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Design and Management of Rotatable Road Sign using Shear Key Structure for Strong Wind Load

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ABSTRACT

A rotatable road sign using a shear key structure is designed in order to ensure the safety of road sign structures. In other words, to reduce the wind load, a shear key structure is installed in the middle of a road sign structure to enable rotating in the event of typhoons or blasts, etc. If a wind is blown over the design wind speed, the road sign structure rotates on its inner steel pipe. In this paper, the technology developed could be used for the safety of a road sign structure because the distributed area of wind load, which is the main load of the road information sign support structures, is minimized. For expand of applicability, a rotatable road sign using the shear key structure is installed in a real in-field expressway.

1. INTRODUCTION

In Korea, a very powerful typhoon, "Mammy" whose maximum instantaneous wind speed was over 60m/s attacked the southern coast in September 2003, and lots of road information facilities were destroyed on the Namhae Expressway and national roads(Shon, et al, 2006). Thus, the functions of roads were degraded due to the damage of facilities caused by wind load or the secondary damage may occur due to blocking off roads or the damage or function loss of facilities. In this reason, a rotatable road sign using a shear key structure is designed in order to ensure the safety of road sign structures, which are requisites to ensure safety in road transportation and smooth transportation (Choi et al, 2010). In this paper, design and management of the developed rotatable road sign was described.

It is stated that strong winds with speed higher than the design wind speed have recently increased due to climate change (KMA, 2018). A rotatable road sign using a shear key structure was used in order to prevent road signs from being damaged due to strong winds and secondary accidents from occurring and to enhance the safety of road signs and the efficiency of maintenance. As a result, the wind load was reduced.

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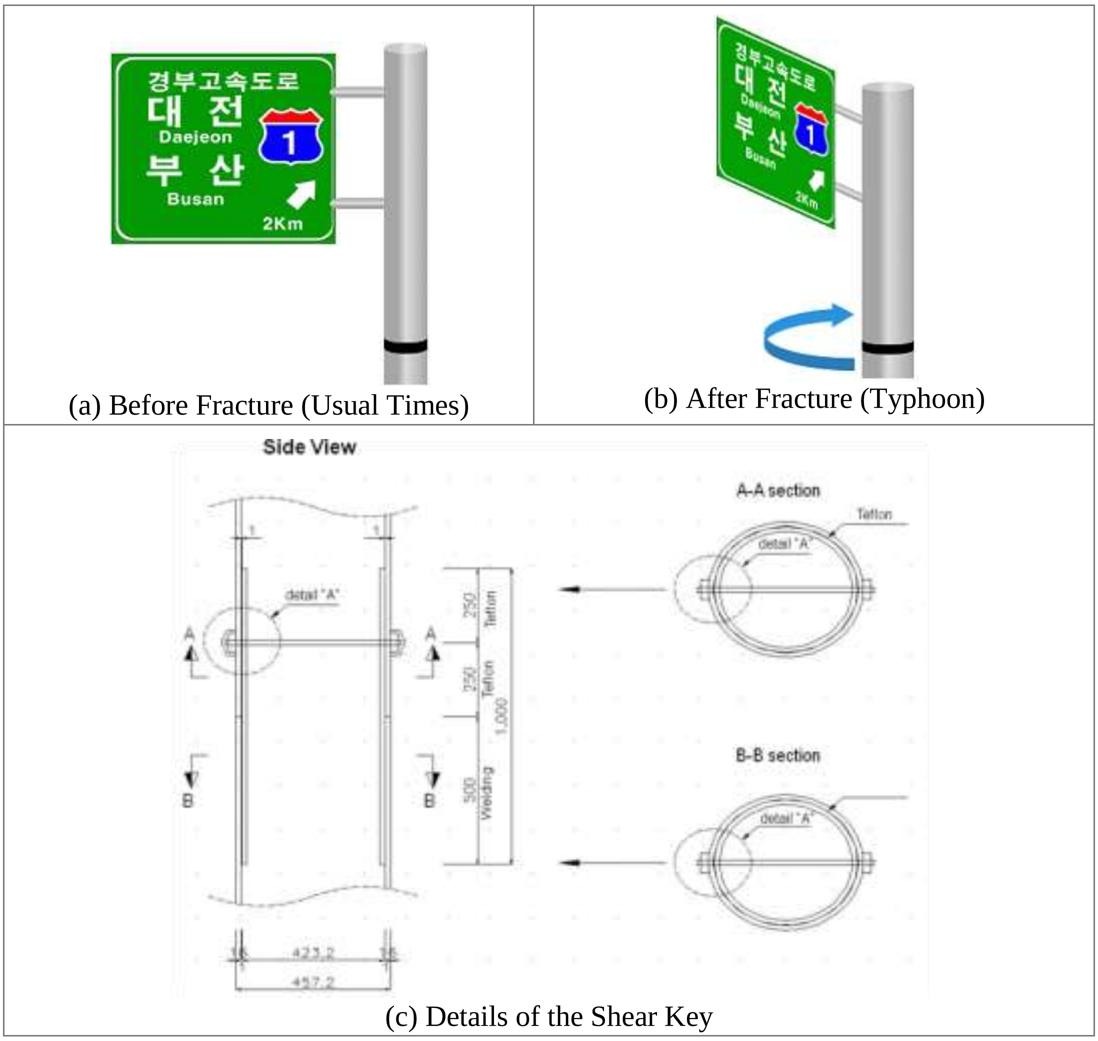
The developed road sign was applied to an actual expressway as a pilot test to verify its practicability.

2. THE ROTATABLE ROAD SIGN USING A SHEAR KEY STRUCTURE

For the understanding, the rotatable road sign using a shear key structure are described as follows: A shear key structure was installed on the mid-section of the support for road signs and wind load was reduced to prevent signs on expressways from being damaged under an abnormal climate where a strong wind occurs higher than the design wind speed. The support endured a wind with the design speed by using the shear key that enabled structural behavior. When a strong wind with speed higher than the design wind speed occurred, the support rotated at the axis of the inner steel tube due to the brittle destruction of the shear key.



(a) Before Fracture (Usual Times)

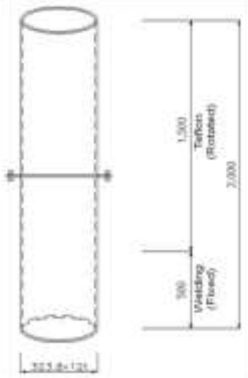
(b) After Fracture (Typhoon)

(c) Details of the Shear Key

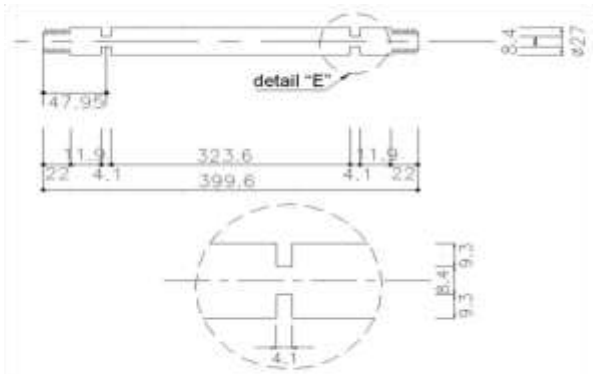
Fig. 1 Concepts of the Rotatable Road Sign and Detailed Structure of the Shear Key

In order to verify the brittle fracture and shear stress of the material (Chromium Molybdenum Steel; SCM440)(API, 2009) used for the shear key structure and to determine the optimal diameter of the shear key, which meets the design wind speed, an Laboratory shear test was performed. The shear test was to determine the optimal diameter of the shear key after shear loading (applied 30㎧ of wind speed) using a UTM test instrument (weight: 200 t). The specification of the main materials used for the test and quality criteria are shown in Fig 2.

It is noted that the result of the indoor shear test met the analysis result of 12.6mm, which was the processing diameter of the shear key groove based on the structural analysis of the yield stress in accordance with the KS(KSA, 1997) and US standards (API, 2009) and 30m/s of the design wind speed (KRTA, 2005). Depends on the wind speed change, diameter of shear key can be changed. As a result, the shear key was fractured at the shear groove as expected, and rotation was properly performed after fracturing. Thus, it was confirmed that the actual trial construction had no issues or problems.



(a) Details of the Internal Steel Tube



(b) Details of the Shear Key

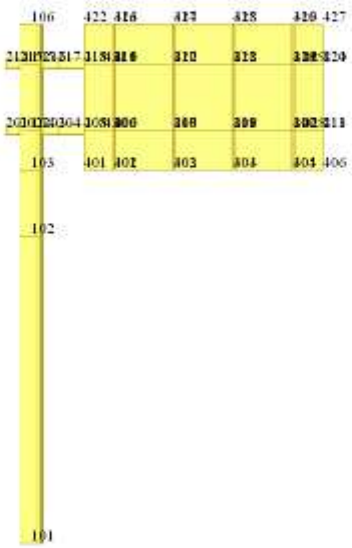
Specification [7]	API5L-B (Steel Tube for Oil Supply)	Specification [6]	SCM440(Chromium Molybdenum Steel)
Yield Point (kgf/㎟)	≥24.6	Yield Point (kgf/㎟)	≥85
Pull Strength (kgf/㎟)	≥42.2	Pull Strength (kgf/㎟)	≥100
Elongation Rate (%)	≥7	Elongation Rate (%)	≥12
Shock (J/㎠)	-	Shock (J/㎠)	≥59

Fig. 2 Specifications of Materials and Quality Criteria

In order to calculate the maximum stress of the rotatable road sign, a structural analysis was performed for the cantilever named [421-3](MOLIT, 2016) by using the structural analysis. Using this rotatable technology, section of the vertical or horizontal member, which is the main material for the current road signs, can be reduced and the road sign ensures better performance in terms of safety level.

After the shear key structure is being fractured, the maximum stress sharply decreased from 90.7kN/㎡ to 28.5kN/㎡. This value was about 31% of the stress of the traditional road signs. In addition, the safety factor against the allowable stress (140kN/㎡) increased from about 1.5 to 4.9. The safety factor increased by about 327%

compared to the value of the traditional road signs. It was theoretically analyzed that the rotatable road sign was able to endure 117 ㎧ of the maximum instantaneous wind speed in case of the improvement proposal for the cantilevered [421-3] (vertical member: Φ406.4×9mm) with the exception of the effects of the foundation and soil quality.



Material Name	Sectional Dimensions
Vertical Member (Support)	Φ 406.4 ㎜ × 9 ㎜
Horizontal Member	Φ 216.3 ㎜ × 4.5 ㎜
Horizontal Reinforcement	50 ㎜ × 100 ㎜ × 3.2 ㎜
Sign Plate	4.35 m × 3.5 m

Load Combination	
I	Static Load (D)
II	Static Load (D)+Wind Load (W)

Fig. 3 Sectional Dimensions and Load Combination of the Analysis Model.

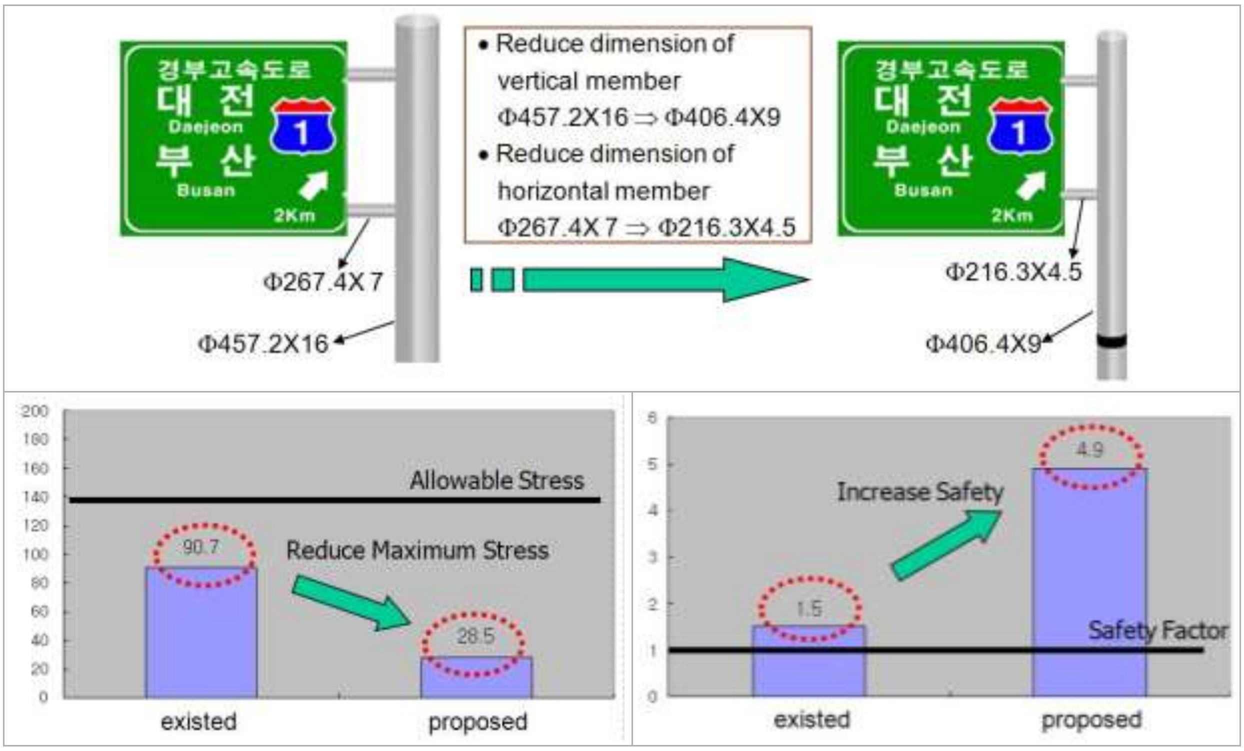


Fig. 4 Safety Factor Analysis of the Cantilevered [421-3] (Design Wind Speed 40m/s).

3. APPLICATION AND MANAGEMENT

Above description of the beneficial safety effects, if road sign using shear key structure is applied, sectional dimensions of road sign can be reduced as shown in Fig 4 and 5. For finding approval reason, weather data is investigated. Based on the data of the Korea Meteorological Administration, the maximum instantaneous wind speed for the last 10 years and the areas where typhoons had occurred were examined. As a result of comparing the extreme value of wind speed at about 200 weather stations, the number of times that the wind speed exceeded 40m/s, the number was not exceed 1 per year. Thus, we determined sectional dimensions of road sign can be possible but, it can be controversial.

Fig. 5 Examples of reduced dimension standards

In order to test and verify rotatable road signs, one Cantilevered [421-3] 3-Place Name Milepost road sign was installed at the STA. 2+000 of the first section on OO~OO Expressway in southern coast region in Korea. The purpose of the prototyped trial construction was to check if the shear keys at the rotatable road signs well operated when a strong wind occurred and to find out issues and problems. After 2 year of the trial installation, additional 7 rotatable road signs are constructed at the OO~OO Expressway in west southern region for the in-depth test and investigation.

Hold a rope	Draw a rope	Change the shear key

Fig. 6 Maintenance works

In the event of a strong wind, a shear key structure with a fracture groove is applied to the vertical support of a cantilevered road sign. After the shear key is fractured when wind speed is higher than the design wind speed, the road sign rotates and as a result reduces wind load. Once the strong wind ends, the shear keys just need to be replaced with new ones for complete maintenance. Maintenance time for replacing shear key will be estimated within 30 minutes. Because all works are just rotate back to initial position drawing 1~2 persons with rope and replace shear key on ladder as shown in Fig 6.

4. CONCLUSION

Design and management of the developed rotatable road sign was described. The mid-section of the support for the road sign was equipped with a shear key structure as a method for reducing wind load in order to prevent structures on expressways from being damaged and to ensure safety from strong winds whose speed was higher than the design wind speed. In order to verify its feasibility, actual trial construction was performed.

The technology developed in this paper can improve the safety of supports for road information facilities by minimizing the distribution area of wind load, which is the main load of road information facilities. In addition, if the technology is expanded, safety will be improved and cost-effectiveness will be able to be ensured.

It is concluded that this technology can contribute to expressways from being blocked to eliminate the inconvenience of expressway users and to prevent facilities on expressways from being damaged, especially in strong wind area.

- Safety is ensured and the next accident is prevented from occurring to enable the quick reduction of wind load when a wind with speed higher than the design wind speed occurs.
- Construction costs are reduced by about 8% to 26% by optimizing the sections of the road sign support due to lowering the design wind speed.
- If damage occurs due to a strong wind, the shear key just needs to be replaced with a new one. The time required to replace the shear key is only about 30 minutes. Because all works are just rotate back to initial position drawing 1~2 persons with rope and replace shear key on ladder. It is easier to maintain than the traditional road signs in case of failure due to strong wind load.

REFERENCES

Choi, Hyunho; Kim, Ki-Hwan; Lee, Eui-Joon; and kim, Jeon-Geun (2010), “Development of Rotatable Road Signs using a Shear Key Structure”, *Transportation Research Board (TRB) 89th Annual Meeting*.

Sohn, Yong-chun; Yu, Gil-hwan; Park, Su-yeong; Yim, Jong-guk; and Shin, Min-cheol (2006), “A study on the wind-resistant specific of road sign support structures”, *10th Spring Conf., the Korean Society of Road Engineers,* pp. 387-394.

KRTA (Korea Road & Transportation Association)(2005), Standards for the Design of Road Bridges.

MOLIT. (2016), *Installation and Management Guidelines of Road Safety Facilities*

KMA (Korea Meteorological Administration), *Annual and monthly Reports,www.kma.go.kr. Accessed March 2, 2018.*

KEC (Korea Expressway Corporation)(2006), Expressway Construction Road Sign Design.

KSA (Korean Standards Association)(1997), KS Handbook Steel.

API (American Petroleum Institute)(2009), Specification for Line Pipe, Forty-fourth Edition, Includes Errata and Addendum.