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Report No. 460,353 /2

Assignment: Impact tests on safety strips for protruding reinforcement bars

Object of investigation: Safety strips with the brand name NEVO SAFE-PLUS®
Customer reference:
Your order dated: 12/03/2012
Receipt of test objects: 30/03/2012 and 27/04/2012 (safety strips)
Test conducted on: 30/03/2012 and 27/04/2012
Number of pages: 8
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Distribution: 3 copies to addressee
Archiving: The test objects were collected by the Ordering Party.

Summary

The NEVO SAFE-PLUS® safety strip has been developed for use on building sites. It is clipped on to the protruding ends of reinforcement bars left standing as a transition to further layers of concrete, in order to prevent a falling construction worker from being impaled on them. The objective of the present investigation was to ascertain whether the safety strip, when mounted on vertical reinforcement bars with diameters of 8, 10, 12, 14 and 16 mm and at the spacing commonly used in actual practice, can withstand the impact of a compact, 100 kg sandbag dropped centrally from a height of 3 m.

In all tests, the construction worker – simulated by the sandbag – was protected from being impaled. The safety strips that were tested met all the defined requirements to the full.

Dübendorf, 09/05/2012	Swiss Federal Material Testing and Research Institute
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Note: The results of the investigation are applicable only to the object tested. Any use of the report for advertising purposes, even the mere reference to it and publication of excerpts of it, must be approved by Empa (see info sheet). Report and documentation will be archived for 10 years.

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1 ASSIGNMENT

The NEVOSAFE-PLUS® safety strip has been developed for use on building sites. It is clipped on to the protruding ends of reinforcement bars left standing as a transition to further layers of concrete, in order to prevent a falling construction worker from being impaled on them. The objective of the present investigation was to verify the protective effect against impalement of the safety strips provided by the Ordering Party under the framework conditions defined by the Ordering Party.

2 TEST CONDITIONS AND TEST SET-UP

The test set-up is shown in Fig. 1. The main framework conditions were:

- Mass of sandbag: Nominally $m = 100$ kg (actually approx. 102 kg), checked with the “Dynafor” digital scales (Log. No. 121-25.016). The compact unit was formed using a strong plastic bag and bracing straps running crosswise.
- Nominal dimensions of sandbag (length x width x height; rounded mean values):
 - For reinforcement bars $\varnothing 8 - 14$ mm: 600 mm x 600 mm x 300 mm, see Fig. 4/d
 - For reinforcement bars $\varnothing 16$ mm: 600 mm x 400 mm x 350 mm, see Fig. 2/e
- Alignment of sandbag to safety strip: Contact on impact close to the long axis of symmetry of the bottom of the bag (slight scatter due to horizontal offset and rotation of the sandbag during free fall).
- Distance of free fall of sandbag before impact: Nominally 3 m, actually 3.01 – 3.03 m. The distance of the drop was checked with a 3-meter wooden lath before each test.
- Triggering of sandbag from suspended rest: Sudden, through opening of the three-jaw chuck in which the retaining pin was clamped.
- Arrangement of the reinforcement bars: Vertically, all on approximately the same vertical plane; lower ends either screwed into threaded sleeves poured into concrete or inserted in holes drilled in concrete. In principle, the attachment of the reinforcement bars in the concrete block can be considered as stiff against bending (high buckling load on the reinforcement bars).
- Diameter of reinforcement bars: 8, 10, 12, 14 and 16 mm.
- Number of reinforcement bars: 4 or 5, as defined in Table 1.
- Distance between reinforcement bars (spacing): 150 mm to 300 mm, as defined in Table 1. The spacing was specified by the Ordering Party, based on that normally used in actual practice. In the case of reinforcement bars with a diameter of 14 mm, one test was carried out with a rather smaller than average spacing of 150 mm, and three tests with a conservatively exaggerated spacing of 300 mm. (According to the Ordering Party, the typical spacing for 14 mm \varnothing in actual practice is 200 mm.)
- Exposed length of reinforcement bars: 450 – 670 mm, as defined in Table 1.
- Number of impact tests per bar diameter: 3 to 10, as defined in Table 1, defined on the basis of the following test strategy: Should the steel inset in the protective strip not rupture after the first 3 tests at a given reinforcement-bar diameter, no further tests are carried out (obvious significant safety reserves).
- Form of ends of reinforcement bars: Slightly oblique, sharp-edged cut surfaces, Fig. 3 (typical “worst case” in actual practice). Reinforcement bars that had been significantly bent by the impact were replaced before the next test (Table 2).
- Ambient temperature: approx. 23°C.

Diameter of Bars Ø [mm]	Number of Bars [-]	Nominal Spacing of Bars [mm]	Nominal Length of Bars [mm]	Number of Tests
8	5	150	450	3
10	5	150	500	3
12	4	200	670	3
14	5	150	650	1
	3	300	650	3
16	4	200	520	10

Bars: Reinforcement bars

Table 1: Test parameters, which varied according to the diameter of the reinforcement bars.

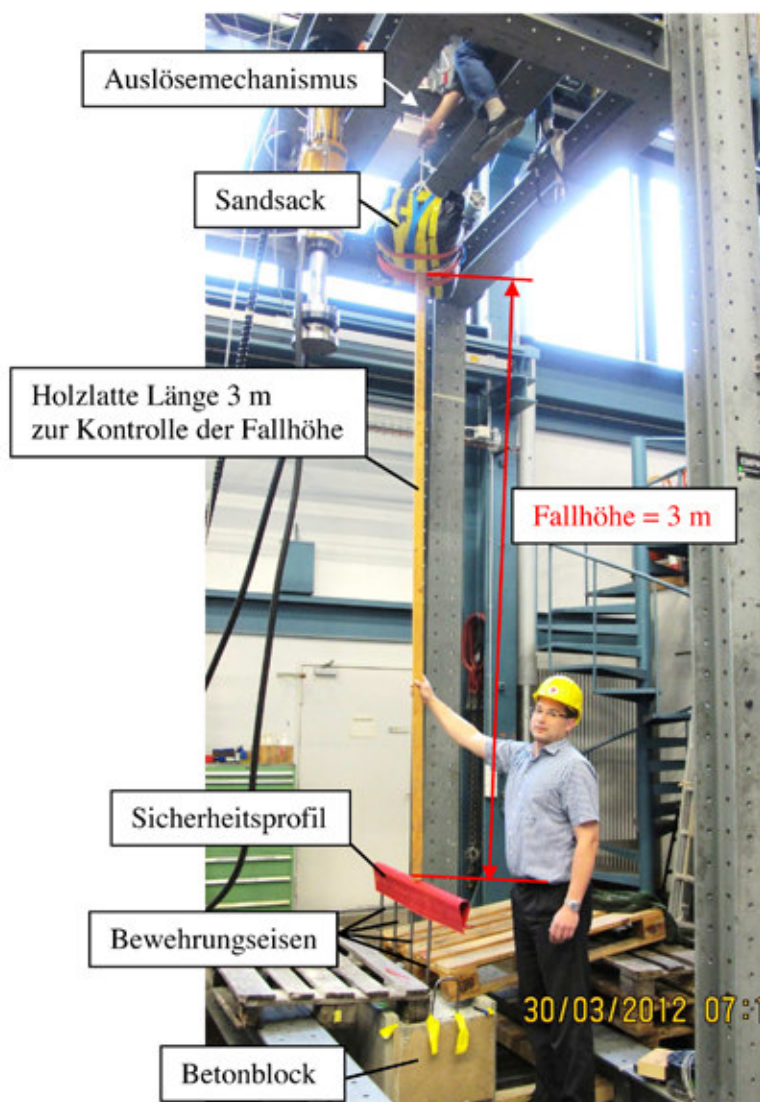


Fig. 1: Test set-up. Photo taken while checking the drop height of the sar

[Legend for photo:]

Auslösemechanismus: Release mechanism

Sandsack: Sandbag

Holzlatte Länge 3 m zur Kontrolle der Fallhöhe: 3 meter wood lath for checking drop height

Fallhöhe = 3 m: Drop height = 3 m

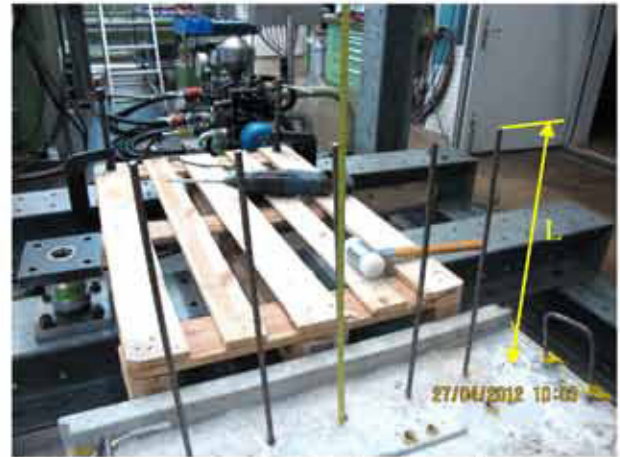
Sicherheitsprofil: Safety strip

Bewehrungseisen: Reinforcement bars

Betonblock: Concrete block



a) Arrangement of reinforcing bars, \varnothing 8 mm
 $n=5$, $a=150$ mm, $L=450$ mm



b) Arrangement of reinforcing bars, \varnothing 10 mm
 $n=5$, $a=150$ mm, $L=500$ mm



c) Arrangement of reinforcing bars, \varnothing 12 mm
 $n=4$, $a=200$ mm, $L=670$ mm



d) Arrangement of reinforcing bars, \varnothing 14 mm
for V01-14, $n=5$, $a=150$ mm, $L=650$ mm



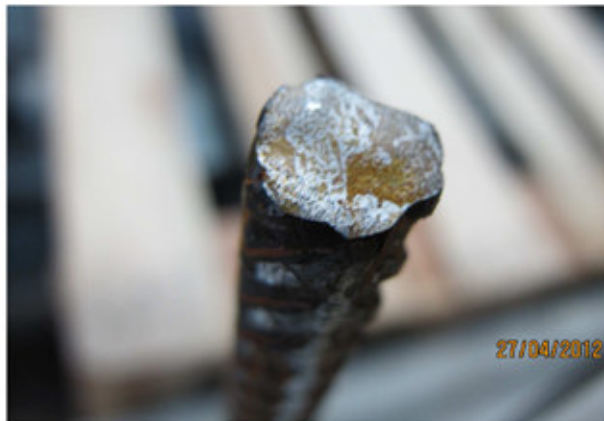
[Legend:
„deaktivierte“ Bewehrungs-eisen: “deactivated”
reinforcement bars/
e) Arrangement of reinforcing bars, \varnothing 14 mm
for V02/03/04-14, $n=3$, $a=300$ mm, $L=650$ mm



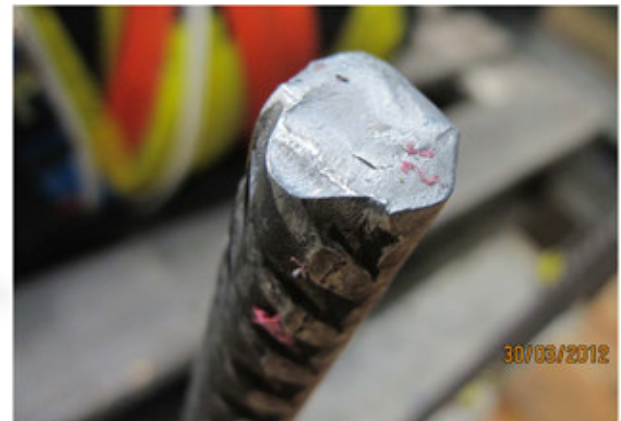
[Legend:
Sandsack: Sandbag/
f) Arrangement of reinforcing bars, \varnothing 16 mm
 $n=4$, $a=200$ mm, $L=520$ mm

n: Number a: Nominal spacing L: Free length

Fig. 2: Arrangement of reinforcement bars according to diameter.



a) Reinforcing bars, $\varnothing 10$ mm



b) Reinforcing bars, $\varnothing 16$ mm
(Photo taken after 10 impact tests)

Fig. 3: Two typical examples of sharp-edged, cut ends of reinforcement bars

3 TEST MATERIALS

The Ordering Party provided the following materials:

- Safety strips 1 m long with steel insets 1.5 mm thick
- Prepared reinforcement bars (cut at the top end)
- Materials for making up the sandbag (except for the bracing straps)
- Concrete block for anchoring the reinforcement bars

4 ORGANISATIONAL INFORMATION

The tests took place on 30/03/2012 and 27/04/2012 in the metal shed of the Empa company in Dübendorf. The following persons were present:

- Mr. F. Kiener, Ordering Party (first day of testing)
- Mr. P. Schuler, Ordering Party (second day of testing)
- Mr. H. Simon, Ordering Party (second day of testing)
- Mr. H. Michel, Empa (both days)
- Mr. G. Piskoty, Empa (both days)

The test process, including the checking of the important parameters such as drop height and centring of the sandbag, and the evaluation of the damage caused to the safety strips by the impact were carried out by the Empa staff. The employees of the Ordering Party gave practical assistance without influencing the results or their evaluation.

5 TEST PROCEDURE

The safety strip was clipped to the reinforcement bars. The sandbag, which was suspended centrally over the reinforcement bars, was released suddenly. After impact on the safety strip, a visual evaluation was made to determine whether the sandbag had been – or the falling construction worker whom the sandbag simulated would have been – protected from impalement by the safety strip.

6 TEST RESULTS

Fig. 4 shows the damage typical of each diameter of reinforcement bar. In the tests with bars of $\varnothing 8$ and $\varnothing 10$ mm, the reinforcement bars buckled significantly. In some cases, the plastic cover of the protective strip received localised damage in the form of cracks or plastic deformation. In the case of reinforcement bars of $\varnothing 16$ mm, the steel inset was ruptured at individual points of contact with the tips of the bars; in all other cases, there was only a more or less well-defined pressure point (imprint of the tip of the bar), coupled with local plastic deformation of the steel inset. **In none of the tested cases would a construction worker – as simulated by the sandbag – have been injured by impalement.**



a) Test V01-08 (bar $\varnothing 8$ mm)



b) Test V02-10 (bar $\varnothing 10$ mm)



c) Test V03-12 (bar $\varnothing 12$ mm)



d) Test V03-14 (bar $\varnothing 14$ mm
and bar spacing 300 mm)



[Legend: „deaktivierte“ Bewehrungseisen:
“deactivated” reinforcement bars]

e) Test V03-14 (as in photo d)

Photo taken after removal of the sandbag



f) Tests V06-16 and V07-16 (bar $\varnothing 16$ mm)
with the same strip
Arrows show pressure points caused by test V06-16

Fig 4: Typical evidence of damage depending on the diameter of the reinforcement bars (bar: reinforcement bar).

Bar Ø [mm]	Test No.	Reinforcement Bars	Impalement
8	V01-08	All new	NO
	V02-08	All new	NO
	V03-08	All new	NO
10	V01-10	All new	NO
	V02-10	All new	NO
	V03-10	All new	NO
12	V01-12	All new	NO
	V02-12	Same as before	NO
	V03-12	All new	NO
14	V01-14	All new ^b	NO
	V02-14	Same as before ^c	NO
	V03-14	Same as before	NO
	V04-14	Same as before	NO
16	V01-16	All new	NO
	V02-16	Same as before	NO
	V03-16 ^a	Same as before	NO
	V04-16	Same as before	NO
	V05-16 ^a	Same as before	NO
	V06-16	Same as before	NO
	V07-16 ^a	Same as before	NO
	V08-16	Same as before	NO
	V09-16 ^a	Same as before	NO
V10-16	Same as before	NO	

- a The same strip as in the previous test, but offset by 100 mm (as seen in Fig. 4/f)
The other tests were carried out with unused safety strips.
- b 5 reinforcement bars, spacing 150 mm
- c 3 reinforcement bars, spacing 300 mm (2 bars from Test V01-14 deactivated, Fig. 2/e)

Table 2: Summary of test results.

7 ASSESSMENT

In all tests, a construction worker – simulated by the sandbag – was protected from being impaled. The safety strips tested met all the requirements defined by the Ordering Party to the full.