

Harpur Hill, Buxton
Derbyshire, SK17 9JN
T: +44 (0)1298 218000
F: +44 (0)1298 218590
W: www.hsl.gov.uk



**Assessment of the effects of different types of
abrasion on the tensile strength of safety
harness and lanyard webbings**

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Project Leader: **Louise Robinson B.Eng (Hons)
ProfGradIMMM**

Author(s): **Louise Robinson B.Eng (Hons)
ProfGradIMMM**

Science Group: **Engineering Control Group**

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EXECUTIVE SUMMARY

Objectives

The main objective of this project was to examine the effects of different types of abrasion on the tensile properties of webbings used to manufacture safety harnesses and lanyards. Safety harnesses and lanyards are mainly used on construction sites and are exposed to many degrading factors which affect their performance.

Two webbing types, numbers 5 and 8, were chosen from research conducted in 2002, entitled *Assessment of the factors that influence the tensile strength of safety harness and lanyard webbings*, (Parkin and Robinson).

The abrading surfaces chosen for this study were concrete, angle iron and scaffold pole. Exposure to abrasion over hexagonal bar was also included for comparison as an additional abradant as this is a US Federal Standard wear test for seatbelt webbings. Abrasion exposure was conducted over 50, 1000 and 5000 cycles for all abradants except concrete, for which 5000 cycles was too aggressive. The samples were abraded over concrete for 50, 100, 500 and 1000 cycles.

Main Findings

Abrasion over concrete was extremely severe and caused very large losses of strength after only a small number of cycles. Abrasion over angle iron was the second most severe, with the largest losses in strength occurring after 1000 cycles. Abrasion over hexagonal bar was the third most severe, with the largest loss of strength occurring after 5000 cycles of abrasion. Abrasion over scaffold pole was the least severe and caused almost no change in performance of the webbing.

Both webbing types behaved similarly after all types of abrasion, with the only difference occurring after 1000 cycles of abrasion over concrete, where webbing 8 performed significantly worse than webbing 5.

This work illustrates the need to protect products manufactured from webbing materials from abrasion sources as severe reductions in strength can result. Of particular importance is the need to protect against abrasion over concrete and ironwork edges during use of webbing products.

Recommendations for further work

Further research examining the effect of abrasion damage at low cycles, particularly abrasion over concrete, would be useful to better understand how quickly the strength reduction occurs. Abrasion over scaffold pole causes little damage and so it would not be useful to include this in any further work, and hexagonal bar causes little reduction in strength however other building site materials could be introduced such as brick, scaffold board and breeze block edges.

Aggregate concrete could also be included as only non-aggregate concrete was considered in this work. Inspections of harnesses used on construction sites could also provide valuable information. With further research on other webbing types and studies of webbing products in service and recently withdrawn from service, a visual database of abrasion damage could be produced which may better help to estimate the safe lifespan of these products.

1 INTRODUCTION

1.1 BACKGROUND

Following the publication of research by Health and Safety Laboratory, HSL, into the factors which affect the tensile strength of webbings (Parkin and Robinson, 2002) further research was commissioned by HSE to examine these webbing materials.

The purpose of this project was to examine the effects of different types of abrasion on the webbings used to manufacture safety harnesses and lanyards. Safety harnesses and lanyards are frequently used on construction sites and are exposed to many degrading factors, including abrasion, which may affect their performance in a fall situation. Knowledge of how exposure to abrasion affects the performance of webbing products would enable better predictions to be made of the expected lifetime of these products.

Abrading surfaces were chosen to represent those typically found on building sites. Using the results obtained from the ingress of dirt experiments conducted in the previous study, only the best and worst performers were selected for abrasion testing.

1.2 MATERIAL INFORMATION

The two webbing materials chosen were from the same selection as in the previous study, but with three types of webbing removed from those available for the current test programme. Webbing 3 was removed because it failed to meet the minimum tensile strength of 22 kN required by BS EN 354:1993 “Personal protective equipment against falls from height – Lanyards”. Webbings 9 and 10 were removed, because they have been withdrawn from the manufacturer as a result of the findings of that study.

The webbing chosen for testing were webbings 5 and 8, using the designation from the previous study. This designation will continue for the purposes of this study for ease of reference to the previous work, and to maintain the anonymity of the manufacturers.

The webbing materials had been tensile tested to failure in the previous research, and this information was used to draw comparison with the results for abraded samples.

1.3 ABRADANTS

Four tests were identified to examine the effects of abrasion of webbings over different types of materials:

- abrasion over concrete
- abrasion over a hexagonal bar (standard seat belt test)
- abrasion over an angle iron
- abrasion over a scaffold pole

Three of these abradants, concrete, scaffold pole and angle iron, were chosen since they are common materials likely to be encountered on a construction site and materials with which safety harness and lanyard webbings are likely to come into contact.

The hexagonal bar test was included as it is a standard wear test for webbing materials required by the United States (U.S.) Department for Transport, as described in Federal Motor Vehicle Safety Standard (FMVSS) No. 209: Seat Belt Assemblies. There is currently no equivalent British, European or International standard wear test for webbing materials.

2 TEST METHOD

2.1 EXPOSURE TO ABRASION

Abrasion exposure was conducted using the equipment shown in Figure 1. The samples were attached to a partially rotating drum, passed over the abradant, and the free end attached to a mass of 2.75 kg to tension it over the abradant. The drum was set to oscillate at 30 revolutions per minute, with each movement causing the drum to move through 90°. The drum had a circumference of 400mm and so the oscillation resulted in 100 mm of linear displacement. One metre samples were used with the centre of this length exposed to the abradant, so that approximately 100mm of the webbing was abraded. The ends of the webbing samples were heat sealed to prevent fraying during testing. The 2.75 kg mass was chosen as it was just sufficient to tension the sample over the edge to allow it to abrade. Lighter tensioning masses resulted in the webbing gathering up on one side of the abradant, and so not abrading over the full 100 mm area of the sample.

Three samples of each type of webbing were abraded for each test condition, which comprised of exposure to increasing numbers of cycles over each abrading surface. A cycle consisted of one forwards and backwards movement of the webbing over the surface, resulting in the same part of the webbing being abraded twice. The abrading surface was changed after each test to ensure the surface condition was always similar, as smoothing and polishing effects could reduce the surface roughness.

All test were carried out at ambient temperature and uncontrolled ambient humidity.

2.1.1 Abrasion over concrete

Concrete blocks measuring 20cm x 20cm x 5cm were prepared using a mixture of 1 part sharp sand to 4 parts cement and no aggregate. Each block was clamped in the abrasion rig so that the webbing abraded over one edge of the block only, Figure 1. A fresh edge was used for each abrasion test.

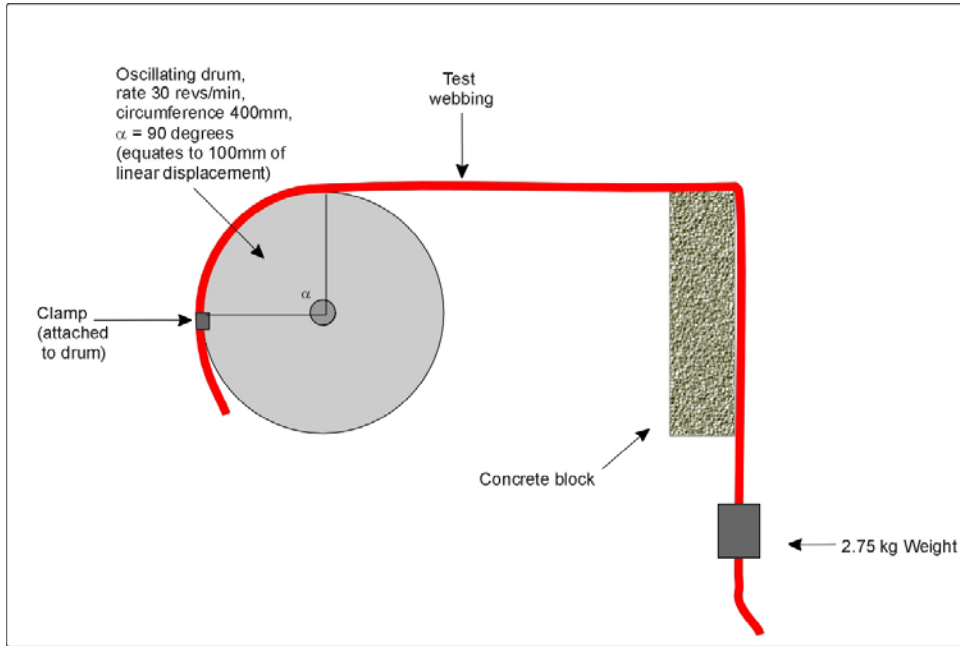


Figure 1: Schematic of abrasion over concrete set up

Abrasion was to be carried out over 50, 1000 and 5000 cycles, at the customer's request, in order to cause low, medium and high severity damage. During exposure, however, the 5000 cycle exposure had to be removed from the test programme after it was found that one of the samples abraded to failure after only 1428 cycles. This led to the inclusion of exposures of 100 and 500 cycles to assess the extent of damage at lower numbers of cycles.

2.1.2 Abrasion over hexagonal bar

The purpose of this test was to evaluate the performance of the webbings using the United States (U.S.) Department for Transport standard seatbelt test as described in Federal Motor Vehicle Safety Standard (FMVSS) No. 209: Seat Belt Assemblies. A hexagonal bar of $\frac{1}{2}$ inch diameter was placed in the abrasion rig, with a flat surface uppermost so that the webbing abraded over two of the six corners of the bar (Figure 2). It was placed so that the angle formed between the webbing as it passed over the bar was 85° , as required by that standard.

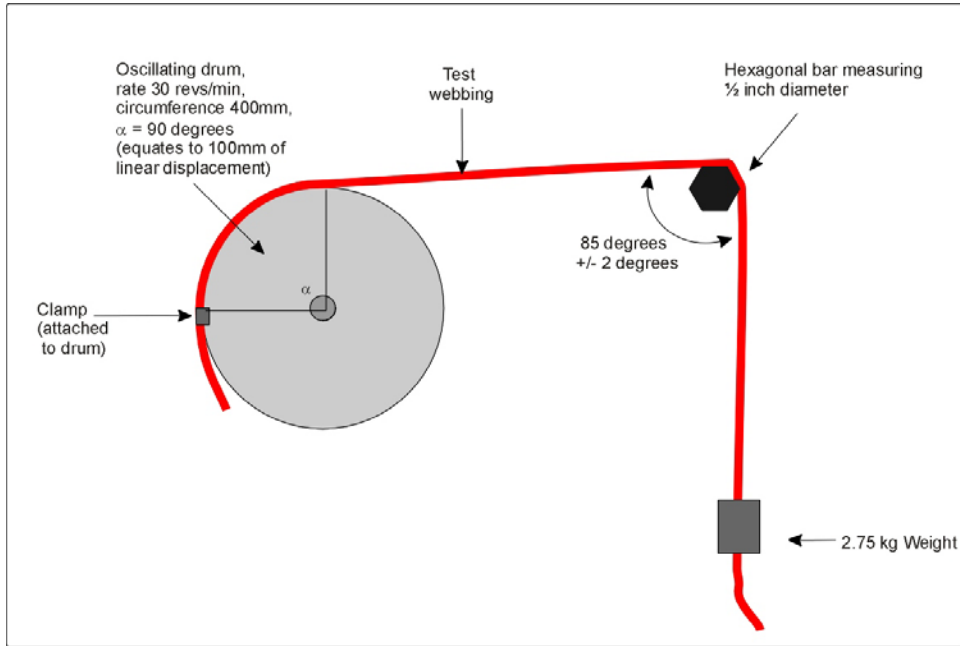


Figure 2: Schematic of abrasion over hexagonal bar

Each piece of hexagonal bar was cleaned with a fast drying alcohol based solvent cleaner prior to testing to remove grease and dirt.

Abrasion exposure was performed for 50, 1000 and 5000 cycles

2.1.3 Abrasion over angle iron

A piece of angle iron measuring 70 mm by 70 mm, 5mm thick was cut into 150 mm long sections. Each piece was cleaned with a fast drying alcohol-based solvent cleaner to remove oil and dirt prior to testing. The surface condition of the angle iron was as received. The test was set up so that the lanyard abraded over one surface and an edge of the angle iron, and a fresh edge was used for each test (Figure 3).

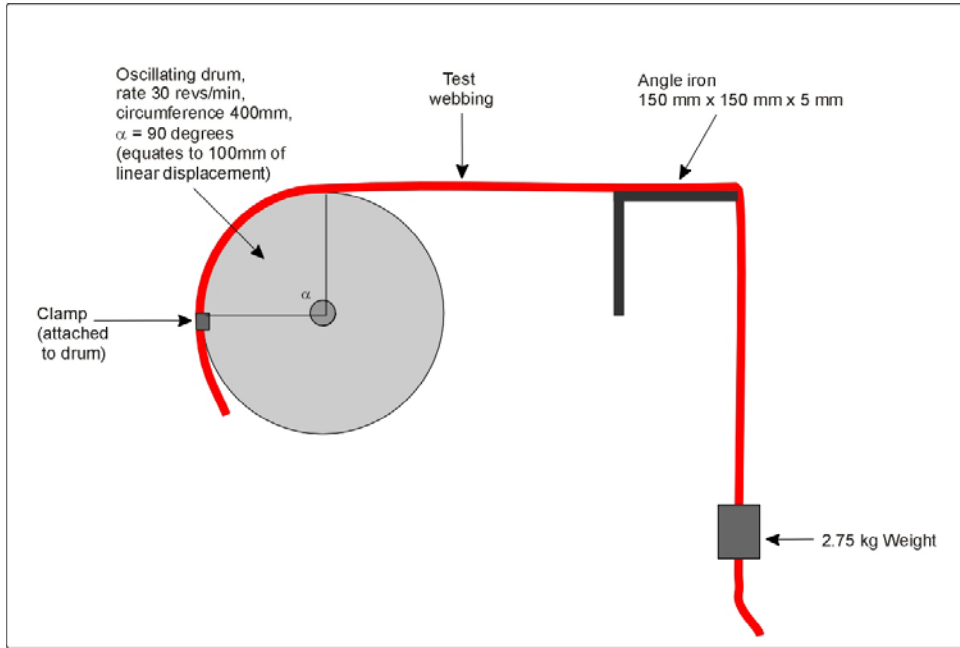


Figure 3. Schematic of abrasion over angle iron

Abrasion exposure was performed for 50, 1000 and 5000 cycles

2.1.4 Abrasion over scaffold pole

A steel scaffold pole was cut into 6 lengths of 20 mm to allow it to fit into the abrasion rig. The surface of the pole was in the normal as-received condition, with no special finish. The test arrangement can be seen in Figure 4.

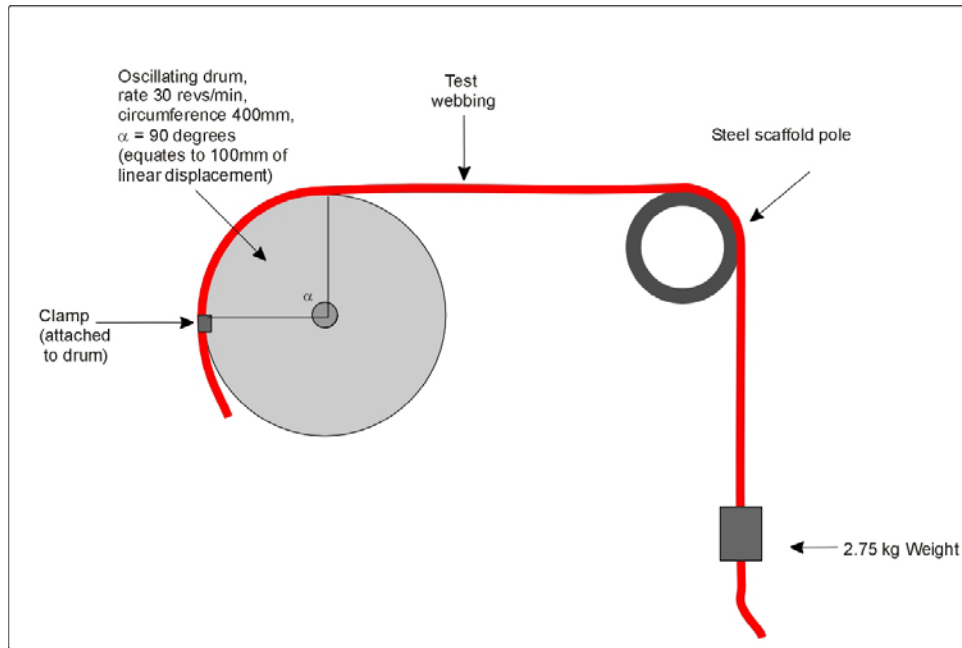


Figure 4. Schematic of abrasion over scaffold pole

Each piece of scaffold pole was used 3 times, rotating through 120° after each abrasion test to ensure a fresh surface was used each time. Each piece used was cleaned with fast drying solvent cleaner and a clean cloth, then allowed to dry prior to testing to ensure no contamination of the webbing by dirt occurred during abrasion.

Abrasion exposure was performed for 50, 1000 and 5000 cycles.

2.2 TENSILE TESTING

Tensile testing was then performed on each abraded sample using a Denison Mayes 1MN testing machine with a Rubicon controller. The machine was calibrated to an accuracy of +/- 1.0% on load measurement and +/- 3.0% on displacement measurement. The crosshead velocity of the actuator was 50 mm per minute for all tests.

The samples were clamped using a hemispherical grip arrangement, to prevent breaking of the samples at the grips, allowing a 150 mm gauge length. The samples were clamped so that the abraded section was central in the grip arrangement. Load and actuator stroke were measured and logged every 10N during each test; from these results values of elongation to failure and energy absorption to failure were calculated.

3 RESULTS

3.1 VISUAL EXAMINATION

Figures 5 to 8 show the progression of damage caused by each abrasion type for one of the webbing types tested. Figure 5 shows the effect of abrasion over concrete and is shown at 1.26 x magnification. Figures 6, 7 and 8 show the effects of abrasion over hexagonal bar, angle iron and scaffold pole respectively, and are all shown at 1.48 x magnification.

3.1.1 Abrasion over concrete

Abrasion over concrete was an aggressive test, with many broken surface fibres for both webbing types after only 50 cycles. The webbing also abraded the concrete, debonding the sand and cement mixture, allowing ingress of these substances into the webbing. This was visible as whitening of the webbing surface, however webbing 5 tended to pick up more of this powder than webbing 8. Webbing 8 appeared more worn than webbing 5 throughout the abrasion testing.

After 1000 cycles webbing 5 had some broken surface fibres, visible as lines of fuzz between the fibre bundles, running perpendicular to the gauge length. After 500 cycles this fuzzy appearance worsened and more fluff was generated by the abrasion.



Figure 5. Showing the progression of damage from abrasion over concrete

After 1000 cycles webbing 8 was worn approximately halfway through its thickness, and a large amount of fluff had been generated. Webbing 5 had many broken surface fibres and had taken on a fuzzy appearance, but was not as severely worn.

Webbing 8 failed after 1480 cycles, so testing to 5000 cycles was not be performed.

3.1.2 Abrasion over hexagonal bar

This test was less aggressive than the abrasion over concrete, but still caused a large amount of surface fibres to break after 50 cycles. After 100 cycles many fibre bundles were broken on the abraded surface. On the non-abraded side of the webbing the fibre bundles were raised from the surface of the webbing resulting in them having a 'pulled' appearance. Both types of webbing took on a distorted appearance in the abraded area.

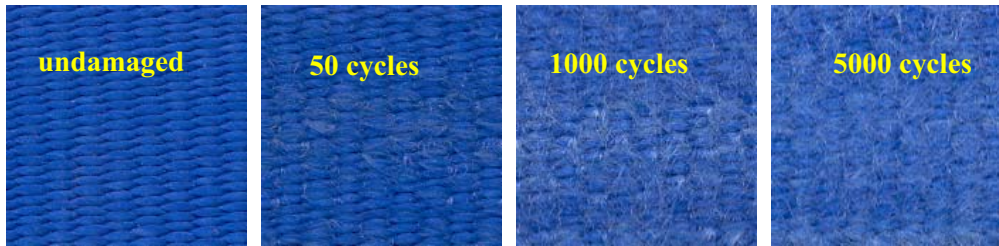


Figure 6. Showing the progression of damage from abrasion over hexagonal bar

3.1.3 Abrasion over angle iron

This test was less aggressive than abrasion over concrete, but more aggressive than abrasion over hexagonal bar.

After 50 cycles both types of webbing were polished but showed little signs of damage. After 1000 cycles wear was evident at the edges of the webbing 5. The sample appeared to be either stretched in the central area, or contracted at the edges. After 5000 cycles the central 20mm of webbing 5 was distorted but showed no signs of wear. The edges of the webbing, however, were heavily worn, with most of the surface fibres abraded away and the inner fibres exposed. The fibres on the non-abrasing side were broken and pulled through giving the appearance of damage on both sides of the webbing.

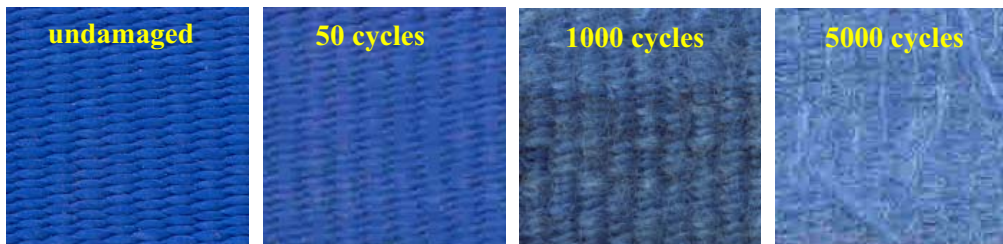


Figure 7. Showing the progression of damage from abrasion over angle iron

Webbing 8 showed uniform wear across its surface after 1000 cycles and had a very fuzzy appearance due to many broken surface fibres. After 5000 cycles the surface of the webbing had worn away, with many broken fibres and loose fluff on the surface of the webbing.

3.1.4 Abrasion over scaffold pole

Both types of webbing showed no obvious signs of damage from this test after 50, 1000 and 5000 cycles, although the surface fibres appeared slightly polished and there was slight discolouration of the webbing.

The degree of polishing and discolouration increased with increasing number of cycles.

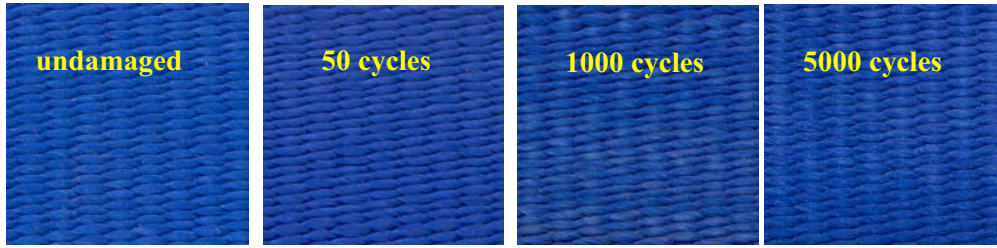


Figure 8. Showing the progression of damage from abrasion over scaffold pole

3.2 TENSILE TESTING RESULTS

3.2.1 Abrasion over concrete

The effect of abrasion over concrete on the performance of the webbings can be seen in Tables 1 and 2, and also in Figure A1.

Abrasion over concrete caused a large reduction in the strength of both webbings after only 50 cycles. Increasing numbers of cycles of damage caused further decreases in strength, but the effect was not linear. The reduction in strength for webbing 5 after 1000 cycles was almost the same as that after 500 cycles. Webbing 8 was particularly susceptible to abrasion over concrete, losing almost all its strength after 1000 cycles.

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	25.49	0.133	1.58
<i>50 cycles</i>	17.39	0.096	0.86
<i>100 cycles</i>	15.98	0.089	0.73
<i>500 cycles</i>	10.89	0.063	0.40
<i>1000 cycles</i>	10.71	0.062	0.37

Table 1. Results for webbing 5

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	28.67	0.192	2.08
<i>50 cycles</i>	18.01	0.145	0.99
<i>100 cycles</i>	13.33	0.141	0.81
<i>500 cycles</i>	11.29	0.134	0.66
<i>1000 cycles</i>	1.80	0.027	0.03

Table 2. Results for webbing 8

Figure A1 in the Appendix, illustrates the decrease in breaking strength of both webbings with increasing numbers of cycles of abrasion. The graph also shows, for comparison, a horizontal line at 22 kN, indicating the BS EN 354:2003 requirement for the minimum breaking strength of webbing lanyards. It can clearly be seen that after less than 50 cycles of abrasion over concrete both webbing samples would fail to meet this requirement. This finding is highly significant. Although the method of abrasion used for testing is not how wear would occur on site, it is reasonable to assume that a degree of wear equivalent to 50 cycles could occur during the lifetime of the harness or lanyard.

Figure A5 shows the decrease in elongation to failure for both webbings with increasing numbers of cycles of abrasion. Figure A9 shows the decrease in energy absorbed by both webbings with increasing numbers of cycles of abrasion.

3.2.2 Abrasion over hexagonal bar

The effect of abrasion over hexagonal bar on the performance of the webbings can be seen in Tables 3 and 4, and also in Figure A2.

Abrasion over hexagonal bar was less severe than over concrete, with both webbings showing small decreases in strength over 50 cycles, and larger decreases after 1000 and 5000 cycles.

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	25.49	0.133	1.58
<i>50 cycles</i>	25.43	0.126	1.51
<i>1000 cycles</i>	24.18	0.124	1.39
<i>5000 cycles</i>	18.53	0.108	1.03

Table 3. Results for webbing 5

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	28.67	0.192	2.08
<i>50 cycles</i>	27.32	0.179	1.82
<i>1000 cycles</i>	23.25	0.173	1.49
<i>5000 cycles</i>	21.91	0.169	1.42

Table 4. Results for webbing 8

Figure A2 in the Appendix, shows that after 5000 cycles, both webbings had dropped below the BS EN 354:2003 minimum strength of 22 kN. Figure A6 shows the decrease in elongation to failure for both webbings with increasing numbers of cycles of abrasion. Figure A10 shows the decrease in energy absorbed by both webbings with increasing numbers of cycles of abrasion.

3.2.3 Abrasion over angle iron

The effect of abrasion over hexagonal bar on the performance of the webbings can be seen in Tables 5 and 6, and also in Figure A3.

Abrasion over angle iron had a moderately severe effect on the webbings, causing relatively little damage after only 50 cycles, but increasingly severe damage over 1000 and 5000 cycles. Both webbings performed similarly in terms of loss of strength, reduction in elongation to failure and energy absorbed.

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	25.49	0.133	1.58
<i>50 cycles</i>	24.66	0.128	1.50
<i>1000 cycles</i>	15.90	0.098	0.90
<i>5000 cycles</i>	9.44	0.070	0.49

Table 5. Results for webbing 5

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	28.67	0.192	2.08
<i>50 cycles</i>	27.00	0.190	1.80
<i>1000 cycles</i>	16.90	0.159	0.97
<i>5000 cycles</i>	11.94	0.150	0.72

Table 6. Results for webbing 8

Figure A3 in the Appendix shows that between 50 and 1000 cycles of abrasion the webbing suffers significant damage causing the breaking strength to fall below the 22 kN minimum requirement of BS EN 354. Figure A7 shows the decrease in elongation to failure for both webbings with increasing numbers of cycles of abrasion. Figure A11 shows the decrease in energy absorbed by both webbings with increasing numbers of cycles of abrasion.

3.2.4 Abrasion over scaffold pole

The effect of abrasion over scaffold pole on the performance of the webbings can be seen in Tables 7 and 8, and also in Figure A4.

Abrasion over a scaffold pole had no significant effect on either of the webbings. Variations observed in breaking strength, elongation and energy absorbed to failure were due to natural variation in performance caused by the weave of the webbings. Although a small decrease in strength was observed after 50 cycles subsequent abrasion showed little decrease in strength.

Both webbings performed similarly, although webbing 8 was marginally the worse performer due to a small decrease in elongation to failure and energy absorbed with increasing abrasion.

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	25.49	0.133	1.58
<i>50 cycles</i>	24.75	0.124	1.47
<i>1000 cycles</i>	25.53	0.128	1.56
<i>5000 cycles</i>	25.41	0.126	1.55

Table 7. Results for webbing 5

	<i>Breaking load, kN</i>	<i>Elongation to failure, m</i>	<i>Energy to failure, kJ</i>
<i>As received</i>	28.67	0.192	2.08
<i>50 cycles</i>	27.79	0.189	1.94
<i>1000 cycles</i>	28.30	0.191	2.00
<i>5000 cycles</i>	28.27	0.194	2.03

Table 8. Results for webbing 8

Figure A4 in the Appendix shows the overall effect of abrasion over scaffold pole was minimal, and that both webbings exceeded the minimum strength requirement of 22 kN after all exposures. Figure A8 shows the decrease in elongation to failure for both webbings with increasing numbers of cycles of abrasion. Figure A12 shows the decrease in energy absorbed by both webbings with increasing numbers of cycles of abrasion.

4 DISCUSSION

Table 9, below, shows the percentage loss of strength for each webbing type after 50 and 1000 cycles of abrasion over each abradant, with abradants listed in decreasing order of severity. Table 10 shows the effect of abrasion on the elongation to failure of the webbings, listed in order of severity and Table 11 shows the energy absorbed during testing for each webbing type, again listed in order of severity.

	<i>Webbing 5</i>		<i>Webbing 8</i>	
	<i>50 cycles, %</i>	<i>1000 cycles, %</i>	<i>50 cycles, %</i>	<i>1000 cycles, %</i>
<i>Concrete</i>	31.78	57.97	37.20	93.71
<i>Angle Iron</i>	3.13	37.49	5.75	40.98
<i>Hexagonal bar</i>	0.24	5.10	4.63	18.80
<i>Scaffold</i>	2.81	-0.39	2.34	1.33

Table 9. Percentage loss of strength of webbings

The test programme revealed that abrasion over concrete had a very severe effect on the tensile properties of webbing materials. The effect of concrete abrasion on webbings may be two fold: abrasion over the rough concrete surface causing mechanical damage of the fibres, and debonding of the sand cement mixture allowing sand particles to ingress into the webbing causing internal abrasion of the fibres.

Of particular concern was the extent of abrasion damage after only 50 cycles (one cycle was one forwards and backwards movement across the abrasive surface). The webbing samples did not appear to be significantly damaged after this exposure, with some surface fuzz and little ingress of cement powder. Tensile testing, however, revealed significant loss of strength, resulting in a breaking strength below that required by BS EN 354:2003, and also significant losses in energy absorption were also recorded. Table 11 shows losses of energy absorption of almost 50% in both webbing types, after only 50 cycles of abrasion; these losses are the most severe in the entire test regime.

Further research would need to be conducted to determine after how many cycles the strength of the webbings dropped below the 22 kN requirement, and also how quickly the energy absorption capabilities of the webbing decrease.

Abrasion over concrete was significantly more damaging than any other abradant used in the test programme. The concrete was relatively homogenous and had no aggregate include in the mix. The addition of aggregate is likely to affect the extent of damage suffered by the webbings, and could be better or worse depending on whether the webbing passed over a large smooth stone or a hard, rough surfaced stone.

	<i>Webbing 5</i>		<i>Webbing 8</i>	
	<i>50 cycles, %</i>	<i>1000 cycles, %</i>	<i>50 cycles, %</i>	<i>1000 cycles, %</i>
<i>Concrete</i>	27.8	53.4	24.5	85.9
<i>Angle Iron</i>	3.8	26.3	1.0	17.2
<i>Hexagonal bar</i>	5.3	6.8	6.8	9.9
<i>Scaffold</i>	6.8	3.8	1.6	0.5

Table 10. Percentage reduction in elongation of webbings

Angle iron was the second most severe abradant used in the test programme causing only a small amount of damage after 50 cycles of abrasion, but causing a large loss of strength after 1000 cycles. This was also the case for the reduction in energy absorption of both webbing types. The webbing was abraded over one surface and one edge of the angle iron. The surface of steel over which the webbing was abrading measured 150 mm, and it then passed at 90° over an edge 5 mm in width. Damage was likely to have occurred by two mechanisms: external abrasion caused by the metal edge and internal abrasion of the fibres in the bundles, caused by passing over a sharp angle over a small radius. Thicker steel edges are likely to cause a different extent of abrasion, as there will be more metal in contact with the webbing, increasing the external abrasion, but less internal abrasion due to the webbing passing over a larger radius.

	<i>Webbing 5</i>		<i>Webbing 8</i>	
	<i>50 cycles, %</i>	<i>1000 cycles, %</i>	<i>50 cycles, %</i>	<i>1000 cycles, %</i>
<i>Concrete</i>	45.6	76.6	52.4	98.6
<i>Angle Iron</i>	5.1	43.0	13.5	53.4
<i>Hexagonal bar</i>	4.4	12.0	12.5	28.4
<i>Scaffold</i>	7.0	1.3	6.7	3.8

Table 11. Percentage reduction in energy absorption of webbings

Hexagonal bar produced only a small amount of abrasion and an almost linear reduction in strength with increasing cycles of abrasion. Only after 5000 cycles was the damage sufficient to cause the tensile strength of the webbing to drop below 22 kN. This test was a standard wear test for seat belt assemblies in vehicles, which would be expected to have a considerably longer lifespan than safety harness and lanyard webbings, and in a far less aggressive environments. This test was not really representative of abrasion sources on a building site, and it would be of little further value to investigate this type of abrasion.

As would be expected the smooth surface and relatively large diameter of scaffold poles presented no significant abrasion problem for webbing materials, with virtually no reduction in

strength. The slightly lower results obtained after 50 cycles could be as a result of inhomogeneity of the webbing samples or simply be caused by a small amount of surface roughness on some of the scaffold pole samples.

Both webbings performed in a similar way during this research. Webbing 8, in general, performed worse after abrasion over concrete and abrasion over hexagonal bar, but the results were broadly similar otherwise.

This work illustrates the need to protect products manufactured from webbing materials from abrasion sources as severe reductions in strength can result. Of particular importance is the need to protect against abrasion over concrete and ironwork edges during use of webbing based products.

5 CONCLUSIONS

1. The most severe form of abrasion was that over concrete, with webbing 8 showing a reduction in strength of 37 % and webbing 5 a reduction of 32% after only 50 cycles.
2. Abrasion over concrete caused losses of energy absorption of almost 50% in both webbing types, after only 50 cycles of abrasion; these losses are the most severe in the entire test regime
3. The second most severe form of abrasion was that over angle iron, with a large loss of strength, 41% for webbing 8 and 37.5% for webbing 5, after 1000 cycles.
4. The third most severe form of abrasion was that over hexagonal bar, with a maximum loss of strength of 18.8% for webbing 8 and 5.1% for webbing 5 after 5000 cycles.
5. The least severe form of abrasion was that over scaffold, with virtually no reduction in strength, even after 5000 cycles.
6. Webbing 8 was the worst performer in terms of loss of strength, elongation to failure and energy absorbed after all types of abrasion exposure.
7. This research highlights the severe reduction in strength of webbing materials after low levels of abrasion over concrete.
8. This research illustrates the importance of protecting webbing from abrasion over concrete and ironwork edges.

6 RECOMMENDATIONS FOR FURTHER WORK

Further research examining the effect of abrasion damage at low cycles would be useful to better understand how quickly the strength reduction occurs. Abrasion over scaffold causes little damage and so it would not be useful to include this in any further work, however other building site materials could be introduced such as brick, scaffold board edges and breeze blocks.

Also a study of wet abrasion could yield important results. All testing so far has been on dry webbing material, but wetting the webbing could change its abrasion characteristics. Ingress of wet grout, cement and mortar could cause chemical degradation as well as abrasion and so it may be useful to examine these effects.

With further research on other webbing types and studies of webbing products in service and recently withdrawn from service, preferably with a well documented service history, a visual database of abrasion damage could be produced which may better help to estimate the safe lifespan of these products.

7 REFERENCES

R Parkin and L Robinson, *Assessment of the factors that influence the tensile strength of safety harness and lanyard webbings*, HSL/2002/16, 2002, <http://www.hse.gov.uk/research/hsl/hsl02-16.htm>

U.S. Department for Transportation, *Laboratory test procedure for FMVSS 209 seat belt assemblies*, <http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Vehicle%20Safety/Test%20Procedures/Associated%20Files/TP-209-06.pdf>

8 APPENDIX

8.1 GRAPHS OF BREAKING STRENGTH AGAINST NUMBER OF CYCLES

Figure A1. Abrasion over concrete

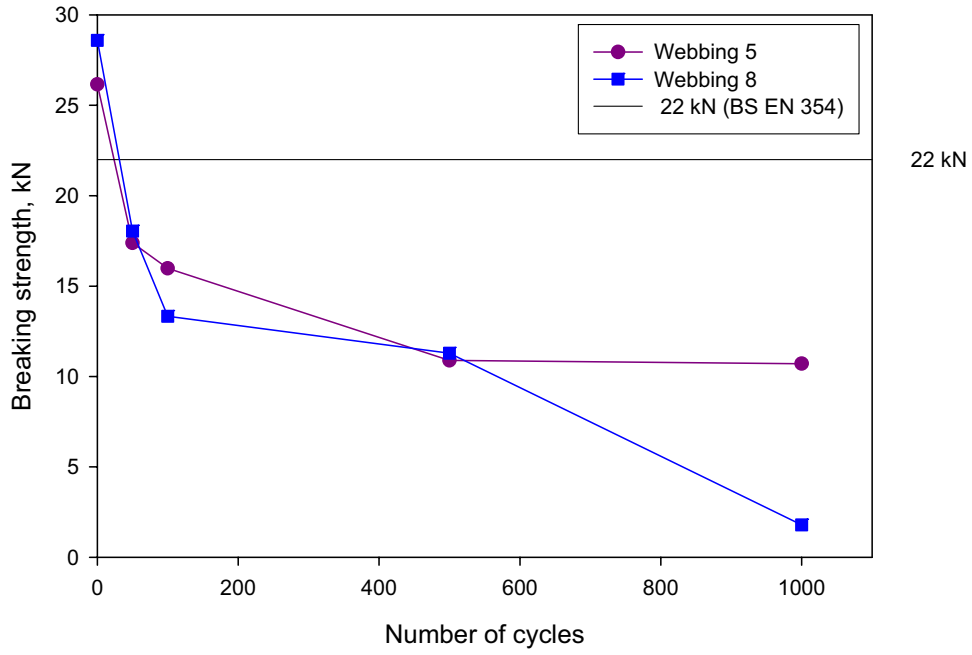


Figure A2. Abrasion over hexagonal bar

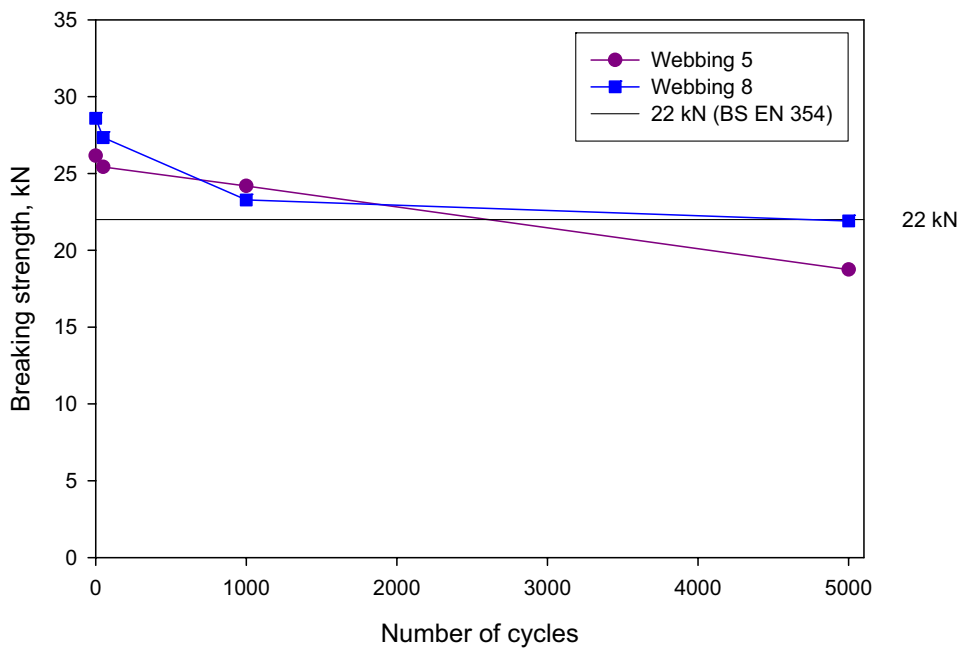


Figure A3. Abrasion over angle iron

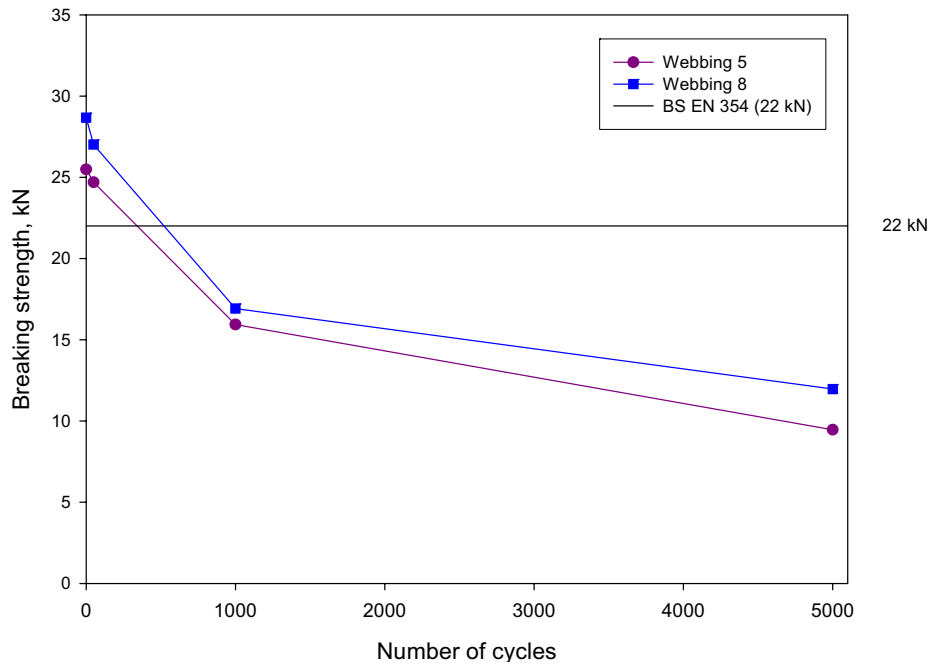
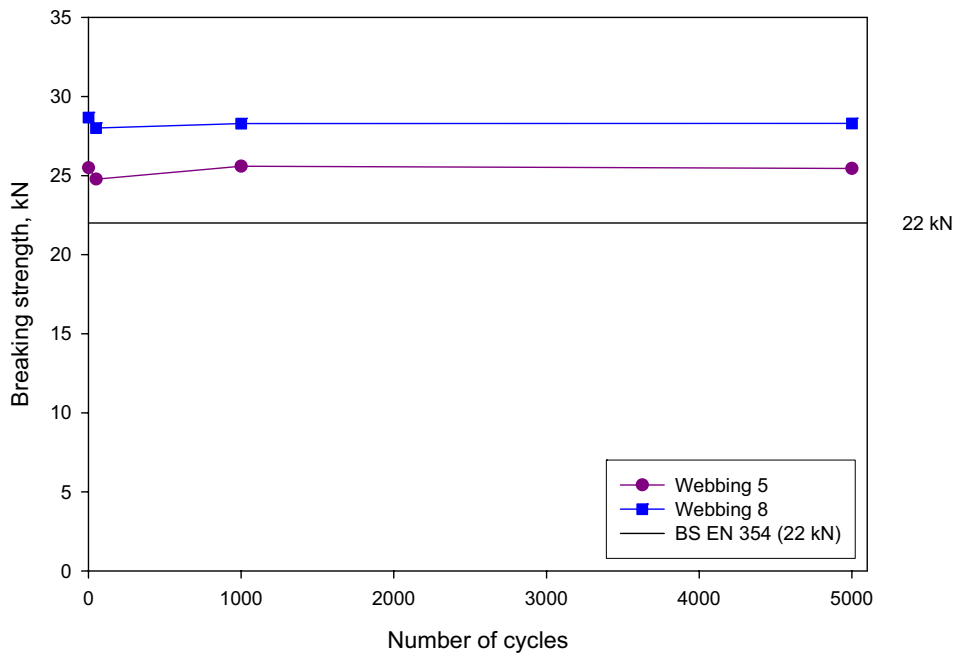


Figure A4. Abrasion over scaffold pole



8.2

GRAPHS OF ELONGATION AGAINST NUMBER OF ABRASION CYCLES

Figure A5. Abrasion over concrete

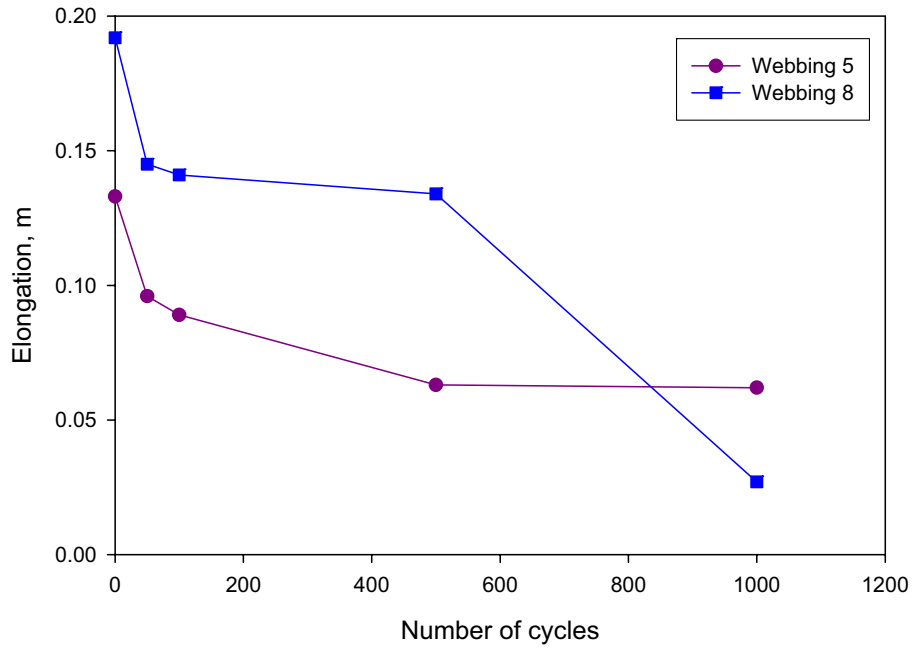


Figure A6. Abrasion over hexagonal bar

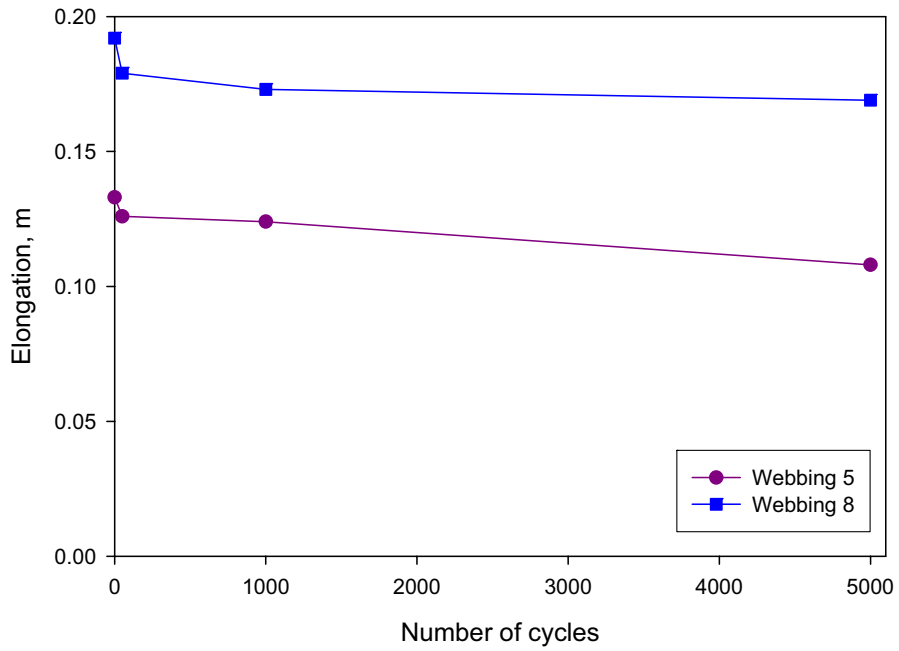


Figure A7. Abrasion over angle iron

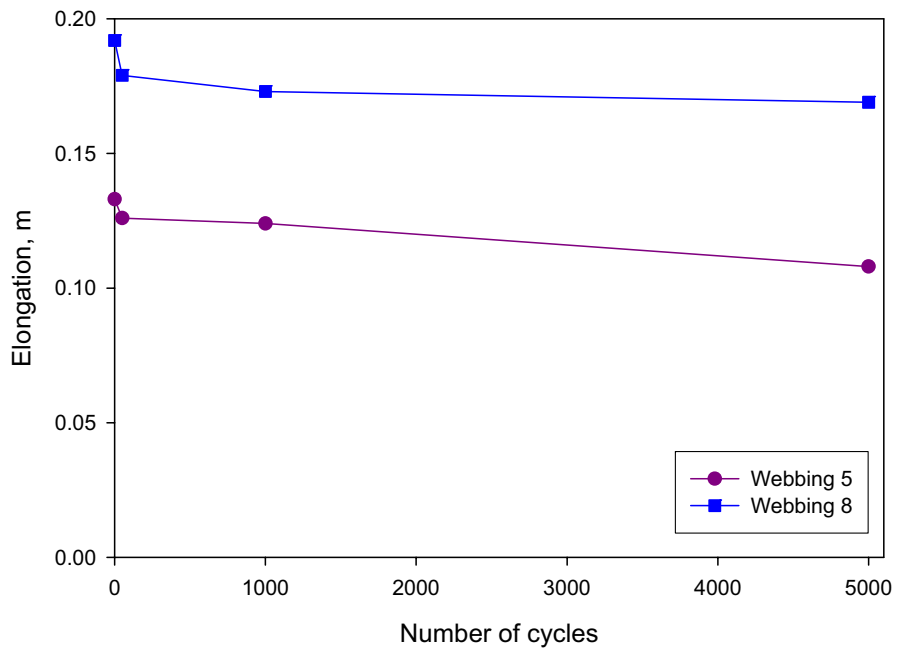
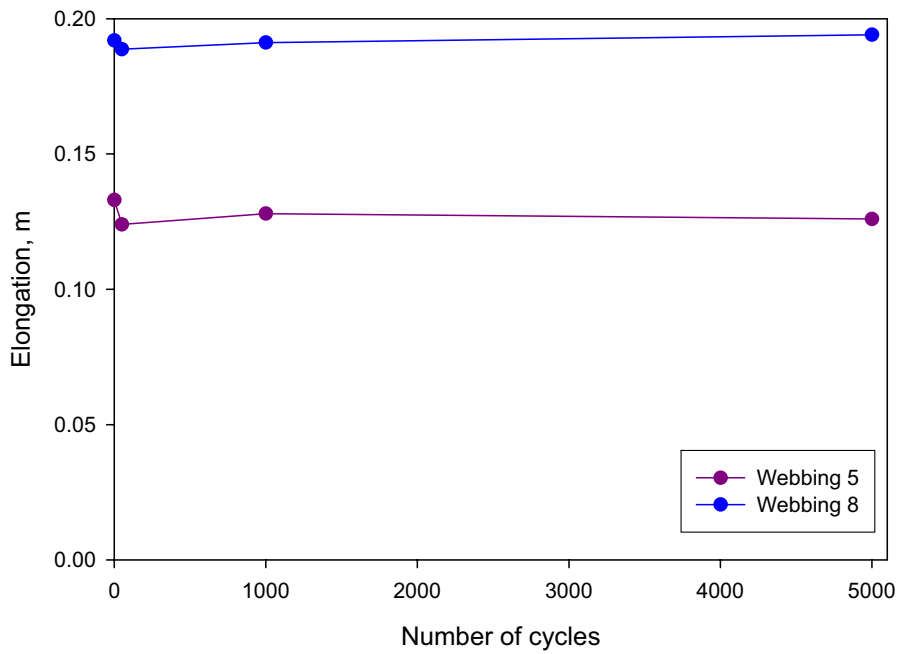


Figure A8. Abrasion over scaffold pole



8.3

GRAPHS OF ENERGY ABSORBED AGAINST NUMBER OF CYCLES

Figure A9. Abrasion over concrete

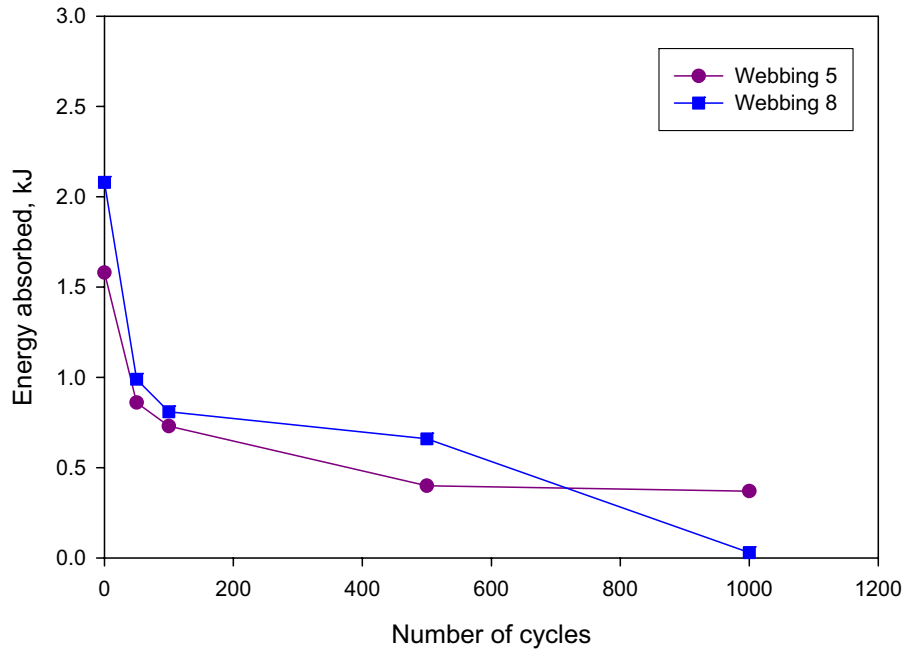


Figure A10. Abrasion over hexagonal bar

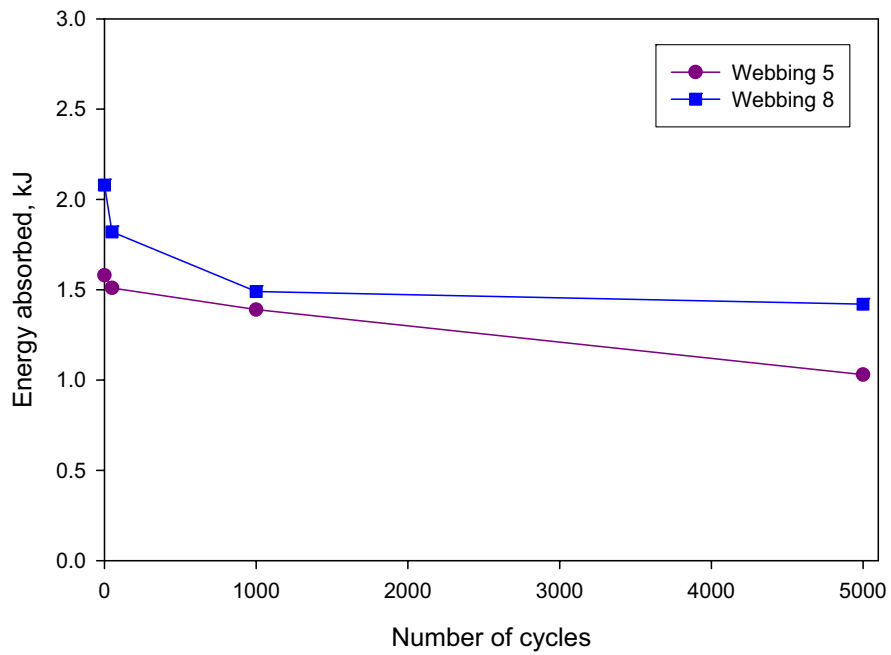


Figure A11. Abrasion over angle iron

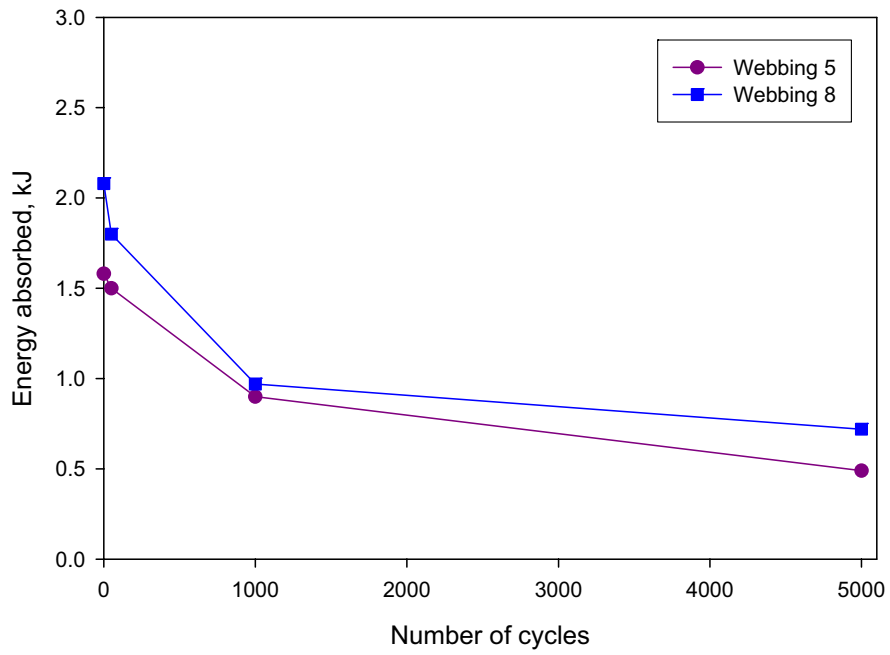


Figure A12. Abrasion over scaffold pole

