Effects of Fall Restraint Systems at a Nuclear Power Plant Construction Site

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1. Introduction

According to the Occupational Safety and Health Administration (OSHA), the leading causes of fatalities at a construction site are “falls”, followed by “struck by object”, “electrocution”, and “caught-in/between” during the 2016 calendar year. These “Fatal Four” were responsible for more than half (64%) of the construction worker deaths; with 384 out of 991, or 39% of total deaths at construction sites in 2016 due to falls [1]. Falls are closely connected with ‘working at height’ activities and nuclear power plant (NPP) construction sites have many ‘working at height’ activities.

However, if a NPP project eliminates the root causes of working at height risks, many worker’s lives can be saved. Therefore, the stability of safety facilities for structural steel work at NPP construction sites would be an important part of a fall restraint system. This paper will describe how construction safety was implemented at the Barakah Nuclear Power Plant (BNPP) project as well as analyzing on site incidents and accident data.

2. Stability Test and Methods

There are two types of fall restraint systems used at the BNPP site as shown in Fig. 1. One is a self-assembly fall arrest system and the other is a safety net system.

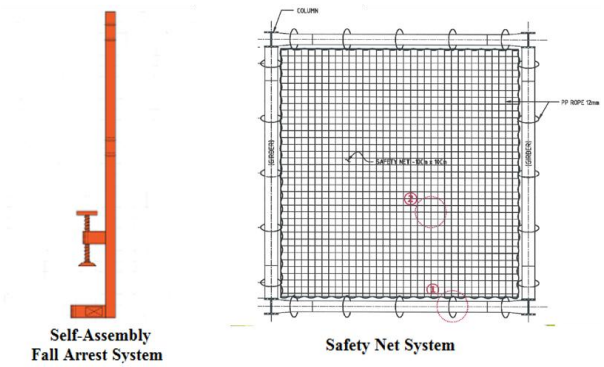

Fig. 1. Two types of fall restraint system. [2, 3] .

When installing the self-assembly fall arrest system, a metal wire is used between posts for hanging a safety harness. It is called a life line. The requirements of each equipment used for two types of fall restraint system are shown in Table I.

Table I: Equipment requirements [2].

System	Equipment/ Material	Standard	Minimum Requirement
Fall Arrest System	Horizontal Life Line	Wire Rope 8 mm	Breaking strength 2.2 ton
	Clip	Wire Clip 8 mm	-
	Post	Verified by KTFA	
	Lanyard	L: 180 cm	Breaking strength 2.2 ton
Safety Net System	Safety Net	-	10cm x 10cm
	Border Rope	Synthetic Rope (12 mm)	Breaking strength 1.4 ton

2.1. Self-Assembly fall arrest System Test

The test considers two cases of applied load for safety of the facility. One is the vertical force applied to the life line and the other is the vertical force applied to the post. The applied load on the self-assembly fall arrest system is based on the free fall of one person.

According to OSHA 1923.502.(d).(15), anchorages used for attachment of personal fall arrest equipment shall be independent of any anchorage being used to support or suspend platforms and capable of supporting at least 5,000 pounds (22.2 kN) [4]. Therefore, the applied vertical force is 22.2 kN for this test.

When freefall occurs at a life line, a vertical load of 22.2 kN is applied perpendicularly to the horizontal life line. At the same time, horizontal loads are applied along the life line on each side. The vertical load of 22.2 kN should be divided into 2 because the resultant vertical load will always on the center of the life line. The initial sagging and additional sagging due to freefall is accounted for. Details of all impact loads imposed on the life line and post could be calculated by using the geometry as shown in Fig. 2.

The maximum load imposed on the life line from Fig. 2 is 33.66 kN, while breaking strength of life line prequalified by metal wire manufacturer is 45 kN. Therefore, the life line is safe.

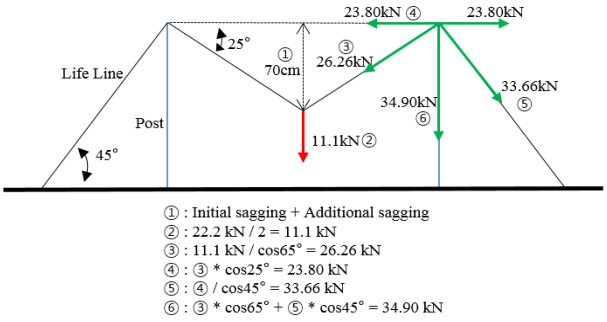

Fig. 2. Imposed loads analysis when freefall occurs at a life line. [5].

When freefall occurs at a post, a vertical load of 22.2 kN is applied directly to the post as shown in Fig. 3 below.

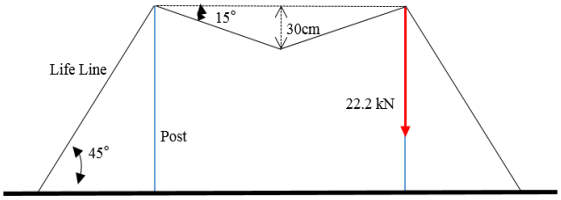

Fig. 3. Imposed loads analysis when freefall occurs at a post. [5].

The post is also prequalified for safety requirements by Korean Temporary Facility Association [6].

2.2. Safety Net System Test

According to OSHA 1962.502.(c).(8), each safety net (or section of it) shall have a border rope for webbing with a minimum breaking strength of 5,000 pounds (22.2 kN) [7]. And according to AD EHS RI-Cop 230.3.12.(e), personnel nets shall be 100 mm mesh intended to catch a person falling from above [8].

For the BNPP project, when installing a safety net, a contractor must follow a conceptual schematic in accordance with BNPP Site Internal Procedure. A safety net has four sides and each side has five loops tied with column [2].

When freefall occurs, a vertical load of 22.2 kN is distributed four ways. At the same time, five loops of each side divide the distributed load equally. The load imposed on the border rope of the safety net could be calculated by using the geometry as shown in Fig. 4.

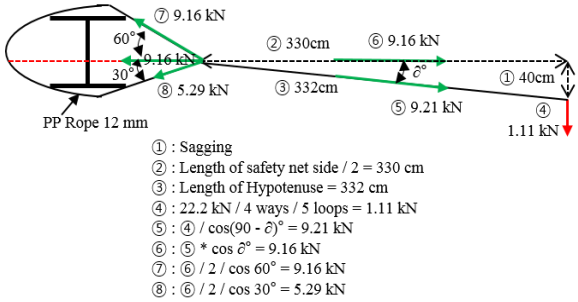

Fig. 4 Distributed load imposed on safety net. [5].

The maximum load imposed on a border rope is 9.21 kN, while the breaking strength of 12 mm PP rope verified by a third party certificate authority is 22.2 kN.

3. Results

The fall arrest system and safety net are very important safety facilities to prevent falls accidents. As OSHA classifies falls as a leading cause of fatalities at a construction site, falls may cause a serious accident to workers. There is a criteria indicating a degree of injury. BNPP is following a stricter criteria other than OSHA's basic requirement. According to BNPP recording procedures, a recordable injury can be classified as one of four types: Lost Time Injury (LTI), Restricted Work Case (RWC), Medical Treatment Case (MTC), and First Aid Case (FAC).

According to the lists of BNPP recording injuries, there were 6 falls accidents out of 279 injuries in 2013. Moreover, there was 1 case of RWC, 3 MTCs, and 2 FACs.

This study also analyzes the accidents related to falling objects to show the connection between the presence of safety nets and falls accidents. There were 17 cases of accidents related to falling objects out of 279 injuries in 2013. There were 3 RWCs, and 14 FACs. These detailed numbers, as well as others, are summarized in Table II below.

Table II: Accident status of falls and falling objects.

	RWC	MTC	FAC	Total
Falls	1	3	2	6
Objects	3	-	14	17
Total	4	3	16	23

A stability test of BNPP fall restraint systems was conducted in September 2013 as well as many 'working at height' activities that started in early 2013. The number of accidents before and after September 2013 had been analyzed to verify the effect on the two fall restraint systems. Total number of accidents related to falls and falling objects decreased from 14 to 9 and declined by 36% after applying the fall restraint systems as shown in Table III. In case of falls accident,

the RWC accident increased to 1, but total number of cases fell by half, from 4 to 2. Also, the number of falling objects cases decreased from 10 to 7 as shown in Fig. 5.

Table III: Accident status before and after September 2013.

		RWC	MTC	FAC	Total
Before Sep. 2013	Falls	-	2	2	4
	Object	2	-	8	10
	Sub-tot.	2	2	10	14
After Sep. 2013	Falls	1	1	-	2
	Object	1	-	6	7
	Sub-tot.	2	1	6	9

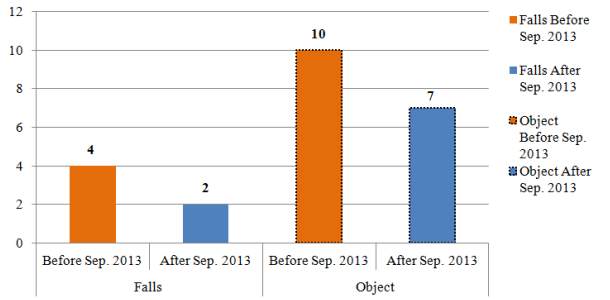

Fig. 5. Accident trend analysis for falls and falling objects.

4. Conclusion

Even though the number of BNPP accidents related to falls and falling objects declined after September 2013, it is still early to conclude that the number of accidents has been decreasing since the data was insufficient.

As the accident trend analyst clearly showed that the stability tests and managing a safety facility are critical and effective method in order to reduce the number of accidents at NPP construction sites.

To ensure a safe construction site, the fall arrest system and the safety net system are significant safety precautions.

REFERENCES

[1] O.S.H.A Commonly Used Statistics: OSHA Data & Statistics U.S department of labor, 2016.
[2] Hyundal E&C and Samsung C&T Joint Venture, "SIP-AR-07" Rev.4, Attachment 2, 2014.
[3] "조립식 안전난간", [Online], Available: http://sunjinico.com/safepole/309, [Accessed: 07-Aug-2018].
[4] O.S.H.A Laws & Regulations. Standards – 29 CFR, Part 1926 – Safety and Health Regulations for Construction, Subpart M – Fall Protection, 502 – Fall protection Systems Criteria and Practices, 1926.502.(d).(15).
[5] KEPCO, Doc.No. 0-300-D-301-006, Structural review of safety facility for structural steel work, 2013.
[6] Sekyung, Certificate No. 10-DA2BP-0200, Korea Occupation Safety and Health Acts, Clause 34, And Regulation 58.4, 2012.
[7] O.S.H.A Laws & Regulations. Standards – 29 CFR, Part 1926 – Safety and Health Regulations for Construction, Subpart M – Fall Protection, 502 – Fall protection Systems Criteria and Practices, 1926.502.(c).(8).
[8] Abu Dhabi EHSMS Regulatory Framework, EHS ReNNPPgulatory Instrument, Code of Practice 230.3.12.(e).