclusion, can it therefore be said that non-metallic safety caps are as safe as those made from steel? Based on all the evidence to date and provided that they can be shown to meet all the standards necessary then, yes, they would appear to be so. There are other factors that also come into play, one of which is weight. With ever increasing health and safety legislation leading to the use of safety footwear in more diverse working environments and the increasing number of women now wearing safety footwear as a consequence, weight is an increasingly important consideration and composite safety caps clearly have an advantage in this respect.

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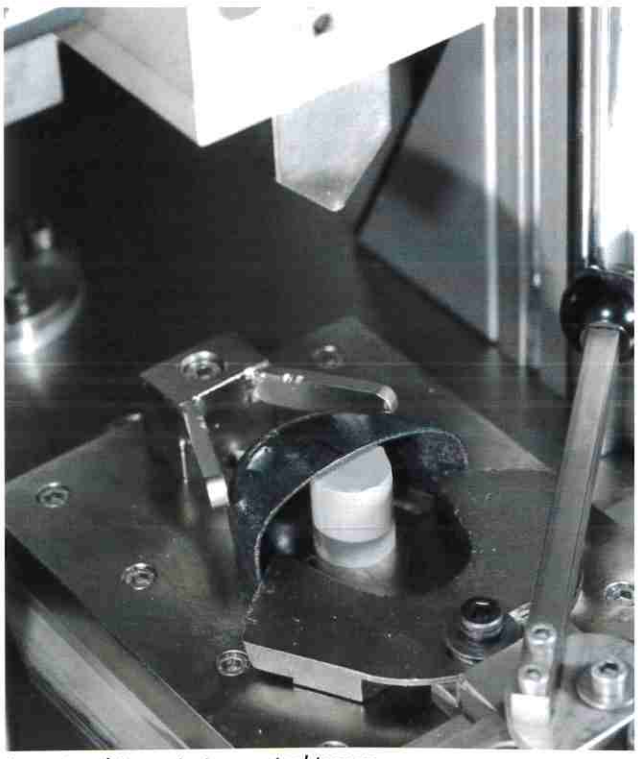

Impact resistance test on a steel toecap.

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