Maintenance effects of national freeway slope safety using facility full lifecycle management methods

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ABSTRACT

A huge landslide disaster occurred suddenly at 3.1k of the Freeway No.3 in 2010. It caused serious traffic interruption and 3 casualties. Two things were considered keeping the slopes in safe condition after this tragic event. One is to make the appropriate revisions on the maintenance manual; another is to build up a lifecycle-based maintenance and management system. To achieve the goals of aggressive and preventive maintenance, there are 4 grades of slope classifications based on the urgency degree of treatment. The photos of the degree of damage conditions for the periodical inspection items were sorted out which can be referred by tablet on working. From the statistical analysis, drainage inspections become the most critical works before the rainy season. The typical anchor detection grade results are shown by the photos. The percentages of anchor conditions beyond passably range from 57% to 86%. All of the anchors were checked and renovated to safe condition. The slope maintenance and management system is supported by the slope inspection operation system and the slope information sharing platform. All of them are very powerful and easy to work. It is evaluated that the data management time can be saved more than 30%. The inspections by electronic equipment can increase about 50% working efficiency. Through the operation manual revision and management system setup, the freeway slopes are safeguarded now.

Keywords: slope safety; maintenance management; full lifecycle

1 INTRODUCTION

The freeway network is the most important road transportation system in Taiwan. It was very shock that all the lanes at 3.1k of the No.3 Freeway were blocked due to huge landslide disaster on the clear weather condition. It occurred suddenly on April 25, 2010. Three cars were buried, caused 4 casualties. One cross over bridge was thrusted to collapse. The covered area was approximately 200 x 60 square meters and total volume of landslide was estimated about 100,000 cubic meters. After 55 days construction for recovery, the No.3 Freeway at 3.1k was re-opened. Then the slope reinforcement plan was proposed to avoid any potential problems such as 3.1k happening. 32 dip slopes along No.3 Freeway were examined by Chinese Taipei Geotechnical Society. According to these investigation results, the Freeway slopes were classified into 3 categories, i.e., the first priority sections, the second priority sections, and the others. The slope inspection, comprehensive ground anchor detection, monitoring, slope stability analysis and slope reinforcement design and construction were carried out in a sequential way. By the above doings, all the slopes were upgraded to at least grade C (no obvious signs of instability) or grade D (stable condition). At the same time, two things were considered keeping the slopes in safe condition. One is to make the appropriate revisions on the maintenance system, i.e., studying out the revised slope safety maintenance manual; another is to build up a lifecycle-based maintenance and management system i.e., a computerized operation system. The effects based on executive experiences and data collections are described as follows.

2 MAINTENANCE MANUAL

The slope maintenance manual (Freeway Bureau, 2017) contents include slope inspection, detection, monitoring and investigation; slope maintenance; personnel management and education; slope management meeting; establishment and application of slope maintenance information management system. It is the SOP of slope maintenance and management. The rolling modifications for the manual are done each year in the supervised meetings to increase the effects of maintenance.

2.1 Slope grade

In order to get the most efficient and money saving management, the slope must be classified into different grades. There are four slope grades (A, B, C, D) whose categorizations are based on the slope inspection, monitoring, anchor detection and stability assessment results.

Grade A Slope: obvious signs of instability can be observed, it needs to be announced immediately and

take some effective actions collocated with intimate inspection and monitoring.

Grade B Slope: some suspicious signs of instability can be observed, some maintenance, reinforcement and curing need to be taken with increasing inspection and monitoring.

Grade C Slope: no obvious signs of instability, it needs to take some inspections or regular maintenances, and monitoring done as needed.

Grade D Slope: stable condition, it still needs to take casual inspections.

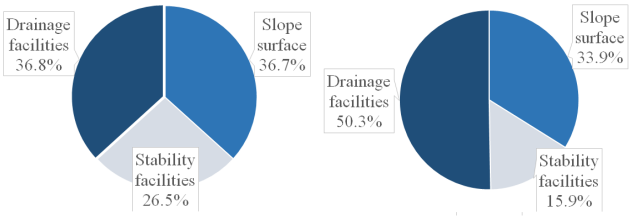
Now all of the Freeway slope grades are either C or D. They may be adjusted after impacts of earthquakes, typhoons, heavy rains or human factors. The slope inspection results are the fundamental data for the grades. The emphasis and frequency of patrolling, periodical and special inspection are shown in Table 1. There are 3 main items for periodical and special inspection, i.e., slope surface, stability facility and drainage. Each contains several items which need to be filled with the degree of damage condition during inspection. Some photos with high, medium and low degree of damage conditions of each item are shown in Fig. 1. All the inspection works can be done by the tablet and the necessary information can be referred through internet.

The characteristics of the slope classifications are according to the degree of treatment that can achieve the goals of aggressive and preventive maintenance. Fig. 2 shows the shortage statistics of main items of slope inspection in 2014 and 2017 for Northern Region Branch Office. It can be seen that the percentage shortage of drainage increased from 36.8% to 50.3%. On the other hand, the percentage shortage of stability facility decreased from 26.5% to 15.9%. Therefore drainage inspection becomes the critical works before the rainy season now.

Table 1. Inspection category, emphasis and frequency

Category	Patrolling	Periodical	Special
Emphasis	Influences to users, collapse or damage need emergently to deal with	Comprehensive detection to realize slope safety, finding deterioration of structures beforehand	Assessments of slope safety, structure condition and maintenance demand
Frequency	At least once every day, in daytime by patrol car	A：per month B：per season C：per year D：every 3 years	After typhoon, heavy rain or earthquake

Fig. 1. Photos of degree of damage conditions for some inspection items.



(a) 2014 (b) 2017

Fig. 2. The shortage statistics of main items of slope inspections in 2014 and 2017 for Northern Region Branch Office.

2.2 Anchor detection

The anchor detection works include function detection which contains test point chosen, visual inspection of head protection and inside component, wire corrosion checked by endoscope and lift-off test; anchor grade evaluation; protective seat of anchor head recovery and protection, etc. (Freeway Bureau, 2017). The photos of grade for protective seat of anchor head appearance inspection, grade for component of anchor head and grade for wire corrosion are shown in Fig. 3, Fig. 4 and Fig. 5, respectively. The anchor detection results by the above 4 methods from 2011 to 2013 are shown in Fig. 6. The percentages of anchor conditions beyond passably range from 57% to 86%. All of the anchor free ends were grouted for the protection of their wires and the anchor head were covered with galvanized plate and their internal spaces were filled specified grease. It can be seen that all of the anchors

renovated to safe condition.

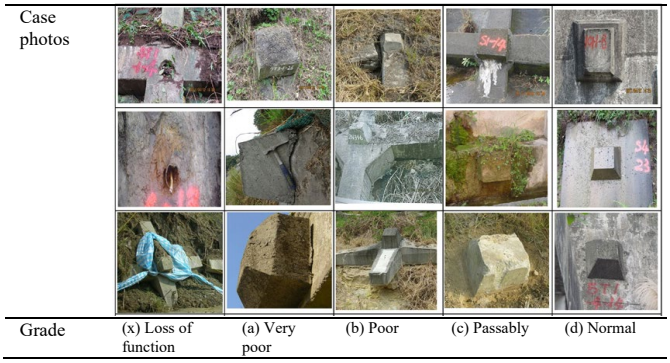


Fig. 3. Grade for protective seat of anchor head appearance inspection.

Fig. 4. Grade for component of anchor head.

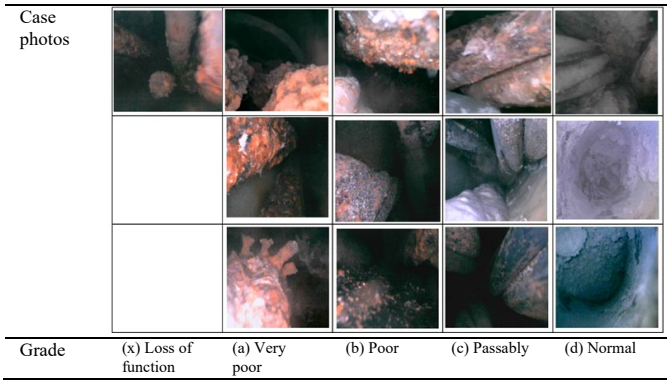


Fig. 5. Grade for wire corrosion.

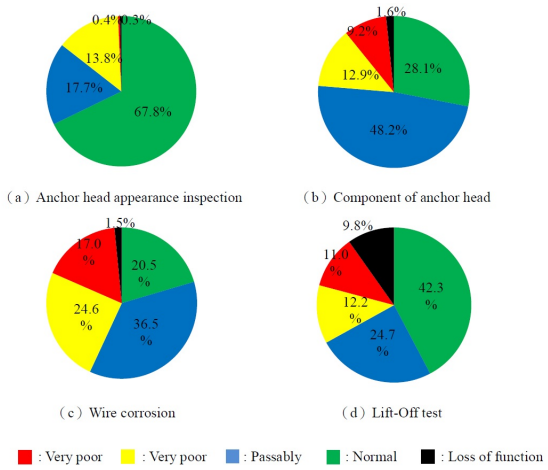


Fig. 6. Detection results of anchors from 2011 to 2013.

3 MANAGEMENT SYSTEM

3.1 Features

The key points for the services of running facility are to increase their lives and safe conditions. In order to achieve these objects, the maintaining works should start from planning, through construction, then to operation service. The most efficient and cost-down method is to utilize the aggressive and preventive procedures which include many small scale rehabilitations. Thus the period and transportation influence by maintenance works can be decreased. The slope maintenance and management system (SMMS) is developed based on the full lifecycle management idea. Two systems were developed too, i.e., the slope inspection operation system (SIOS) and the slope information sharing platform (SISP).

The SMMS system is not only the normal management information system (MIS) but also an interactive and visualization system. Except providing the functions of data collection, storing, classification, inquiry, the functions of situation reciprocation and processing tracing, waiting list notice and tracing, abnormal event notice, focus section monitoring and controlling are developed. Moreover the system also increases the values of information which include statistical analysis of inspection and maintenance records, accumulations of damage histories, slope grading and safety evaluation, etc.

The SIOS uses the tablet as the operation tool during inspection. It can download the recent fundamental slope information and offline map; show the shortage of the position and photo in the last inspection; locate the shortage position and take the picture; the shortage records (containing pictures) return to SMMS with 3G or upload in the office if no 3G signal insitu; record the track of inspection and confirm if the check points passing through. The SISP is a large quantity of document database which includes slope fundamental data, inspection data, maintenance data, detection and monitoring data, safety analysis and reinforcement data, disaster cases, education and

training data, specification, manual and the others. All of these systems are very powerful and easy to operate.

Many integrated function can be completed in this system, e.g., the northern Freeway map is set on the disaster potential map made by Central Geological Survey, MOEA, shown as Fig. 7. It can easily catch out what is the potential disaster along the freeway. The landslide accumulated rainfall thresholds established by National Science and Technology Center for Disaster Reduction (NCDR) can be used as early warning value in the beginning (Lin et al. 2018). It showed another typical integrated function provided by the system for the early warning.

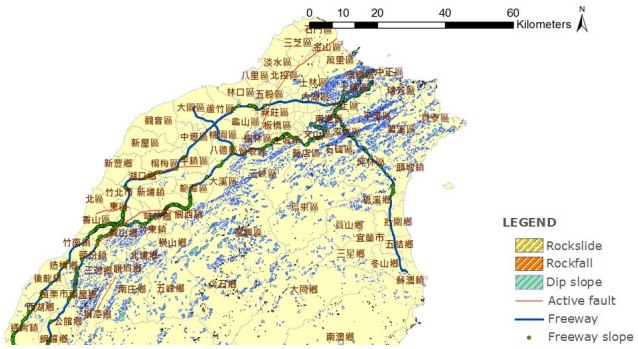


Fig. 7. Disaster potential map for the northern Freeway.

3.2 Effects

There are totally 2,565 slopes along freeway including 927 excavation slopes and 1,638 embankment slopes. Until now, there are 148 slopes installed with 1,942 monitoring sets and 139 slopes stabilized with 27,396 ground anchors. All of their monitoring and detection data have been input to the system. And the 60,561 inspection data (including slope defect photos) can be inquired by the system. Meanwhile, the system also provided the management for more than 300 engineering and technical service cases. The different management and statistic tables and synthetic working results can be generated. It is evaluated that the data management time can be saved more than 30%. The inspections by electronic equipment can increase about 50% working efficiency, automatic check processing can decrease the time and human resource.

4 CONCLUSION

Through the operation manual revision and management system setup, the freeway slopes are safeguarded now. The overall inspections will be done to check all the maintenance actions following the referred regulations. It is the first case in Taiwan that the maintenance was implemented completely based on the manual regulations and all of the concerning data were recorded in the system. All of these experiences can be referred for the other slope maintenance offices or companies.

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