IGF Project 17741N

Nail Penetration Test

In mid-2015 PFI concluded a research project entitled «Optimisation of Penetration-resistant Inserts in Safety Shoes». The goal of the project was to optimise the penetration resistance of inserts for safety shoes of category S3. An associated task was to critically scrutinise the test criteria for penetration resistance as set out in the currently valid standards for safety shoes and penetration resistant midsoles.

Research work began with the testing of safety shoes and inserts from various manufacturers with regard to their penetration resistance as laid down in the existing standards DIN EN 12568 and DIN EN 20345. The overwhelming majority of the products passed these tests; only a few failed.

Critical scrutiny of the penetration resistance standards yielded the following results:

- **Determination of a meaningful test velocity**
  Evaluation of gait analyses afforded a vertical impact velocity of about 850 mm/min. In current tests on safety shoes and penetration-resistant inserts according to the valid standard, a test nail is pushed into the test piece at a velocity of 10 mm/min ± 3 mm/min. A considerable discrepancy thus exists between the real-life vertical impact velocity and the currently valid test velocity.

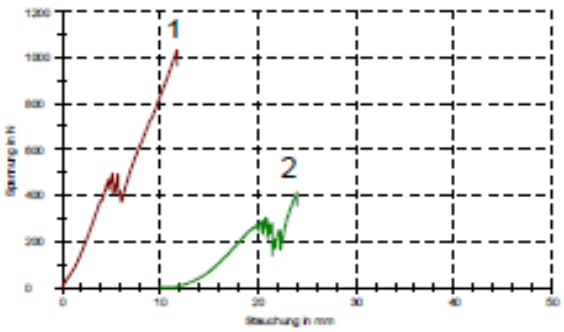
- **Effect of test velocity on nail penetration**

  Measurements failed to provide unequivocal information about the effect of test velocity on the test result. Some inserts showed almost the same test results for a test velocity of 10 mm/min as for 800 mm/min while others were more readily penetrated at higher velocities.

- **Influence of the test nail on the test result**
  All the tested inserts were found to comply with the current standard with regard to penetration resistance on use of test nails up to a diameter of 3.5 mm and thus to resist penetration at a force of up to 1100 N. However, a force of 800 N is sufficient to penetrate an insert at test nail diameters of less than 2.5 mm.

New materials were also investigated in the course of the project and their suitability for preventing test nail penetration was examined. Among all the materials tested, Vectran fabric offered the greatest resistance to penetration by a test nail. Examination of the penetration zone after the test showed that not a single Vectran fibre was torn or destroyed; instead, the fibres were merely pushed aside.

To establish whether it is advisable to bond or glue several layers of Vectran fabric together when examining its suitability for preventing nail penetration, six layers of fabric were bonded together with the aid of a thermal adhesive in powder form and the behaviour of the composite material compared with that of six non-bonded layers of fabric.



Red curve (1): With adhesive; penetration at 493 N
Green curve (2): Without adhesive; penetration at 250 N

Figure: Penetration testing with and without thermal adhesive (Vectran fabric)

The figure shows the force required for the test nail to penetrate the bonded layers of fabric. Compared to the non-bonded layers, almost twice the force is necessary to penetrate the bonded layers.

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The complete final report can be ordered from

Dipl.- Ing. (FH) Thorsten Knierim
Research and Development Technical Department
Tel.: +49 6331 2490 47
E-Mail: thorsten.knierim@pfi-germany.de