Structural Safety Evaluation of Zip-Line Due to Dynamic Impact Load

Bu Seog Ju, Jae Sang Kim, Woo Young Jung

***Abstract*—**In recent year, with recent increase of interest towards leisure sports, increased number of Zip-Line or Zip-Wire facilities has built. Many researches have been actively conducted on the emphasis of the cable and the wire at the bridge. However, very limited researches have been conducted on the safety of the Zip-Line structure. In fact, fall accidents from Zip-Line have been reported frequently. Therefore, in this study, the structural safety of Zip-Line under dynamic impact loading condition were evaluated on the previously installed steel cable for leisure (Zip-Line), using 3-dimensional nonlinear Finite Element (FE) model. The result from current study would assist assurance of systematic stability of Zip-Line.

***Keywords*—**Zip-Line, Wire, Cable, 3D FE Model, Safety.

I. Introduction

RECENTLY, number of people enjoying leisure sports increases significantly nationally and internationally. As a result, number of Zip-Line facilities has been increasing steadily. Previously, many researches were conducted on the cable and wire connected to the bridges [1]. However, researches on the behavior analysis of cable were very limited. Fall accidents from Zip-Line were being reported frequently due to the lack of consideration of cable behavior designed for leisure sports. In addition, due to its characteristics of Zip-Line, people are only replying on the cable of the Zip-Line. Therefore any accident occurring during the Zip-Line experience is directly related to injury or loss of life. Hence, it is necessary to evaluate the behavior of cable connected to the bridge. In current study, the steel cable facilities with prior history of fall accident were evaluated for the structural safety from dynamic impact using a finite element analysis using ABAQUS [2].

II. Finite Element Method of Zip-Line

Upon receipt of CAD drawings of Cable Wire, as shown in Figs. 1-3, three-dimensional finite element analysis were conducted using a general-purpose finite element analysis program, ABAQUS on two kinds of different shapes of cable wire and they were labeled as Case1 and Case 2. The physical properties used for 3-D finite element modeling can be found in Table I. Interpretation of current work focused on the cable wire, and the connected structure of cable wire were modeled as sieve attached to the rigid structure. The weight of loading conditions were selected in consideration of initial tension force (Case 1: 1.8*ton·f*, Case 2: 1.4*ton·f*) and moving load (for 150*kg* of move) for the dynamic impact analysis. The speed of moving load was considered to 54km/hr [3].

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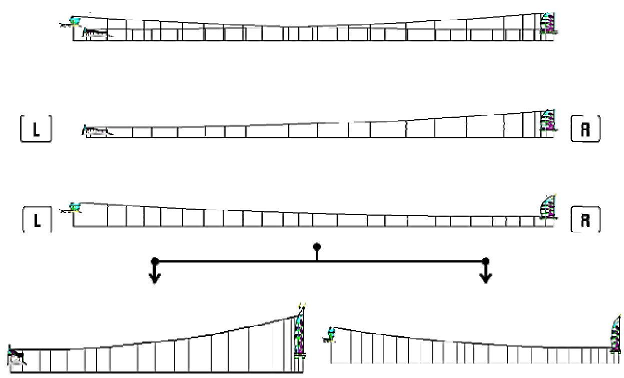
TABLE I
MATERIAL PROPERTIES OF CABLE WIRE

Symbol	Properties	Values
D	Diameter	12*mm*
A_c	Effective area	82.7mm^2
W	Weight	0.843*kg f*
E	Young's modulus	200000*MPa*
ν	Poisson's ratio	0.3
ρ	Density	7.454E-9t/mm^3
P	Weight of the moving load	150*kg*



(a) Case1 (b) Case2

Fig. 1 Schematic design of the cable (case1 & case2)

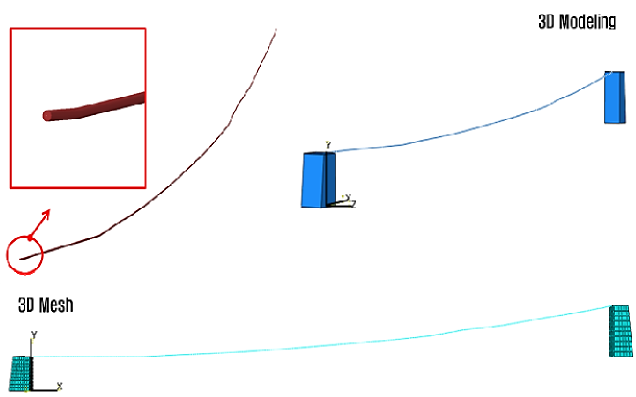


Fig. 2 Cable wire 3D modeling (case1)

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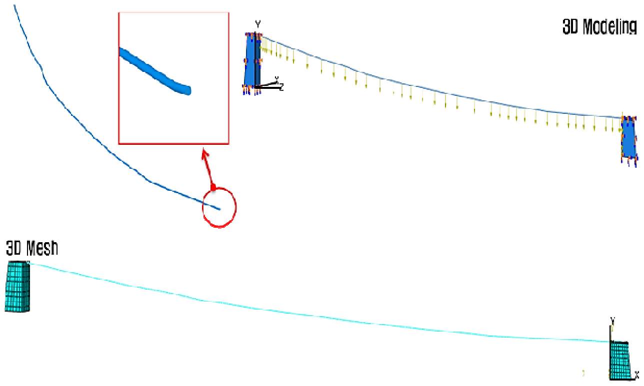

Fig. 3 Cable wire 3D modeling (case2)

III. Analysis Result and Discussion

Finite Element Analysis results revealed the maximum tensile stress from cable wire, as shown in Table II. The distribution of cable wire tension and stress were found in Figs. 4-7. In order to ensure the structural safety of cable wire, turnbuckles capable of holding larger than maximum tension of cable wire, and the materials holding greater yield strength than maximum stress, need to be selected for design and construction.

TABLE II
Dynamic Analysis Results for Cable Wire

Conditions	Maximum tension			Maximum stress (*MPa*)
	Horizontal tension (*ton·f*)	Vertical tension (*ton·f*)	Resultant force (*ton·f*)	
Case1	4.354	0.499	4.383	477.6
Case2	4.731	0.155	4.734	500.1

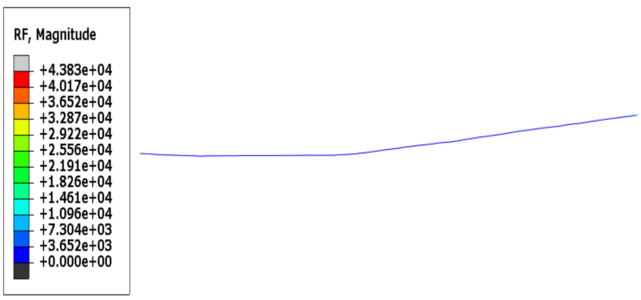

Fig. 4 Tension distribution for cable wire (case1)

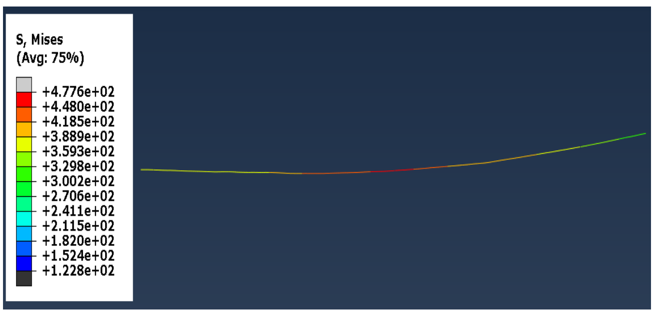

Fig. 5 Stress distribution for cable wire (case1)

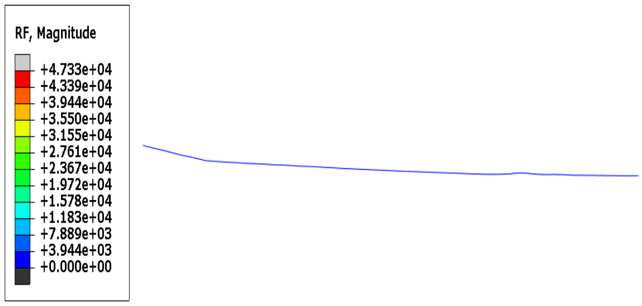

Fig. 6 Tension distribution for cable wire (case2)

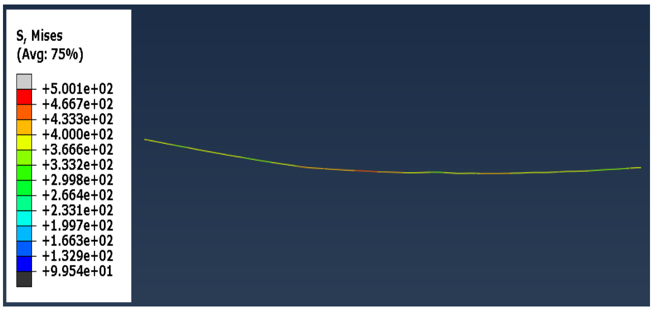

Fig. 7 Stress distribution for cable wire (case2)

Fig. 8 shows the test report of wire rope (KS D3514) [4]. Based on the current yield strength of wire rope, it is expected to measure the ultimate strength at the point of destruction, rather than measuring the yield strength of wire rope.

– Specified Breaking Load is defined as the minimum allowable force required for making a cable.
– Actual Breaking Load were the breaking load produced during the actual cable application test

Cables considered for current analysis satisfied the minimum allowable force standard, and the results can be found in Fig. 8. However the design criteria considered for current cable construction were not presented. Therefore, the tensile strength of current work was based on the specified breaking load, in consideration of safety factor. The allowable stress fracture of cable was selected on the basis of the results obtained from the actual cable failure experiment.

$$\text{Allowable Stress} = \frac{P}{A_c} = \frac{\textit{Specified Breaking Load}}{\textit{The Effective Area}} = \frac{12{,}900\times 10}{82.7} \fallingdotseq 1{,}559.85\ (MPa) \quad (1)$$

As a result of current analysis, the analyzed maximum tension from Case 1 is expected to be about 4.38*ton·f*. The maximum stress occurring at the cable, along with caused tension was 478*MPa*, and it seems to satisfy the allowable stress of1559.85*MPa* given by (1). The maximum tension from Case 2 was expected to be about 4.73*ton·f*, and the caused maximum tension was 500*MPa*, which also satisfy the allowable stress. However, this analysis did not considered the safety factor in accordance with the design criteria. The safety factor of each is 3.12 and 3.27, respectively.

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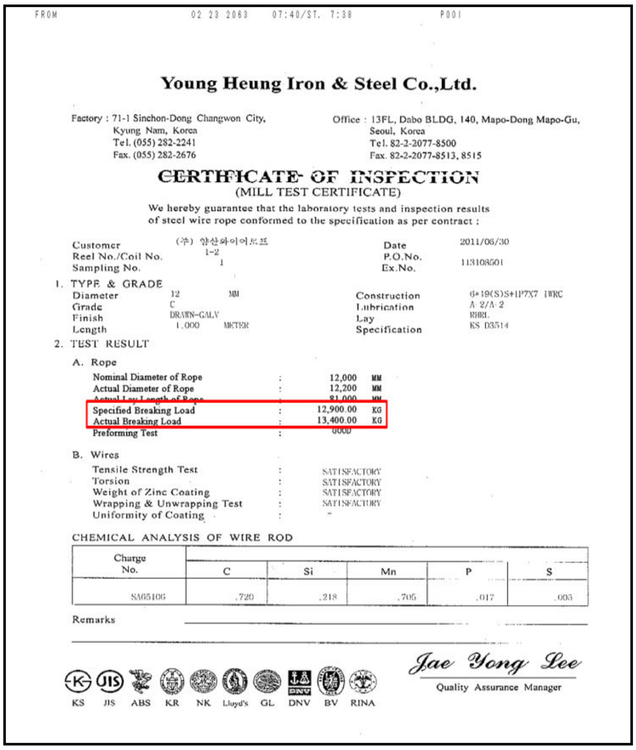

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CERTIFICATE OF INSPECTION
(MILL TEST CERTIFICATE)

We hereby guarantee that the laboratory tests and inspection results of steel wire rope conformed to the specification as per contract :

Customer (주) 양산와이어로프
Reel No./Coil No. 1-2
Sampling No. 1
Date 2011/06/30
P.O.No. 113108501
Ex.No.

1. TYPE & GRADE
Diameter 12 MM
Grade C
Finish DRAWN-GALV
Length 1,000 METER
Construction 6*19(S)S+IP7X7 IWRC
Lubrication A-2/A-2
Lay RHRL
Specification KS D3514

2. TEST RESULT

A. Rope
Nominal Diameter of Rope : 12,000 MM
Actual Diameter of Rope : 12,200 MM
Actual Lay Length of Rope : 81,000 MM
Specified Breaking Load : 12,900.00 KG
Actual Breaking Load : 13,400.00 KG
Preforming Test : GOOD

B. Wires
Tensile Strength Test : SATISFACTORY
Torsion : SATISFACTORY
Weight of Zinc Coating : SATISFACTORY
Wrapping & Unwrapping Test : SATISFACTORY
Uniformity of Coating : -

CHEMICAL ANALYSIS OF WIRE ROD

Charge No.	C	Si	Mn	P	S
SA65106	.720	.218	.705	.017	.005

Remarks

Jae Yong Lee
Quality Assurance Manager

KS JIS ABS KR NK Lloyd's GL DNV BV RINA

Fig. 8 Certificate of inspection for the steel wire (KS D3514)

IV. Conclusion and Future Effort

Based on the analysis results, prevention of destruction of both ends by using the turnbuckle with maximum tension capacity of approximately 4.73*ton·f* or higher was recommended. The occurred maximum stress would satisfy the allowable stress. However, current work considered the ultimate strength as the allowable stress, and the safety factor in the design criteria was not considered. Thus, In order to ensure that the result is within the range of allowable stress, it is necessary to take only small portion of yield stress and consider the safety factor from design criteria. Current work evaluated the structural safety of 280*m* cable wire at the dynamic impact. Introduction of other factors, such as safety factor, and the external variables such as wind and temperature of the ocean may impact the result. Therefore these external factors need to be considered in the future study. Current work contributes the systematic structural safety and stability of Zip-Line facilities from the design to the construction, and the results would be utilized as a fundamental data for the future research.

Acknowledgment

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References

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