Kassel Regional Administration

Hessen Equipment Testing Office

Final report

Focus initiative 2010:

PPE,

Penetration resistance of safety footwear

Department 35.3

Centre for Product Safety and Hazardous Substances

Hessen Equipment Testing Office

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1. Introduction and description of the problem

Hessen Equipment Testing Office carried out penetration resistance tests on safety footwear in 2009. Because of shortcomings identified during these tests and repeated instances of people sustaining penetration injuries to their feet, despite wearing Category 3 safety footwear, the market surveillance authorities in Hessen decided that the focus initiative should be pursued further.

As a result, twenty different Category 3 safety shoes were tested to determine whether they complied with the relevant standard. They also underwent more extensive testing geared to actual conditions of use.

Safety shoes with metal inserts and safety shoes with non-metal inserts were compared and assessed. Unlike metal inserts, which involve a metal plate being inserted into the sole to make it pierce-resistant, non-metal inserts are made of materials such as thermoplastic polyamide laminate which are very flexible and have the characteristics of a textile (Image 1). These non-metal inserts are often described as Kevlar soles.

The accident statistics produced by the umbrella organisation for accident insurers in Germany [*Deutsche Gesetzliche Unfallversicherung*] show a reduction in the number of notifiable workplace accidents involving foot injuries between 2000 and 2005; by contrast, there was an increase in the number of penetration injuries to feet during the same period [1]. One reason for this could be the non-metal inserts which had recently been developed. The expressions "penetration resistant" and "penetration resistance" therefore do not appear to reflect the requirements which users/consumers would assume. Under DIN EN ISO 20344 [2], a safety shoe is considered to be penetration resistant if a force of 1100N is required to penetrate the sole using a test nail with a diameter of 4.5 mm. This involves forcing the test nail at a speed of 10 mm/min through the lower part of the shoe from four different points in the sole.

1100N corresponds to a mass of approximately 110 kg, or the force of a 90 kg person taking a step while walking [1]. It is clear that not only the mass used during the test but also the speed at which the nail is forced through the shoe and the diameter of the test nail do not reflect actual conditions.

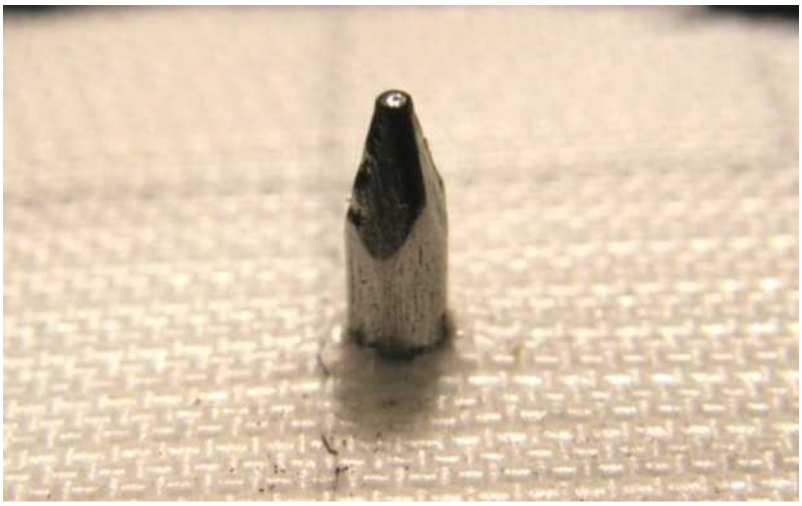

Image 1: Nail in non-metal insert

2. Legal basis

The following documents were taken as the basis for assessing whether the products were fit to be placed on the market:

- Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment

- Act on Technical Equipment and Consumer Products (Equipment and Product Safety Act / *Geräte- und Produktsicherheitsgesetz – GPSG*)

- Eighth Regulation on the Equipment and Product Safety Act (Regulation on the placing on the market of personal protective equipment) (*8. GPSGV*)

- DIN EN ISO 20345: 2007-12 Personal protective equipment – Safety footwear

- DIN EN ISO 20344: 2007-11 Personal protective equipment – Test methods for footwear

3. Study

Following a number of preliminary tests, more than 250 measurements were taken from 25 pairs of Category S3 safety footwear and the findings were evaluated. The study involved two stages.

3.1. Testing of the safety footwear in accordance with § 8(7) GPSG

The Category S3 safety footwear first underwent partial testing in accordance with DIN EN ISO 20344. The following were tested:

- Labelling and information which should be enclosed

- Construction and size of penetration resistant insert

- Determination of penetration force

The samples made available for testing were taken by the regional administrations, which are the bodies responsible for the surveillance authorities in Hessen, from trade outlets, namely building supply stores and specialist outlets.

Testing was carried out by the accredited Hessen Equipment Testing Office in Kassel. A detailed test report is available for each shoe.

3.2. Determination of penetration forces using thin nails

In a further test, penetration forces were determined using thin test nails. The maximum force was determined by forcing nails of three different diameters (2.8 mm, 3.1 mm, 4.5 mm) through the sole at defined points at a speed of 10 mm/min. Apart from the test nail, the test design complied with the requirements of test standard DIN EN ISO 20344.

4. Results

4.1. Results of the test to determine compliance with the standard

Of the 20 safety shoes which were examined, 12 were found to have shortcomings. This corresponds to a shortcoming rate of 60%. On closer examination, however, it would appear that most of the shortcomings concerned formalities, e.g. the labelling or instructions for use were often inadequate.

Only 5% of the shoes were found to have safety-related shortcomings.

40% without shortcomings, 60% with shortcomings:

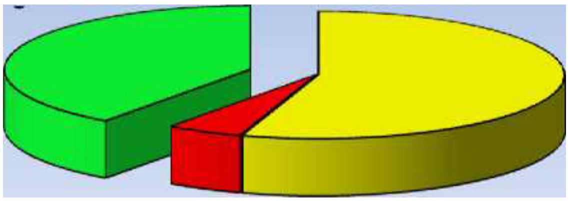

Diagram 1: Shortcoming rate of the safety shoes examined

With regard to penetration forces, all the shoes, apart from one, met the requirements of the standard. The penetration forces determined during testing are shown in Diagram 2. Samples 1-9 had a metal insert within the sole, while samples 10-20 had a non-metal insert on the inner side of the shoe.

When the shoes were tested in accordance with the standard the penetration forces for the shoes with non-metal inserts tended to be higher than for the shoes with steel inserts. Only one shoe failed to reach the force of 1100N indicated in the standard [3].

Key to graphic on p. 6 of original text	
Original text	**Translation**
Durchtrittskraft [N]	Penetration force [N]
Mittelwert	Mean value
Norm-Sollwert	Reference value indicted in the standard
Schuh mit Metalleinlage	Shoe with metal insert
Schuh mit Nichtmetalleinlage	Shoe with non-metal insert

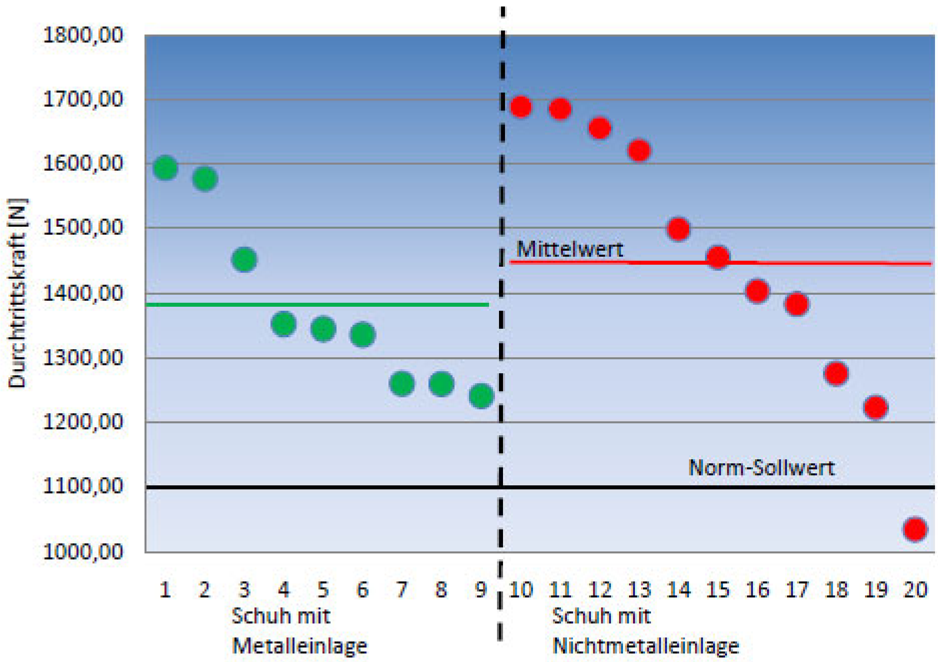

Diagram 2: Penetration forces during testing in accordance with the standard. Samples 1-9 have a metal insert, samples 10-20 non-metal penetration protection.

4.2. Results when thin nails are used

All the shoes underwent testing to determine penetration force when using a thin test nail (2.8 mm).

The results were remarkable. Shoes with non-metal inserts were found to offer over 65% less penetration protection when a thin test nail was used than when tested in accordance with the standard. In other words, while the penetration forces for shoes with non-metal inserts were originally found to have a mean value of 1500N, the protective function of the shoe fell to around 700N when a thin nail was used. This means that the shoes **do not provide sufficient protective effect** for a person who weighs around 55 kg and is walking. All the values determined for the shoes with non-metal inserts were much lower than the required penetration force of 1100N.

Key to graphic on p. 7 of original text	
Original text	**Translation**
Durchtrittskraft	Penetration force
Normsollwert	Reference value indicted in the standard
Schuhe mit Metalleinlage	Shoes with metal inserts
Schuhe mit Nichtmetalleinlage	Shoes with non-metal inserts

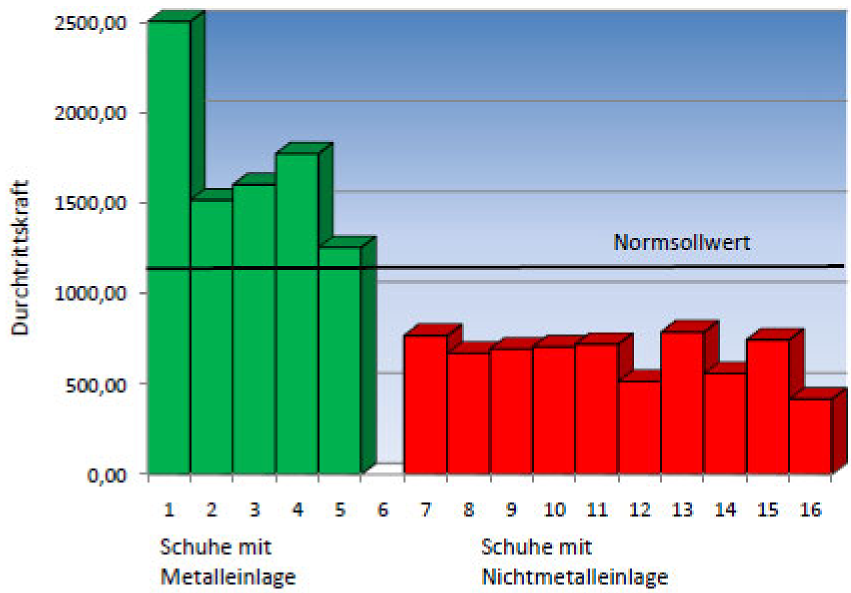

Diagram 3: Penetration forces with 2.8 mm test nail

The same test was carried out on shoes with metal inserts. It is readily apparent that the shoes offer the same level of protection when a thin nail is used as when the test is carried out in accordance with the standard. All the penetration forces recorded during the test were much higher than for shoes with non-metal inserts (Diagram 3).

A further test was conducted to determine to what extent the diameter of the nail had an effect on the type of insert used in the shoe.

For shoes with non-metal inserts, the results clearly show that the protective effect of the insert diminishes as the diameter of the test nail becomes smaller. This means that the fabric of non-metal inserts can theoretically be penetrated even by thin needles. Diagram 4 shows the penetration force required for test nails of various diameters.

By contrast, in the case of shoes with non-metal inserts, it was found that considerable force was needed to push even thin test nails through the inserts and that protective function was not compromised. Very thin nails cannot be forced through the metal inserts, even with the application of considerable force, as the nails break before they can be forced through.

Key to graphic on p. 8 of original text	
Original text	**Translation**
Durchtrittskraft [N]	Penetration force [N]
Metalleinlage	Metal insert
Nichtmetalleinlage	Non-metal insert
Normsollwert	Reference value indicted in the standard
Durchmesser Prüfnagel [mm]	Diameter of test nail [mm]

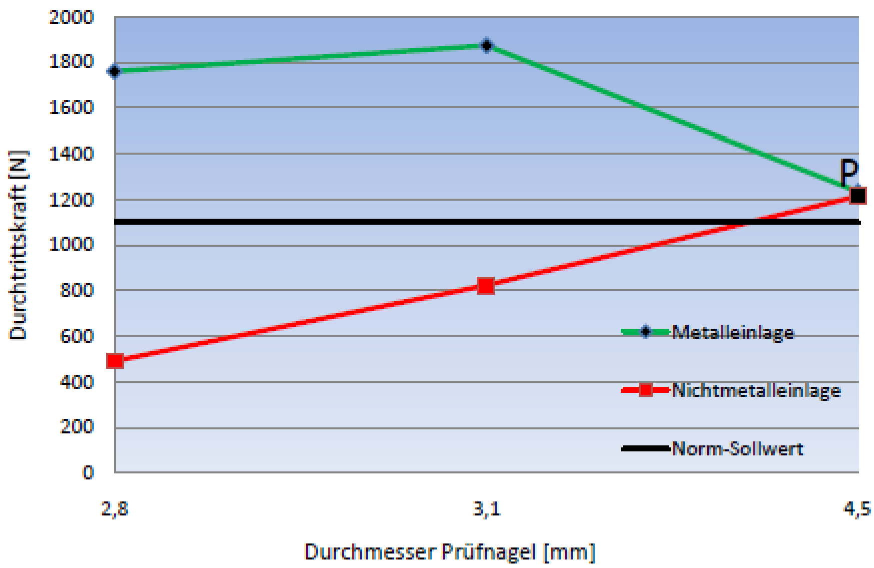

Diagram 4: Penetration force depending on the diameter of the test nail. At test point **P**, the same penetration force was measured on both soles in accordance with the requirements of the standard

5. Summary and conclusion

When testing was carried out in accordance with the standard, more than 50% of the shoes did not meet the requirements laid down in the standard. The main shortcomings involved the shoes not being labelled, or being incorrectly labelled, and there was often no indication of the manufacturer, the type of shoe or the test standard. 5% of the shoes had safety-related shortcomings, one shoe failed to achieve the requisite penetration force and a further two pairs had minor shortcomings regarding the construction of the sole. When all the shoes in the study are viewed as a whole, the outcome of the test to determine compliance with the standard initially appears to be positive.

In reality, however, the situation is different. The shoes with the more modern non-metal inserts have distinct shortcomings, especially when tested using thin nails.

When non-metal inserts are used, it is clear that penetration forces fall significantly as the diameter of the nail is reduced. This means, for instance, that the sole of the shoe is likely to be penetrated by a steel nail with a diameter of 2.8 mm when worn by a person weighing no more than 55 kg. The shoe therefore certainly cannot be described as penetration resistant.

By contrast, the shoes with metal inserts clearly show a more consistent protective effect. Given that both types of shoe are advertised as being penetration resistant, the tests to check compliance with the standard should be corrected in such a way that they can be used to prove that <u>all</u> shoes are safe in practice.

The tests showed that shoes with metal inserts had a much higher penetration resistance when tested with thin objects. Although both types of shoe provide a reasonable standard of penetration protection irrespective of the material used, not all the shoes are penetration resistant, even if they have passed the type approval test. In case of doubt and as long as the existing test procedures are not capable of proving the actual protective effect of the shoes, it is recommended that tried-and-tested safety shoes with steel inserts be used.

[1] *Sicher ist sicher – Arbeitsschutz aktuell* [Better safe than sorry – Health and safety in the workplace today] 7-8, 2008

[2] DIN EN ISO 20344, November 2007:

Personal protective equipment – Test methods for footwear

Beuth Verlag GmbH, 10772 Berlin

[3] DIN EN ISO 20345, December 2007:

Personal protective equipment – Safety footwear

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