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Development of Real-Time condition Assessment method For Landing Pier-Type wharf Structure monitoring System

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Abstract: *This study introduces a real-time condition assessment diagnosis system for landing pier-type wharf structures based on the Internet of things. This system is comprised of (a) installation of FBG sensors (strain, displacement, and speedometer) to the wharf structure, (b) wireless transmission of collected data, and (c) real-time data analysis to determine structure stability. The real application of this system has been carried out on a wharf structure situated in Marayng-Meon, Korea. This system utilizes LTE communication protocol to transfer sensed data to the IoT gateway. The proposed system utilizes assessment algorithm to comprehensively analysis the stability of the structure and determines the damage information. This system stores data and share information in real time with the remote users such as safety supervisor via Smartphones. Moreover, this system warns by sending an alarm and LED digital display boardon the structure. Thus, the proposed system enhances the functional efficiency and objective evaluation on monitoring of wharf structure by connecting it with IoT sensors, telecommunication, and real-time structural analysis.*

Keywords: *Condition Assessment;Structure Health Monitoring;Wharf Structure; FBG Sensing; Internet of Things*

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I. Introduction

In Korea, more than 25% of domestic port facilities were developed in the 1960s and 1970s, and these facilities are rapidly aging. Since many structures have passed thirty years of their service, therefore, now the maintenance of such structures become of vital importance. Furthermore, the weak stratum for the harbor soil conditions in Korea is deep, caused to construct numerous piers type wharf structures in the soil. Generally, after a certain period of service, the piles or other components of wharf structure become corroded and causes the development of cracks.Therefore, periodic inspections are regularly performed every year to enhancethe safety management and durability of these structures[3][4][5].The existing port facility maintenance management system carries out the conditionassessment by inspection and diagnosis under the "Special Law on Facilities Safety and Maintenance". Most of the facilities inspection and diagnostic methods are conducted through visual inspection to evaluate the condition of the structure. Since the structure is evaluated by an inspector,the opinion of the investigator is reflected to the condition that the assessment will be evaluated subjectively. Therefore, new method for condition assessment of the wharf structures is necessary to evaluate the structure objectively[5].Particularly, the underwater part of the wharf structures is accompanied by the visual inspection through the divers and the sound wave irradiation, but the shellfish or pollutants are fixed on the surface of the underwater structure that makes it hard and time-consuming to investigate. According to the law of the sea, divers cannot work more than two hours per dive and have to take a rest for six hours to prevent from decompression sickness.Thus, new methods of investigation are highly required that would not be interrupted by the shellfish and pollutants or use divers[3][4].Moreover, the degree of wharf structure deterioration and its causes are judged for whether or not structure is damaged after the deterioration. In addition, the time lapse between inspection and maintenance is so large causing to deteriorate structure drastically. Hence, real-time condition assessment method is necessary to prevent damages before it happens and to manage the port facilities efficiently[1][2].Furthermore, since various wharf facilities such as a large size floating piers, floating offshore structus, and immersed tunnels are under construction or planned, objective and real-time condition assessment method for the wharf structure is necessary to increase the new wharf facilities. Therefore, real-time conditionmonitoring and assessment system for landing pier-type wharf structure has been developed using Internet of Things (IoT) technology. . FBG sensors were installed on the various components of structure to replace divers and to get continuous real-time monitoring of wharf structure. Finally, the condition assessment method is designed based on the“Port and Fishing Port Design Standards” to evaluate the structure efficiently.

II. Architecture of Landing pier-type wharf structure monitoring system

Landing pier-type wharf structure monitoring system is installed on a wharf situated in Marayng-Meyon, Korea. The wharf is a national fishing port called Maryang-harbor that is constructed in 1999. The wharf is a pier-type wharf structure that is suitable for durability test and sensor performance test. However, Figure 1 shows the system installed on the structure that (a) and (b) demonstrates the FBG strain sensors on the pile for above and below the sea level. Also, (c) demonstrates the IoT gateway installed on the structure and (d) is the screenshot of the web server for monitoring the structure.[Figure 1]Landing pier-type wharf structure monitoring system is composed of three main parts as Figure 2 demonstrates: FBG sensors, IoT gateway and main server. Gateway collects data from sensor nodes and utilizes LTE module to deliver the sensed data to main server. Main server runs the designed algorithm to evaluate the condition of structure. This system displays the real-time data and also stores this data, moreover, data can be recall any time for the investigations or future design considerations. This system warns managers using Smartphone and share information on the digital display board installed on the structure for the people inside wharf.[Figure 2]

2.1.Fbg Sensors:

Fiber Bragg Grating (FBG) sensors were installed on the pier type harbor structures to detect any feeble change in structureinreal-time monitoring. The FBG sensorsare fiber optic assembly fabricated using the phenomenon that the refractive index is increased by exposing germanium (Ge) added optical fiber core part to strong ultraviolet rays. In the FBG sensor, light propagating along the optical fiber is attenuated, absorbed, dispersed, and changes it wavelength and refractive index causing to change the optical signals resulted from the scattering, interference, diffraction, and non-liberalization effects. Thus, making it possible to measure minute changes according to the external environmental conditions. Therefore, FBG strain sensors, FBG displacement sensor and FBG speedometer were selected in this system among many other options. The physical changes detected by the FBG sensorsare measured by an automatic measuring system. This automatic system converts, analysis numerical values and plots on graphs to evaluate structural safety which is helpful for scheduling maintenance plan.

2.1.1.FBG strain sensors:

FBG strain sensors are installed on the piles to measure stress shown in Figure 2.Qualitatively evaluated damages and impacts were graded using threshold limiting values defined by a ratio between the stress calculated to the allowable stress. In addition, the cracks were categorized according to the crack width opening. The measurement range of the strain gauge sensor is 500 mm having a gauge length of 0.5 m and a resolution < 1/1000 was required for this specific purpose. The bandwidth was <0.15 and error after immersion test was within ± 0.5% (IP Rating: 68). Because of the corrosive environment and harsh operating conditions, it was required to cover all the sensors with waterproof casing. Therefore, all the sensors had stainless steel casing as shown in Figure 3(a) and (b).[Figure 3]

2.1.2. Fbg Displacement Meter:

The displacement meter is attached to the surface of the pier for measuring the bearing strength that is demonstrated in Figure 4. The grade is quantitatively measured and presented using the evaluation criteria according to the amount of pier scour. Further, the measuring range of the sensor is approximately ±18cm or more, the resolution is less than 1/100, the half bandwidth is 0.15 or less, and the error after the immersion test is approximately ± 0.5% (FS) (IP rating: 68). [Figure 4]

2.1.3.Fbg Speedometer:

The FBG speedometer is applied to the wharf structure to measure berthing force thata ship exerts on structure during docking. Generally, during ship docking, the operator of sailors is not sure about the speed of ships, as higher the speed higher the impact force. In order to impose speed limits for the structural safety of wharf, it was necessary to install speedometers to monitor the speed of docking ships. Therefore, FBG speedometers were also installed along with strain and displacement sensors. [Figure 5]

2.2 Internet of Thingsgateway:

Each FBG sensor is connected to the sensor network through the gateway to transmit the data from the sensors. The signal detected by the FBG sensor is transmitted through the gateway and the communication network by optical cable. Furthermore, the signals detected by each FBG sensor are stored in a data logger. The data logger collects the variation data of the FBG sensors and transmits it to the server using LTE module. The management server or manager terminal includes hardware and software for converting, analyzing, and evaluating data in real time.

2.3Main Server:

The system is provided with an integrated control server including a safety diagnosis algorithm to assess safety of pier and end wall for the plurality of the FBG sensors data received from gateway. The main server is also integrated with a web server for the real-time assessment and information sharing. The administrator interface system includes an administrator's PC, tablet, or any mobile devices. The visualization of this system is provided in a graphical user interface so that managers and other related staff can monitor structure anytime anywhere. Whenever, the system detects any abnormality, it automatically sends an alarm to manager and also displays on LED installed on structure for common people.

III. Real-Time Condition assessment Method

Real-time condition assessment and monitoring of structure is the main objective of this study. The entire stages of assessment and monitoring are illustrated by Figure 6. This flow chart explains the factor of safety based on three components, allowable designed stress, bearing capacity of structure, and berthing force. The evaluation of safety factor (SF) of structure follows the standards of “port and fishing port design”.
[Figure 6]

3.1.Allowable stress:

The real-time measurement from the sensors, the stress generated in the pile structure of pierced quay walls is divided into two components: (i) the stress due to the fixed load and (ii) the stress due to the loads other than the fixed load.The prior oneis calculatedfrom structural analysis of the structure. On the other hand, the stress measured by the FBG sensors is classified as a load other than the fixed load. This can be from the docking force, wind pressure, wave force, tidal force, and seismic force. The total stress occurring in the pile structure is calculated by adding the stress due to the fixed load and the real-time generated stresses, and the SF of each pile structure is calculated by the following equation:

$$\mathrm{S.F} = \frac{f_a}{f} \ , \qquad (f = f_d + f_1)$$

where f_a is the allowable stress and f is the actual stress. The actual stress is combination of dead load f_d, that can be calculated from the structural analysis and real-time stress f_1. Moreover, the real-time stress is calculated by following equation:

$$f_1 = \varepsilon_1 \times E$$

where E is young’s modulus and ε_1 is real-time strain value that is measured from FBG strain sensors. From the equation 2, the SF can beeasily calculatedto evaluate the condition of the structure.

3.2.Bearing power:

The safety of the file bearing capacity is difficult to measure from axial force. Therefore, the permissible bearing capacity is determined using the scour generated around the pile, and the bearing capacity is confirmed in real time. In order to, measure the scour in real time, FBG displacement meters are horizontally and vertically installed at the bottom of the pile to observe the condition. In addition, the scour of the ground related to the pile bearing capacity has been evaluated that the supporting force is good if the pile does not occur on the ground. Therefore, the bearing capacity SF of each pile structure is expressed by the following equation:

$$\mathrm{S.F} = \frac{Q_u}{Q_a}$$

where Q_u is the actual reaction and Q_a is the allowable reaction. The allowable reaction can be calculated from the structural analysis. However, the actual reaction is calculated by the following equation:

$$Q_a = \frac{1}{n}(300NA_p + \frac{1}{5}N_A A'_s)$$

where n is the nominal safety rate, N is the value of the pile edge, and N_A is the average N value of the inserted pile. Also, A'_s is multiplication of the total surface area of the inserted pile and circumference length of the pile.

3.3Berthing forceIdeally:

,the berthing force of a boat can be calculated using the velocity of the boat; however, it is difficult to calculate the real-time velocity which depends on unpredictable factors such as the size of the boat, condition of the ocean, etc. Due to such complexity, The Ministry of Oceans and Fisheries officially defines the speed of a boat coming alongside the pier to be 10cm/s. Based on the calculating the average berthing force from the harbor, breasting dolphin is designed to absorb the berthing force. The Speedometer in the breasting dolphin will detect and show the speed of the ship on the display board for the mate which will be helpful minimizing the damage of the structure from the docking.

3.4safety Evaluation Index:

Based on the three evaluation factors, Ratings and Safety Evaluation Index shall be assigned to define the condition of the structure. If SF is more than or equal to 1.0, the Rating will be 5 and Safety Evaluation Index will beA. If SF is less than 1.0 and more than or equal to 0.9, the Rating will be 4 and Safety Evaluation Index will lie in B category. If SF is less than 0.9 and more than or equal to 0.75, the Rating will be 3 and Safety Evaluation Index will be C. If SF is less than 0.75 and more than or equal to 0.6, the Rating will be 2 and the Safety Evaluation Index will beD. If SF is less than or equal to 0.6, the Rating will be 1 and the Safety Evaluation Index will be E. According to "Port and Fishing Port Design Standards", the condition of the structure is the lowest index from the three evaluations of main components of the structures.[Table 1]

3.4.1. Condition Of The Wharf Structure:

From the table above, condition of the structure can be defined from the safety evaluation index. The test that receives an A indicates the best condition with no defects. A test receiving B is one that combines a very good condition of main part of structure and an average condition of auxiliary part with minor damage. A test receivingC indicates an average condition with damage to the structure. A test receivingD requires urgent repair and reinforcement due to some series deterioration in major part of structure such as damage in main structure, severe corrosion, shear crack, subsidence, and conduction in concrete. The use of such facilities may be restricted. The test that receives E prohibits immediate use of facilities and requires repair, reinforcement or reconstruction due to stability issues. There is significant deterioration in main part of structure, loss of cross section and loss of stability of the structure.When the condition of the structure is lower than A, the server will send SMS to manager to alert the situation and visualize the condition in the LED display board that is installed on the structure. Therefore, people on the structures and manager will able to know the condition that can prevent or minimize any accidents and damages.

IV. Conclusion

This research has developed real-time condition assessment method for landing pier-type wharf structure monitoring system. The conclusion is as follows. First,three types of FBG sensors those are; FBG strain sensors, FBG displacement meter, and FBG speedometer are designed to be installed for real-time monitoring of the wharf structure.Second,three assessment techniques were designed to analyze the data from the sensors that are to assess bearing power, allowable stress and berthing force to effectively evaluate the condition for monitoring of the wharf structure from the data.Third, manager can check the condition of the structure anytime and anywhere through the web server. Fourth, the server automatically sends alerts and visualize the condition in the LED display board that is installed in the structure to prevent any accidents or damages.

References

[1]. Andrea Del Grosso, Daniele Inaudi, and Frencesca Lanata(2000) Strain and Displacement Monitoring of a Quay. 2nd ENPC European Conference. 3-6.

[2]. Andrea Del Grosso, Daniele Inaudi, G. Brunetti, and M. Fedolino(1999) Monitoring of the SanGiorgio Pier in the Port of Genoa with Fibre Optic Displacement Sensors. Int. Conf. Monitoring and Control of Marine and HarbourStructures, Genoa, 1-4.

[3]. JaeHyung Park, JeongTae Kim, and SoYoung Lee (2011) Performance Evaluation of Imote2-Platformed Wireless Smart SensorNode for Health Monitoring of Harbor Structures. Korean Society of Coastal and Ocean Engineers. 26-33.

[4]. SooBong Shin, and SungWoo Lee (1999) Development of Inspection and Maintenance of Pier-Type Port Structures. Korean Society of Civil Engineers Conference.1-8.

[5]. SooWon Cha (2012) A Study on the Cause Analysis of Damage And Methods for Maintenance of Port Concrete Structures. University of Ulsan

List of Figures:

Figure 1 Landing Pier-Type Wharf Structure Monitoring System for the Maryang-harbor.

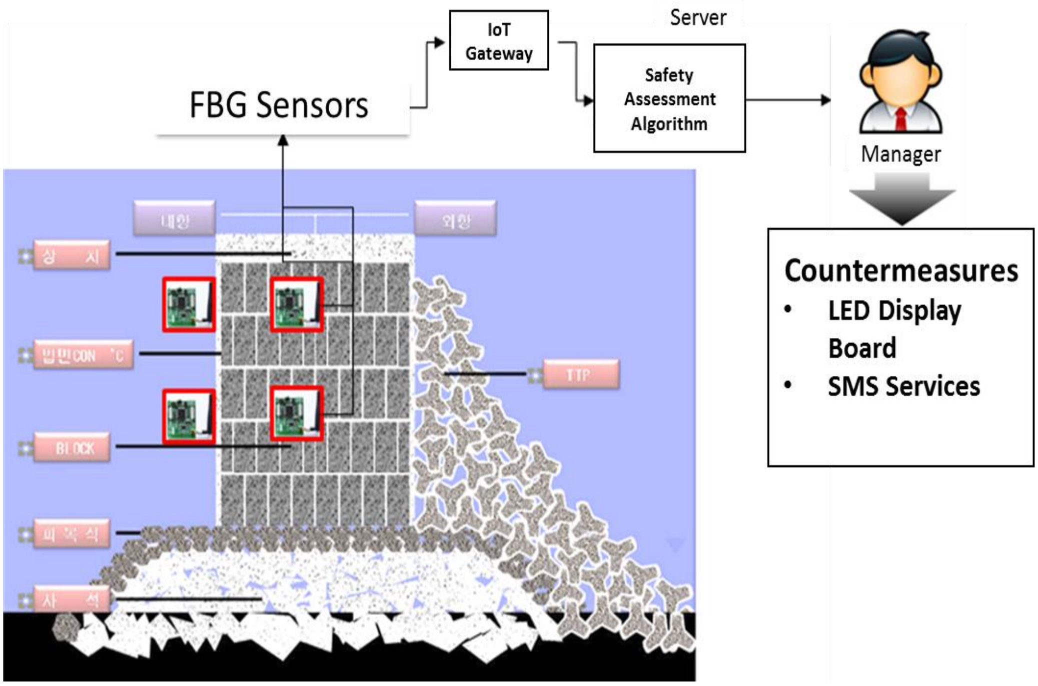

Figure 2 Diagram of Landing Pier-Type Wharf Structure Monitoring System

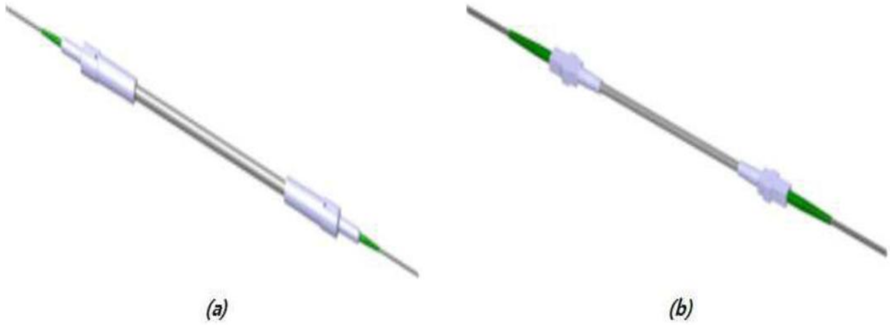

Figure 3FBG Strain Sensor

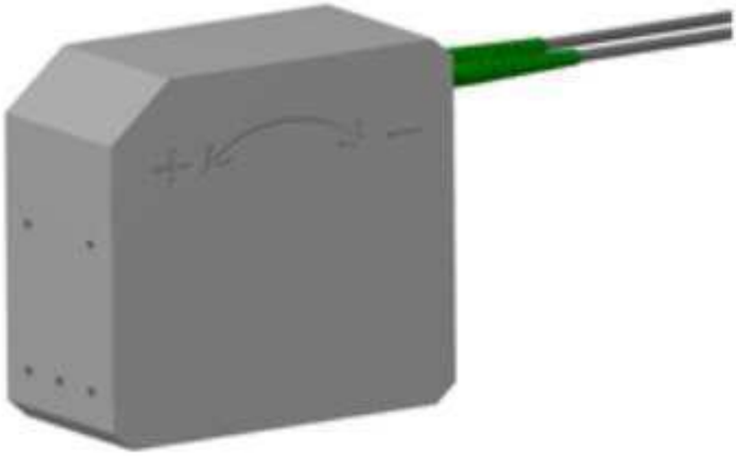

Figure 4FBG Displacement Meter

Figure 5FBG Speedometer

Figure 6 Flow Chart of Real-Time Condition Assessment Method

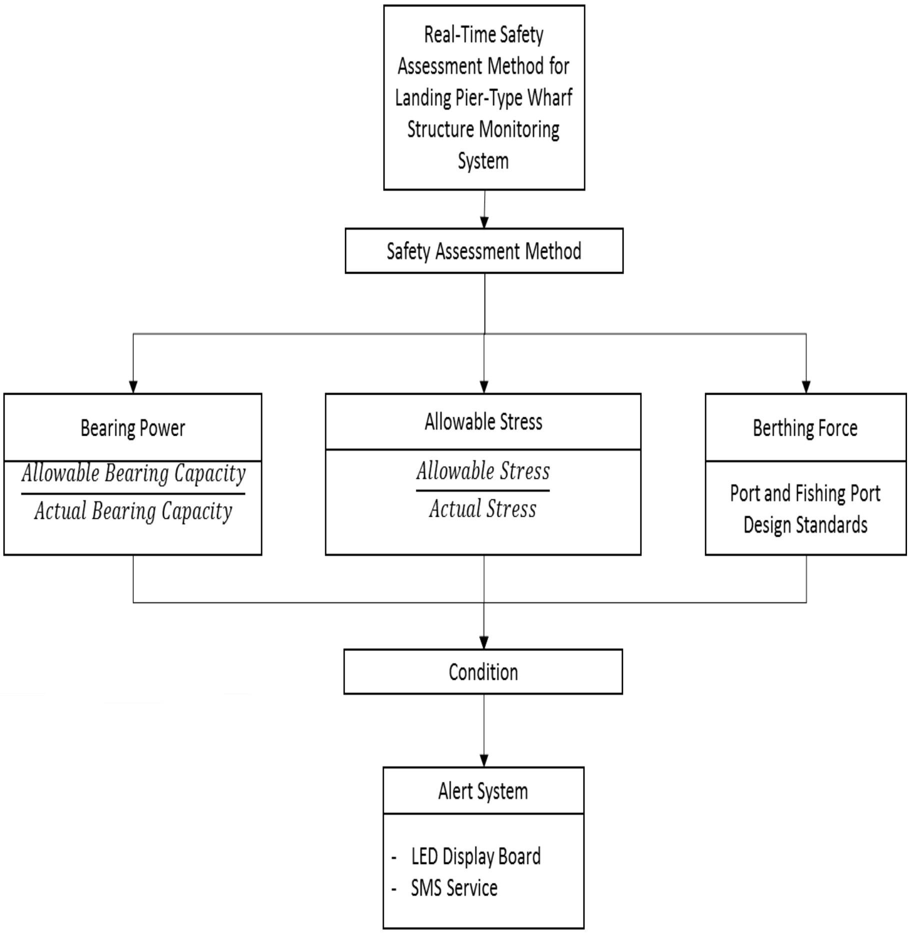

Figure 6 Flow Chart of Real-Time Condition Assessment Method

Table 1 Safety Evaluation Index

Condition	Rating	Safety Evaluation Index
SF≥1.0	5	A
0.9≤SF<1.0	4	B
0.75≤SF<0.9	3	C
0.6≤ SF<0.75	2	D
SF<0.6	1	E

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