

## A Study on the Occupational Accidents and the Standards Concerned with the Failure of Flat Woven Webbing Slings

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### ABSTRACT

**Objectives:** The flat woven webbing sling refers to a sewed textile belt intended for hanging a load on a hook of crane or other lifting device. In South Korea, the use of sling and the relevant occupational accidents have been increased due to the increase in domestic logistics and convenience of use. Especially, the occupational accidents by the failure of the sling were 2.5 times higher in terms of the average labor loss days than other occupational accidents related to the sling according to the result of analyzing occupational accidents in South Korea over the last three years('12~'14). Nevertheless, the related domestic rule in "Local Rule on Occupational Safety and Health Standard" only states that the use of the sling should be prohibited in the case of "One with cut strands" or "Seriously damaged or corroded one", which is quite unclear and subjective.

**Methods:** By taking advantage of the industrial accident statics system of the Korea Occupational Safety and Health Agency, the occupational accidents related to the sling occurred for the last three years('12~'14) were analyzed. The domestic and international standards for removal from service and product strength criteria for the slings were studied. Also, the tensile load tests of the slings in the market were conducted.

**Results:** Through the analysis on the occupational accidents, high riskiness and the characteristics of the accidents by the failure of the sling were confirmed. It was identified that the domestic rule for the sling to remove from service was quite more unclear and subjective than other international rules. Also, the tensile loads of the slings in the domestic market were about 65.7%~96.6% of the product strength criteria for the slings according to the result of the tensile load tests.

**Conclusions:** High riskiness and the characteristics of the accidents by the failure of the sling and the necessity of a clear and objective removal rule from service for the sling were confirmed through this study which was conducted to raise issues and seek resolutions to the inadequate domestic rule in spite of the riskiness of the failure of the sling.

**Keywords:** Occupational accident; Flat woven webbing sling; Failure; Removal criteria; Labor loss days;

### I. INTRODUCTION

A flat woven webbing sling refers to a textile belt composed of sewed web to hang freight on either a hook of crane or other lifting devices. In an industrial site, the unexpected abrupt failure of flat woven webbing sling may drop freight upon workers within a dangerous area to threat safety of workers significantly.<sup>1-2</sup>

Yet, in South Korea, due to an increase of logistics and convenience of use, the number of accidents regarding a use of flat woven webbing sling in an industrial field is increasing. The number of total casualties from accidents with respect to a flat woven webbing sling for the recent three years ('12~'14) was 252, leading the annual average casualty of 84, and the number of casualties from the failure of flat woven webbing sling was 28, or 11.1% of the total casualties of 252, leading to the annual average casualty of 9.3.<sup>3-5</sup> Moreover, the total deaths from accidents with respect to a flat woven webbing sling for the recent three years were 20, leading the annual average deaths of 6.7, and the deaths from accidents of failure of flat woven webbing sling for the recent three years were 6, or 30% of the total deaths from accidents with respect to a flat woven webbing sling, leading the annual average deaths of 2.<sup>3-5</sup> These numbers indicate that although the number of casualties by failure of flat woven webbing sling takes 11.1% of the total casualties from accidents with respect to a flat woven webbing sling, the number of deaths by failure of it takes 30.0% of the total deaths by accidents with respect to a flat woven webbing sling, and thus they represent the danger of industrial accidents by failure of flat woven webbing sling well.

Nevertheless, the domestic laws and regulations in South Korea only command as "One with cut strands" or "Seriously damaged or corroded one" shall not be used under the Local Rule on Occupational Safety and Health Standard, which is

quite unclear and personally subjective. So, this study about the characteristics of industrial accidents and the relative standards regarding the failure of a flat woven webbing sling was conducted to propose issues and to seek resolutions.

## II. CHARACTERISTICS OF OCCUPATIONAL ACCIDENTS

By using the occupational accident statistics system by the Korea Occupational Safety and Health Agency, the accidents regarding a flat woven webbing sling for the recent three years (2012 ~ 2014) have been analyzed to evaluate the characteristics of accidents.<sup>3-5</sup>

### II.A. Accidents Classification by Year/Types of Industry

The rates of all casualties with respect to a flat woven webbing sling in each field for the recent three years were 46.8% (118 casualties) from construction, 44.8% (113 casualties) from manufacturing, and 8.3% (21 casualties) from others to have 91.6% (231 casualties) from construction and manufacturing, and the rates of deaths in each field were 70% (14 deaths) from construction, 20% (4 deaths) from manufacturing, and 10% (2 deaths) from others to have 90% (18 deaths) from construction and manufacturing.

The rates of casualties just from the failure of a flat woven webbing sling for the recent 3 years were 64.3% (18 casualties) from manufacturing, 32.1% (9 casualties) from construction, and 3.6% (1 casualty) from others to have 96.4% (27 casualties) from construction and manufacturing, and the rates of deaths in each field were 66.7% (4 deaths) from construction and 33.3% (2 deaths) from manufacturing to have 100% (6 deaths) from construction and manufacturing.

According to these numbers, the construction and manufacturing were identified as the main fields of accidents from a flat woven webbing sling including the failure of it.

Table 1. Classification of occupational accidents by types of industry ('12~'14)

Unit: Total number of all casualties with respect to a flat woven webbing sling  
 (Number of casualties just from the failure of flat woven webbing sling)

Year		Manufacturing	Construction	Others	Total
2012	Injured	32 (6)	27 (1)	2 (-)	61 (7)
	Death	1 (-)	3 (1)	1 (-)	5 (1)
	Sum (Casualties)	33 (6)	30 (2)	3 (-)	66 (8)
2013	Injured	33 (5)	45 (2)	7 (1)	85 (8)
	Death	-	8 (1)	1 (-)	9 (1)
	Sum (Casualties)	33 (5)	53 (3)	8 (1)	94 (9)
2014	Injured	44 (5)	32 (2)	10 (-)	86 (7)
	Death	3 (2)	3 (2)	-	6 (4)
	Sum (Casualties)	47 (7)	35 (4)	10 (-)	92 (11)
Total	Injured	109 (16)	104 (5)	19 (1)	232 (22)
	Death	4 (2)	14 (4)	2 (-)	20 (6)
	Sum (Casualties)	113 (18)	118 (9)	21 (1)	252 (28)

### II.B. Accidents Classification by the Machine Used

In accordance with the Table 2, the rates of casualties from a work using a crane for the recent three years were 67.5% (170 casualties) out of the total casualties (252), 67.9% (19 casualties) out of the total casualties just by the failure of a flat woven webbing sling (28 casualties), 80% (16 deaths) out of the total deaths (20 deaths), and 83.3% (5 deaths) out of the total deaths just from the failure of a flat woven webbing sling (6 deaths). Also, the rates of casualties just from the failure of a flat woven webbing sling on a crane were 68.4% (13 casualties) from manufacturing and 31.6% (6 casualties) from construction, and the rates of deaths just from the failure of a flat woven webbing sling on a crane were 80.0% (4 deaths) from construction and 20.0% (1 death) from manufacturing. So, it is confirmed that working using a crane in manufacturing and construction had 67.8% of the total casualties and 83.3% of the total deaths just from the failure of a flat woven webbing sling.

Table 2. Classification of occupational accidents by the machine used ('12~'14)

Unit: Total number of all casualties with respect to a flat woven webbing sling  
 (Number of casualties just from the failure of flat woven webbing sling)

Machine Used		Manufacturing	Construction	Others	Total
Crane	Injured	75 (12)	72 (2)	7 (-)	154 (14)
	Death	3 (1)	12 (4)	1 (-)	16 (5)
	Sum (casualties)	78 (13)	84 (6)	8 (-)	170 (19)
Vehicle Type Construction Machinery	Injured	-	21 (3)	-	21 (3)
	Death	-	1 (-)	-	1 (-)
	Sum (casualties)	-	22 (3)	-	22 (3)
Forklift	Injured	2 (-)	-	2 (-)	4 (-)
	Death	-	-	-	-
	Sum (casualties)	2 (-)	-	2 (-)	4 (-)
Others	Injured	32 (4)	11 (-)	10 (1)	53 (5)
	Death	1 (1)	1 (-)	1 (-)	3 (1)
	Sum (casualties)	33 (5)	12 (-)	11 (1)	56 (6)
Total	Injured	109 (16)	104 (5)	19 (1)	232 (22)
	Death	4 (2)	14 (4)	2 (-)	20 (6)
	Sum (casualties)	113 (18)	118 (9)	21 (1)	252 (28)

### II.C. Labor Loss Days from Casualties

In accordance with the Table 3, it is indicated that the average labor loss days by casualties from the failure of a flat woven webbing sling is 1828.1 days, and the average labor loss days by casualties from the non-failure of a flat woven webbing sling is 728.9 days. This leads to the conclusion that the average labor loss days from the failure of a flat woven webbing sling is 2.5 times higher than the average labor loss days from non-failure of flat woven webbing sling when the accidents concerned with a flat woven webbing sling are compared, which shows a significance of accident by the failure of a flat woven webbing sling.

Table 3. Labor loss days caused by the accidents concerned with a flat woven webbing sling ('12~'14)

Accident Type	Number of Casualties	Sum of Labor Loss Days	Average Labor Loss Days
Failure of the Flat Woven Webbing Sling	28	51,188	1828.1
Non-Failure of Flat Woven Webbing Sling	224	163,279	728.9

Table 4. Labor loss days caused by the accidents concerned with a flat woven webbing sling classified by the types of industries ('12~'14)

Unit: Average Labor loss days (Number of casualties)

Accident Type	Manufacturing	Construction	Transportation, Storage and Communication	Others	Total
Failure of the Flat Woven Webbing Sling	1106.4 (18)	3462.1 (9)	-	113.0 (1)	1828.1 (28)
Non-Failure of Flat Woven Webbing Sling	455.7 (95)	941.7 (109)	1201.9 (14)	85.0 (6)	728.9 (224)
Total	559.4 (113)	1134.0 (118)	1201.9 (14)	89.0 (7)	851.1 (252)

As the reference, in accordance with the Table 4, the average labor loss days by the accidents with respect to a flat woven webbing sling in manufacturing (559.4 days), construction (1134.0 days), and transportation, storage, and communication (1201.9 days) were over 500 days, and especially in case of having a disaster from the failure of a flat woven webbing sling, the construction field had the high average labor loss days of 3462.1 days.

According to <Table 3> and <Table 4>, the average labor loss days by casualties from the failure of a flat woven webbing sling is 1828.1 days which is 2.5 times of the average labor loss days (728.9 days) by casualties from non-failure of a flat woven webbing sling, showing the seriousness of accidents by the failure of a flat woven webbing sling, and the construction field had the highest average labor loss days when the accidents from the failure of the flat woven webbing sling occurred

#### II.D. Types of Related Work

According to <Table 5>, the rates of casualties out of the total casualties (252) by the accidents from a flat woven webbing sling were 13.1% (33 casualties) in maintenance or assembling of facility/inputting product material into facility, 10.7% (27 casualties) in loading on to truck or unloading from truck, 10.3% (26 casualties) in handling the form used on construction site, and 27.0% (68 casualties) in rising, moving or lowering of the load with irregular shape, and the rates of casualties out of the casualties (28) by the accidents just from the failure of a flat woven webbing sling were 14.3% (4 casualties) in maintenance or assembling of facility/inputting product material into facility, 7.1% (2 casualties) in assembling, disassembling or adjustment of steel material on construction site, and 64.3% (18 casualties) in rising, moving or lowering of the load with irregular shape.

Table 5. Classification of the flat woven webbing -related occupational accidents by the types of work ('12~'14)  
Unit: Total number of all casualties with respect to a flat woven webbing sling  
(Number of casualties just from the failure of flat woven webbing sling)

Work	Manufacturing	Construction	Others	Total
Maintenance·Assembling of Facility / Inputting Product Material into Facility	30 (3)	2 (-)	1 (1)	33 (4)
Loading onto Truck / Unloading from Truck	12 (1)	9 (-)	6 (-)	27 (1)
Handling the Form used on Construction Site	-	26 (-)	-	26 (-)
Assembling·Disassembling·Adjustment of Steel Material on Construction Site	-	15 (2)	-	15 (2)
Loading onto Ship / Unloading from Ship	-	-	11 (-)	11 (-)
Handling Concrete Pipe	-	9 (-)	-	9 (-)
Press Machine Related Work	6 (1)	-	-	6 (1)
Cleaning / Organizing	2 (-)	3 (-)	-	5 (-)
Assembling·Disassembling·Adjustment of Scaffold	-	2 (-)	-	2 (-)
Assembling·Disassembling of Tower Crane	-	1 (-)	-	1 (-)
Rising·Moving·Lowering of the Load with Irregular Shape	40 (11)	27 (7)	1 (-)	68 (18)
Others	23 (2)	24 (-)	2 (-)	49 (2)
Total	113 (18)	118 (9)	21 (1)	252 (28)

According to <Table 6>, the casualties (19) from the failure of a flat woven webbing sling while working with a crane, which is 67.9% out of the total casualties from the failure of a flat woven webbing sling (28 casualties), were distributed as the followings: 10.5% (2 casualties) from assembling, disassembling or adjustment of steel material on construction site and 68.4% (13 casualties) from rising, moving, or lowering of the load with irregular shape and, when they are classified by the types of industry, they are distributed as 68.4% (13 casualties) from manufacturing and 31.6% (6 casualties) from construction. This leads to the conclusion that under rising, moving, or lowering of the load with irregular

shape by using a crane in manufacturing and construction, 46.4% and 66.7% of casualties and deaths respectively occurred out of the total casualties from the failure of a flat woven webbing sling.

Table 6. Classification of the accidents from the failure of flat woven webbing sling while working with crane ('12~'14)

Instrument Used		Manufacturing	Construction	Others	Total
Maintenance·Assembling of Facility / Inputting Product Material into Facility	Injured	1	-	-	1
	Death	-	-	-	-
	Sum (Casualty)	1	-	-	1
Assembling·Disassembling·Adjustment of Steel Material on Construction Site	Injured	-	1	-	1
	Death	-	1	-	1
	Sum (Casualty)	-	2	-	2
Press Machine Related Work	Injured	1	-	-	1
	Death	-	-	-	-
	Sum (Casualty)	1	-	-	1
Rising·Moving·Lowering of the Load with Irregular Shape	Injured	8	1	-	9
	Death	1	3	-	4
	Sum (Casualty)	9	4	-	13
Other	Injured	2	-	-	2
	Death	-	-	-	-
	Sum (Casualty)	2	-	-	2
Total	Injured	12	2	-	14
	Death	1	4	-	5
	Sum (Casualty)	13	6	-	19

### III. Review of the Rules and Standards about the Failure of Flat Woven Webbing Sling

#### III.A. Removal criteria

<Table 7> shows the criteria of prohibition of using a flat woven webbing sling. 6-8 These domestic and foreign criteria do not have any numerical value or objective standard but rely on visual evaluation of a flat woven webbing sling or parts. Furthermore, the domestic criteria of prohibiting use of flat woven webbing sling were less concrete and more unclear compared to the other criteria.

Table 7. Removal criteria for a flat woven webbing sling

Classification	Prohibition Criteria
Local Rule on Occupational Safety and Health Standard Article 169 (2015)	Article 169 (Prohibition of Use of Strand-Cut Fiber Rope, etc) Fiber ropes or fiber belts which refer to any of the following cases shall not apply to lifting machinery. A. One with cut strands B. Severely damaged or corroded
OSHA 1910.184(i)(9)	1910.184(i)(9) Removal from service. Synthetic web slings shall be immediately removed from service if any of the following conditions are present: 1910.184(i)(9)(i) Acid or caustic burns; 1910.184(i)(9)(ii) Melting or charring of any part of the sling surface;

	1910.184(i)(9)(iii) Snags, punctures, tears or cuts; 1910.184(i)(9)(iv) Broken or worn stitches; or 1910.184(i)(9)(v) Distortion of fittings.
ASME B30.9-5.9.4 (2010)	9-5.9.45 Removal Criteria A synthetic webbing sling shall be removed from service if any of the following conditions are present: (a) missing or illegible sling identification (see Section 9-5.7) (b) acid or caustic burns (c) melting or charring of any part of the sling (d) holes, tears, cuts, or snags (e) broken or worn stitching in load bearing splices (f) excessive abrasive wear (g) knots in any part of the sling (h) discoloration and brittle or stiff areas on any part of the sling, which may mean chemical or ultraviolet/sunlight damage (i) fittings that are pitted, corroded, cracked, bent, twisted, gouged, or broken (j) for hooks, removal criteria as stated in ASME B30.10 (k) for rigging hardware, removal criteria as stated in ASME B30.26 (l) other conditions, including visible damage, that cause doubt as to the continued use of the sling

**III.B. Strength Standards of a Flat Woven Webbing Sling**

Table 8. Tensile Load Strength Standards of a Flat Woven Webbing sling

Classification	Tensile Load Strength Standards
S Mark Certification – A Guideline for Safety Certification on Flat Woven Webbing Sling, Made of Man- Made Fibers (S2-M-9-2009)	<ul style="list-style-type: none"> <li>• Support 7 times of the nominal working load if there is no fitting</li> <li>• Support 5 times of the nominal working load if there is fitting</li> <li>• Here at, the nominal working load is the maximum load to be put on at the unfolded single sling</li> </ul>
Textile slings – Safety- Part 1 : Flat woven webbing slings, made of man-made fibers, for general purpose use (KS K 0929:2008) (EN 1492-1:2000+A1)	<ul style="list-style-type: none"> <li>• The specimen for a sling other than C/Cr-type (with fitting) shall be subjected to a force equivalent to not less than 7 times the WLL</li> <li>• The specimen for a C/Cr-type sling shall be subjected to a force equivalent to not less than 5 times the WLL</li> <li>• Hear at, working load limit (WLL) is maximum mass which the sling is designed to sustain in straight pull and which the sling is authorized to sustain in general lifting service</li> </ul>

The strength standard of flat woven webbing sling is as shown in <Table 8>.1, 2, 9 In case of flat woven webbing sling without fitting, the S mark certification, KS standard, and EN standard applied 7 times or more of the nominal working load, and in case of flat woven webbing sling with fitting, they applied 5 times or more of the nominal working load.

As a reference, the working load limit used in the KS standard and EN standard refers to the maximum vertical load to be supported by a flat webbing sling (a value to be varied under the hanging method of sling or sling parts), but when conducting load test, the load is applied at the unfolded single sling, which means the nominal working load. Therefore, to remove confusion of terms, for the term used for tensile load test, the nominal working load from the S mark certification shall be used instead of a term working load limit from the KS standard.

#### IV. Strength of Flat Woven Webbing Sling in the Market

To check the strength of flat woven webbing sling in the market, the tensile load test was performed on the flat woven webbing slings in the market. The result is as shown in <Table 9>

Table 9. Tensile Load Strength of a Flat Woven Webbing sling

Nominal Working Load (Width * Effective Use Length)	Strength Standard	Test Value	Rate (test/criteria)
0.8 tf (25mm*2000mm)	5.6 tf	3.68 tf	65.7 %
1.6 tf (50mm*2000mm)	11.2 tf	9.93 tf	88.7 %
2.4 tf (75mm*2000mm)	16.8 tf	16.23 tf	96.6 %
3.2 tf (100mm*2000mm)	22.4 tf	18.17 tf	81.1 %

\* A sample flat woven webbing sling is both-end eye type.

\* Applied 7 times the nominal working load as the strength standard (refer to the S Mark Certification and KS Standard)

According to the result of tensile load test, the tensile load strengths of flat woven webbing slings in the market were about 65.7% ~ 96.6% to the tensile load strength standard, and this indicates that lots of flat woven webbing slings in the market may usually have the tensile load strength below the standard. Therefore, through the above experimental test, it seem to be imminent to inspect the flat woven webbing slings in the market and to have accurate and clear disposal criteria of flat woven webbing sling to prevent the failure of them in use.

#### V. Conclusion

This study was to perform the research about the characteristics of industrial accidents and the relative standards regarding the failure of a flat woven webbing sling to propose an issue of insufficient contents of domestic laws and regulations even with seriousness of disaster from disconnection of a flat woven webbing sling in an industrial field and to seek the resolutions, and the results may be summarized as below.

1) The average annual casualties from the failure of a flat woven webbing sling are 9.3, and the rates of casualties are distributed as the followings: 64.3% from manufacturing and 32.1% from construction, leading 96.4% total from construction and manufacturing. Furthermore, the number of casualties from the failure of a flat woven webbing sling (28) took 11.1% of the total casualties by accidents with respect to a flat woven webbing sling (252), and the number of deaths by the failure of flat woven webbing sling (6) took 30.0% of the total deaths by accidents with respect to a flat woven webbing sling (20). This surely indicates seriousness of accidents from the failure of a flat woven webbing sling.

2) The average labor loss days by casualties from the failure of a flat woven webbing sling are 1828.1, or 2.5 times the average labor loss days, 728.9 days, by casualties from non-failure of a flat woven webbing sling, again showing seriousness of accidents from the failure of a flat woven webbing sling, and the average labor loss days in construction was the highest among fields of work.

3) Based on the machines used when the accidents with respect to a flat woven webbing sling occurred, 67.9% (19 casualties) out of the total casualties (28) from the failure of a flat woven webbing sling and 83.3% (5 casualties) of deaths out of the total deaths (6 casualties) occurred concerned with a crane. Furthermore, among casualties from the failure of a flat woven webbing sling on a crane, 68.4% (13 casualties) fell under manufacturing and 31.6% (6 casualties) fell under construction, and out of the deaths (5 casualties), 80.0% (4 casualties) fell under construction and 20.0% (1 casualty) fell under manufacturing. Therefore, 67.8% of total casualties from the failure of a flat woven webbing sling and 83.3% of total deaths from the failure of a flat woven webbing sling were generated from a work using a crane in manufacturing and construction.

4) The rates of casualties from the failure of a flat woven webbing sling (28) in each work type were 14.3% (4 casualties) in maintenance or assembling of facility/inputting product material into facility, 7.1% (2 casualties) in assembling, disassembling or adjustment of steel material on construction site, and 64.3% (18 casualties) in rising, moving or lowering of the load with irregular shape. Furthermore, the rates of casualties from the failure of a flat woven webbing sling using a crane (19 casualties), which takes 67.9% of the total casualties from the failure of a flat woven webbing sling (28 casualties), were

10.5% (2 casualties) in assembling, disassembling or adjustment of steel material on construction site and 68.4% (13 casualties) in rising, moving or lowering of the load with irregular shape, and the rates for each field were 68.4% (13 casualties) in manufacturing and 31.6% (6 casualties) in construction. Therefore, this led to the conclusion that under a work of rising, moving or lowering non-standardized load by using a crane in manufacturing and construction, 46.4% and 66.7% of casualties and deaths, respectively, from the failure of a flat woven webbing sling were generated.

5) Regarding the criteria of prohibition of using a flat woven webbing sling, the criteria do not have any numerical value or objective standard but rely on visual evaluation of a flat woven webbing sling or parts. Moreover, as Local Rule on Occupational Safety and Health Standard only states as, “one with cut strands or severely damaged or corroded shall not be used”, and thus the domestic criteria are less accurate and more unclear. The result of studying about the standard of tensile load strength indicated that in case of flat woven webbing sling with S mark, KS standard, and EN standard but without fitting, the 7 times or more of the nominal working load is applied, and in case of flat woven webbing sling with fitting, the 5 times the tensile load product standard is applied.

6) According to the result of tensile load test of flat woven webbing sling in the market, the tensile load of flat woven webbing sling has about 65.7% ~ 96.6% of the stiffness standard, showing an example that a flat woven webbing sling used in the market may have a strength lower than the standard. Therefore, the above experimental result may become one of reasons to have accurate and clear removal criteria of flat woven webbing sling for its safe use.

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