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Research on the Construction of Health Monitoring System and Evaluation Technology of Coastal High Pile Wharf

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Abstract: Through on-site research, research data analysis and engineering experience, the damage characteristics and damage types of high pile wharves in coastal ports were studied and analyzed, and their structural weaknesses and the first damage parts and components were analyzed. Then, a health monitoring system suitable for coastal high pile wharf structure was designed, and four main monitoring indexes, namely, displacement, strain (stress), ambient temperature and structural vibration, were determined through the analysis. Finally, the structural safety assessment method is determined based on each monitoring index of the coastal highpile jetty structural health monitoring system, and the assessment level based on the monitoring data is delineated, and the warning threshold of each monitoring index is determined, so as to lay a theoretical foundation for the analysis of the data and the early warning of the whole coastal highpile jetty structural health monitoring system.

1. Introduction

Coastal port terminals are generally located in the harsh environmental conditions of the sea, long-term exposure to high temperatures, high salinity and wind and wave erosion in the harsh environment, the stability, durability and reliability of the concrete structure has been a severe test, in order to ensure the safety of the terminal operation, people began to pay attention to such issues and coastal port terminals for structural health testing technology to explore and research.

Early dock structure inspection mainly adopts empirical method, assisted by some simple testing instruments, such as rebound meter to detect concrete strength, ultrasonic method to measure concrete defects, etc. Currently, the structural inspection is moving towards automation, durability and reliability. At present, the structural inspection is developing in the direction of automation and intelligence, and an intelligent dock health online monitoring system is proposed [1-2].

Wharf structural health monitoring technology is an emerging technology in the field of port terminal structural inspection. It is a structural inspection method that evaluates the severity of structural damage and locates the damage location by using the responses of stress and strain detected on site, combined with system characterization. Sensors and computers distributed in different structural parts of the building are used to form a complete system to check whether the structure has suffered damage by measuring its key performance indicators, and after detecting the damage and determining the location and extent of the damage, to determine information such as its remaining service life.

The dock health monitoring system is to monitor the overall behavior of the dock structure in real time through non-destructive monitoring of the physical and mechanical properties of the dock structure, diagnose the location and degree of structural damage, assess the service condition, reliability, durability and load-bearing capacity of the structure, and trigger early warning signals for the dock structure in the case of emergencies or serious abnormalities in the use of the dock structure, and provide a basis and guidance for the dock's maintenance, repair and management decision-making. It provides the basis and guidance for the decision of repair, maintenance and management of the wharf.

Currently, China's port terminals are in a state of disrepair and mass production, and the imperfection of terminal health inspection technology has brought unprecedented pressure on the stability and safety of terminal facilities. Therefore, it is very necessary to sort out the port terminal health inspection projects, indicators and methods, and introduce emerging information technologies such as sensors, Internet of Things and databases into the field of terminal health monitoring on the basis of traditional inspection technologies, and promote their application in the industry, so as to grasp the load-bearing situation and health state of the terminal structure in real time, quickly locate and investigate all kinds of potential safety hazards, and safeguard the safe operation of port terminals across the country, and promote the scientific development of port economy is promoted[3-7].

2. Analysis of structural damage types of high pile piers

High pile wharf is the most common type of wharf structure in China. The structure uses a series of long piles driven into the foundation to form a pile foundation, so as to bear the load from the upper structure, and the pile body above the ground is part of the main structure of the wharf, so it is called high pile wharf. The advantages of this structure are simple structure, can withstand large loads, especially adapt to the foundation of thicker soft soil layer; less sand and gravel material; strong adaptability to dredging over depth. However, its disadvantages are poor durability; easy to damage the pier components; difficult to repair after damage; poor seismic performance and so on.

High-pile wharf has significant characteristics of its own, widely used in both south and north of China, and its damage characteristics are also different. By summarizing the damage types of high pile code, so as to provide ideas and bases for the health monitoring of high pile wharf, and to provide basic references for accurately finding the monitoring object, monitoring location, and monitoring parameters.

(1) Damage of foundation piles

Base piles are divided into two kinds: straight piles and fork piles. The reasons for the damage of the two types of foundation piles are different, but the general rule is that the bending moment on the top of foundation piles is larger, which makes it easy to have damage on the top of the pile foundation. The problem of fork piles is very complicated. Fork pile is a horizontal force member, the horizontal force from the soil body, the horizontal force from the ship hitting the bollard, etc. have more obvious impact on the fork pile, coupled with seismic action, the fork pile damage, cracking damage at the top of the fork pile is a common problem. The damage mechanism of the front fork pile and the rear fork pile is known to be different by the research, therefore, for the damage of the foundation pile, it is very difficult to solve the problem by theoretical calculation, and it is a better means to monitor and control the damage by the monitoring means, and it is also a simple and feasible method.

(2) Durability damage

The durability damage of high pile pier is one of the main problems in the process of later use. The main types of damage include cracking, peeling and spalling. Durability problems are more prominent in piers in the southern region of China, which are affected by temperature, salinity and other factors. The durability damage is attributed to chloride ion erosion, which is an inevitable problem in seawater environments. Chlorine ion erosion of the protective layer of concrete caused by the corrosion mechanism of steel reinforcement will not be described in detail.

(3) Damage caused by deformation and displacement

High-pile dock deformation caused by more damage, mainly due to the high pile dock more construction in the soft ground, soft base in the later use of the process of creep is obvious, soil and structure interaction caused by structural deformation is more common, the role of structural damage caused by structural damage in the structure of the node damage, damage type for the cracking, dislocation, splitting and other damages.

(4) Damage of component force

High-pile terminal components in some of the stress components for the key components, such as foundation piles, rail beams, etc., long-term subjected to different loads, the chances of stress damage is higher. Especially, the deflection of rail beam in the span becomes the key parameter for monitoring.

(5) Collapse and Tipping Damage of Shore Structure

The back of the shore structure is a stockyard, and there is no pile foundation as a support underneath it. Under the action of pile load, the foundation is constantly compressed, coupled with the shore slope from the back to the front along the shore slope showing a continuous decline in elevation, the soil body appears to be displaced to the sea side, resulting in the collapse and damage to the shore structure is a more common type of damage to the high-pile wharf.

(6) Damage caused by impact accident

There are a lot of collision damage accidents of high pile wharf, which may cause damage to the components of the ship and lack of fenders and other ancillary facilities; or cause major accidents such as broken foundation piles, fractured beams and partial collapse. The damage caused by this situation is uncertain.

3. Construction of Health Monitoring System and Monitoring Indicators for Coastal High-Pile Jetties

3.1 Construction of health monitoring system for high pile wharf

The structural health monitoring system for coastal high pile jetties is a comprehensive monitoring system that integrates structural monitoring, system identification and structural assessment. The general large-scale structural health monitoring system needs to monitor the following structural properties:

(1) Structural response and mechanical state under normal loading;

(2) Structures under sudden events (e.g., earthquakes, high winds, high waves, or other severe accidents);

(3) Durability monitoring of structural components, primarily monitoring the state of corrosion of reinforcing steel in concrete structures;

(4) The working condition of important non-structural components and appurtenances;

(5) Environmental conditions in which the structure is exposed, such as ambient temperature, wind, waves, currents, etc.

Therefore, wharf health monitoring is not just a simple improvement of traditional structural testing technology, but the use of modern sensing equipment and photoelectric communication and computer technology, real-time monitoring of structural response behavior in various environmental conditions during the service phase of the structure, access to information reflecting the structural condition and environmental factors, and thus analyze the structural health status, assess the reliability of the structure, and provide scientific basis for the management and maintenance of the structure. Moreover, in the event of sudden contingencies, the monitoring data can be used to recognize the damage of the structure and the change of the key parts, so as to make an objective and quantitative evaluation of the safety and reliability of the structure.

Based on the above analysis, referring to the composition of structural health monitoring systems in other fields, and considering the service environment of the coastal highpile jetty, the health monitoring framework of the coastal highpile jetty structure is designed, which is shown in Fig.1. Considering the requirements of the coastal highpile jetty structure's health monitoring, and centering on the scientific and advanced design of the informatization system, the health monitoring of the coastal highpile jetty consists of the sensors and data acquisition sub-systems, data transmission and storage sub-systems, and the data processing and storage sub-systems. The health monitoring of coastal high piling dock consists of sensor and data acquisition subsystem, data transmission and storage subsystem, and data processing and application subsystem. (see Figure 1)

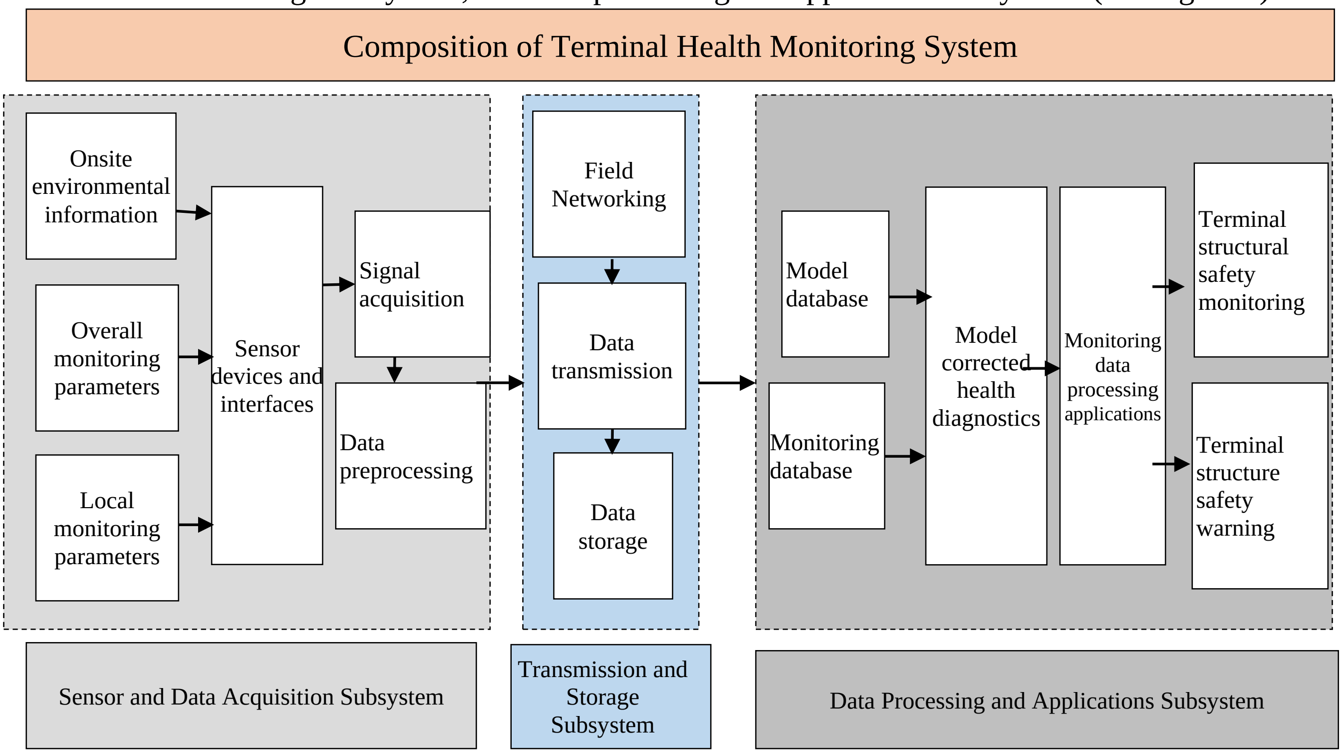

Figure 1: Schematic diagram of the structure of the structural health monitoring system of the wharf

The sensor and data acquisition subsystem is mainly composed of a sensor unit and an automatic data acquisition unit. The sensor unit is mainly used to transform the physical quantity to be measured into electric signals through various sensors, which is composed of the performance parameters of the sensors, the transmission environment and hardware conditions such as equipment interface, including displacement gauge, strain gauge, signal amplifier and connection interface. The automatic data acquisition unit mainly refers to the automatic acquisition process of the measured data from various types of sensors on site. It consists of a signal collector and corresponding data forwarding equipment, which are installed in the structure to be tested to collect data from the sensing system and carry out preliminary processing.

The data transmission and storage subsystem includes on-site sensor networking, monitoring data transmission and data storage. Sensor networking refers to the wired or wireless way to collect data from the field sensors to form a monitoring network, unified access to the industrial control machine. Data transmission is to transmit the collected data to the remote server or cloud through the on-site industrial control machine by means of network communication, including the network operating system platform, the monitoring system and the connection to the Internet. Data storage is to store the data collected on site in cloud storage or local storage for later processing and application.

Data processing and application subsystem is the part of data presentation and application, including high-performance computers and data processing and analyzing algorithms. The collected and pre-processed data are transmitted to the subsystem, and a three-dimensional model of the dock is built to analyze and display the data collected from the monitoring, and the structural monitoring algorithm with damage diagnosis function is used to analyze the received data, determine the occurrence, location and degree of structural damage, and make an assessment of the structural health status, and the system sends out an alarm message immediately once abnormal data is found in the structure.

3.2 Analysis of health monitoring indicators for high pile piers

The prerequisite for the construction of a health monitoring system for a structure is the design of structural health monitoring indicators. Structural monitoring and inspection are two parts complementary to each other, and the structural health monitoring indexes should be carefully divided when carrying out the design of health monitoring indexes, and should be combined with the inspection requirements of high pile terminal structural facilities as much as possible to formulate the corresponding health monitoring indexes, so that the monitoring system can be used to review by manual inspection means after the occurrence of serious alarms, and to realize the timely handling of structural catastrophes. Therefore, the structural health monitoring indicators are determined based on the actual stress characteristics of coastal high pile jetty structures and the damage destruction mechanism of high pile jetty structures analyzed in the previous section. The monitoring indicators are related to the overall deformation and displacement of the high pile jetty structure, the inclination of the foundation piles, the mid-span bending stress of the structural members, and the overall vibration characteristics of the structure, which are mainly categorized into the following three types of monitoring indicators: displacement, stress-strain, ambient temperature, and structural vibration.

(1) Displacement monitoring

The scouring and hollowing out and damage of the foundation of the high pile jetty catchment structure will lead to the slip of the jetty bank slope, the downward drainage of the rear soil body, and the increase of lateral soil pressure acting on the pile foundation of the high pile jetty, which makes the pile foundation tilted and leads to the lateral deformation of the structure as a whole. At the same time, due to the increase in lateral earth pressure, the resulting tilt of the pile foundations is larger than the offset of the upper beams, resulting in the relative displacement of the beams and pile caps, leading to the risk of collapse of the beams and panels. Moreover, improper operation of the ship at berthing will cause the ship to hit the pier, resulting in tilting of the pile foundation or broken piles, resulting in lateral displacement of the pier structure, and when the structural displacement is too large, the structure will collapse locally or as a whole. Therefore, the deformation and displacement monitoring of the pier structure is the most important part of the structural health monitoring system; according to the force characteristics and potential sources of danger of coastal high pile piers, the deformation and displacement monitoring of high pile piers is mainly divided into relative displacement monitoring of components and overall displacement monitoring of the pier.

1) Relative displacement monitoring of components

Under the action of pile load and large-scale mobile machinery load, the soil body of the back yard of the terminal has large lateral earth pressure, and the lateral earth pressure will act on the pile foundation of the back bearing platform from the bottom over the retaining wall, resulting in the tilting of the pile foundation, or even broken loading, which will cause the pile-beam node to be misaligned, and the amount of relative misalignment increases with the growth of the operation time. When a large misalignment between the foundation pile and the simply supported beam occurs, it will reduce the lap length of the beam on the pile cap, and in serious cases, the beam and panel collapse, resulting in serious safety accidents. Even if the misalignment is small, the localized compressive stress is so large that may lead the splitting of the pile cap, which seriously threatens the structural safety and operational safety of the pier.

Shore slope deformation is the direct cause of relative misalignment of pile beam nodes in the rear bearing platform of coastal high pile wharf. The silty clay layer in the shore slope is the soil layer where the largest horizontal displacement occurs, and it is the power channel that causes the misalignment between structural components of the rear bearing platform of the wharf. And the rear yard load overload, large-scale mobile machinery load is the core cause and power source of the deformation of the quay slope. Meanwhile, the corrosion and breakage of continuous pin bars between the pile top and longitudinal and transverse beams are also the cause of misalignment of pile-beam nodes.

The misalignment of pile-beam nodes of high pile wharf can be reflected by measuring the relative displacement between longitudinal and transverse beams and pile caps to reflect the relative degree of misalignment between the components. With reference to the relevant norms and standards for wharf inspection, the relative displacement between longitudinal and transverse beams and pile caps is analyzed to see whether the maximum deformation allowed to occur is exceeded and damage occurs, and an early warning can be issued to notify the staff before the displacement and deformation reaches the maximum allowable deformation, so as to play a role in the protection of the wharf.

Relative displacement monitoring of components is one of the important inspection contents of coastal high pile health monitoring, in order to ensure the measurement accuracy, real-time and service environment, choose to use fiber grating type relative displacement sensor. Fiber grating phase corrosion resistance, can realize automatic data collection at regular intervals, to avoid reading error and human error brought by manual measurement, improve the accuracy of measurement, can meet the requirements of detection accuracy and automatic data collection. According to the empirical measurement data, it can be seen that the relative displacement between foundation piles and longitudinal and transverse beams is in millimeter level, therefore, the fiber grating displacement sensor with millimeter level accuracy is selected for on-site installation and collection of misalignment data of pile and beam nodes.

2) Wharf overall structure displacement monitoring

Since the coastal high pile wharf is mostly constructed on soft ground, the horizontal displacement, settlement and other deformation phenomena will occur in the high pile wharf under the common loading effect of settlement of foundation and working load. Excessive differential settlement or deformation will cause cracking of components or misalignment at component nodes, which will affect the usability and durability of the wharf, and in serious cases, will lead to localized collapse of the wharf, or even the whole wharf collapsing. Therefore, continuous deformation monitoring of the pier is an effective way to grasp the safety condition of the pier and find out the problems in time. Therefore, according to the deformation characteristics of the dock structure, the overall displacement monitoring of the dock includes horizontal monitoring and vertical displacement monitoring of the dock, thus ensuring the overall safety of the dock in the dock production and operation.

(2) Strain (stress) monitoring

Stress is the microscopic set of internal force, which is the force borne on the unit area; strain is the ratio of deformation to the original size; in the linear stage of the structure, stress and strain are linearly related, so the stress state of the structure can be reflected through the monitoring of strain.

The main purpose of the strain (stress) monitoring of the wharf is to determine whether the wharf structure is cracked or collapsed due to excessive working load based on the strain monitoring value, so as to prevent the occurrence of wharf safety accidents.

The strain (stress) monitoring of the coastal high pile pier structure utilizes strain sensors distributed in different structural parts of the building to detect the strain state of the key parts of the structure, and based on the monitoring data to determine whether the structural components are damaged or not, and also to determine the location and degree of damage of the structure, and to provide timely warnings in case of safety risks.

The superstructure of the coastal high pile jetty mainly consists of panels, longitudinal girders, transverse girders, pile caps and ship leaning members. The loads in vertical direction of the high pile jetty, mainly including the self-gravity of the superstructure, stacking load, lifting and transportation machinery load, railroad load, etc., vertically act on the jetty structure in the form of homogeneous and concentrated force, and the load transfer is accomplished in the form of panel-longitudinal girder-transverse girder-pile foundation-foundation path. Therefore, through the analysis of its structural stress, it can be seen that in the stress-strain monitoring of the pier, strain (stress) monitoring is mainly carried out on the pier panels, longitudinal and transverse beams and foundation piles.

(3) Ambient temperature monitoring

The material properties of structures such as coastal high pile wharf are greatly affected by temperature changes, and the stress state of members under different temperature states is different, especially for steel structural members, the structural strain caused by temperature changes is very obvious, and in some cases the temperature is larger than the load strain, so it is difficult to derive accurate results of the load-induced strain if the temperature-induced strain is not eliminated from the measurement results, so that according to the results of such experimental monitoring will lead to misjudging the safety status of the structure. By monitoring the ambient temperature, the temperature strain (stress) state of the structure can be understood, and the stress state monitoring data of the structural members can be compared and corrected to improve the accuracy and reliability of the monitoring data. Therefore, the environmental temperature should be monitored in the structural health monitoring system of coastal high pile wharf, and the sensor selects fiber grating temperature sensor when monitoring.

(4) Vibration monitoring

Monitoring and analyzing the vibration of the pier is of great significance for assessing the safety of the pier. In most cases, vibration is harmful, intense vibration will lead to the emergence and expansion of structural cracks, and finally lead to the fatigue damage of components.

The vibration of the wharf belongs to low frequency vibration with a wide frequency band. Influenced by waves, tides and wind, the vibration amplitude varies in a wide range. According to the structural form of high pile wharf, it can be seen that the structural vibration is divided into two cases: horizontal vibration and rotation.

(1) Horizontal vibration

Vibration sources often exist in the service environment of coastal high pile piers, and there are three main types of vibration sources that jeopardize the pier structure: transient vibration sources, steady state vibration sources and random vibration sources. The most obvious transient vibration source is the impact of the ship on the pier when berthing, which belongs to impulsive impact, and the vibration energy of the vibration source is very large, and its spectral band is wide; the steady state vibration source mainly refers to the impact of the wind, current and wave on the pier structure, and these vibration sources belong to the regular cyclic repetitive action, and the relative vibration energy is small; the random vibration source includes the impact of the crane working on the pier on the upper part of the pier panel, which is governed by the probability of these vibration sources. Under the influence of the above vibration sources, the horizontal vibration of the structure will be excited, and both transverse and longitudinal vibrations will occur in the high pile pier structure. Therefore, in the structural health monitoring system of coastal high pile wharf, the influence range of different vibration sources is fully considered, and the transverse vibration and longitudinal vibration of the wharf structure are monitored at the same time.

(2) Rotation

The vibration of high pile pier structure is not only the horizontal direction vibration, the actual vibration is a complex three-axial six-degree-of-freedom vibration, and there is a rotational component in addition to the advective component. At present, there are fewer studies on the monitoring of the rotation of high pile structures. In the field of earthquake engineering, the structural damage caused by the rotational component has attracted increasing attention. Therefore, the torsional monitoring of the structure is necessary in the structural health monitoring system of high pile wharf. According to the structural vibration test method, the structural torsion information can be measured by accelerometers on both wings of the structural segment. By arranging transverse acceleration sensors and longitudinal acceleration sensors at the two wings of the pier, the vibration signals containing structural torsion information can be obtained, and the torsion frequency of the structure can be obtained through the time-domain analysis of the data.

4. Evaluation Technology for Health Monitoring System of Coastal High Pile Wharf

According to the above discussion, the monitoring indexes of the structural health monitoring system of high pile wharf mainly include the overall displacement of the structure and the deformation of the members, the strain of the key members, the ambient temperature and the structural vibration acceleration.

(1) Structural safety assessment based on structural displacement

The structural displacement monitoring of coastal high pile jetty structural health monitoring system includes the overall structural displacement monitoring and the deformation monitoring of key components such as beams and plates, so the structural safety assessment of high pile jetty based on the displacement monitoring data should be assessed from the aspects of the overall structural displacement and component deformation. The assessment level of the structure is determined in accordance with the theory of work resistance ratio. According to the design theory and engineering experience, the work resistance ratio between the monitoring value and the warning threshold is determined as 4 poles, which are 0.9, 1.0, 1.05, and 1.1, respectively, and the assessment level of the structure is categorized into 5 levels based on the 4 poles, and the criteria for the assessment level are implemented in accordance with Table 1. At the same time, the color corresponding to each assessment level was determined for the structural disaster warning later.

Table 1: Grading criteria for structural safety assessment of high pile piers

hierarchy / items	A+	A	B	C	D
Monitoring indicators	r≥0.9	r≥1.0	1.0≤r<1.05	1.05≤r<1.1	r≥1.1
Early Warning Colors	greener	blue	yellow	orange	red

Note: r indicates the ratio of the monitoring value to the warning threshold

For the coastal high pile pier structure, according to years of testing and monitoring experience, the maximum horizontal displacement is mostly 30mm~60mm, according to the statistical principle, the horizontal warning threshold of high pile pier structure is determined to be 50mm, based on this threshold, according to Table 1, the structural safety level based on monitoring data can be determined. As for the components of the high pile terminal structure, the maximum deflection is different according to the types of components, such as l0/800 for the concrete rail beam, l0/600 for the concrete general beam, and l0/300 for the concrete slab, and thus the deflection threshold can be determined for a specific component of the high pile terminal structure for the purpose of monitoring, and the safety assessment of the components of the high pile terminal structure can be carried out based on the determined threshold according to the Table 1. The structural health monitoring system of the high pile pier will issue an early warning according to the results of the overall structural displacement assessment and the assessment results of the components, and the owner can choose a reasonable repair and maintenance program according to the early warning results.

(2) Strain-based structural safety assessment

The structural components of coastal high pile wharf mainly include reinforced concrete components and steel structure components. For the safety assessment of reinforced concrete members, the concrete material properties are mainly used to control its safety status. The material characteristic of concrete is compressive but not tensile, and the ultimate tensile strain of the material is around 100 με. Therefore, the safety assessment of the structural members of the high-pile jetty based on the strain monitoring data takes the tensile strain of concrete as the controlling index, and according to the tensile strain of the members monitored by the health monitoring system and the ultimate tensile strain of the material, the safety level of the members can be determined in accordance with the criteria in Table 1.

As for the steel structural members, its main material is steel, which is a material with good linear characteristics, the tensile and compressive strains are symmetrical, and generally the tensile strain of steel yields when it reaches 1000 με. Therefore, this value can be determined as the strain threshold value of steel structural members. Then, according to the strain data monitored by the health monitoring system, the safety assessment level of steel members of high pile wharf based on the strain monitoring data can be determined according to the criteria in Table 1.

(3)Structural safety assessment based on structural vibration acceleration

The structural safety assessment method based on structural vibration acceleration is more frequently used in bridges and super high-rise buildings. However, due to the large difference between the frequency response characteristics of high pile jetty structures and those of bridges and super high-rise buildings, it is difficult to apply the relevant methods directly to the safety assessment of coastal high pile jetty structures. Therefore, the structural safety assessment method based on structural vibration signals should be determined according to the mechanical characteristics of coastal high pile jetty structures.

The structural vibration acceleration information monitored in the health monitoring system is the most direct vibration response information of the wharf structure, and the peak value of the vibration acceleration can be used for the safety assessment of the structure. In determining the assessment level, the seismic acceleration corresponding to the local basic intensity can be set as the vibration acceleration threshold value of the structure based on the ground vibration zoning of each region of the country according to the "China Ground Vibration Parameter Zoning Map" (GB18306-2015). Then, based on the peak structural vibration acceleration monitored by the monitoring system, the safety grade of the structure is determined using Table 1 as the standard, and the corresponding disaster warning is made based on the structural safety rating.

The threshold value of early warning indicator refers to the critical value of each early warning indicator calculated according to the regulations and analysis, and is used as the threshold value for issuing early warning after considering the corresponding safety coefficient. Early warning index refers to the index or reference value that combines qualitative and quantitative measurements for predicting the time and space of terminal accidents. The method of determining the warning threshold corresponding to each health monitoring index has been covered in the discussion of structural safety assessment methods based on monitoring data.

According to the above discussion, the monitoring indexes of the structural health monitoring system for coastal high pile wharves mainly include the overall dislocation of the structure and the deformation of the members, the strain of the key members, the ambient temperature and the structural vibration acceleration. Except for the ambient temperature, each of the other indicators is to be used as an indicator for structural safety warning, therefore, the corresponding warning threshold value for each monitoring indicator needs to be determined. The method of determining the warning threshold value for each monitoring index is as follows:

(1) Early warning threshold value of structural displacement

The structural displacement monitoring of the coastal high pile pier structural health monitoring system includes the overall structural displacement monitoring and the deformation monitoring of key components such as beams and plates. For the coastal high pile pier structure, according to years of testing and monitoring experience, its maximum horizontal displacement is mostly 30mm~60mm, according to the statistical principle, it is determined that the horizontal warning threshold of the high pile pier structure is 50mm, while for the components of the high pile pier structure, according to the different types of components, its maximum deformation is different, so the warning threshold of the corresponding components is: l0/800 for the concrete track girder, and Concrete general beam l0/600, concrete slab l0/300, l0 is the calculated span of structural members.

(2) Early warning threshold of structural strain

The structural components of coastal high pile wharf mainly include reinforced concrete components and steel structure components. For the safety assessment of reinforced concrete members, the concrete material properties are mainly used to control their safety status. The material characteristic of concrete is compressive but not tensile, and the ultimate tensile strain of the material is about 100με, so the tensile strain of concrete is used as the control index, and its early warning threshold is 100με. As for the steel structural members, the main material is steel, which is a material with good linear characteristics, and tensile and compressive strains are symmetrical, and generally the tensile strain of steel yields when the tensile strain of steel reaches 1,000με, therefore the strain early warning threshold of steel structural members is 100με. Therefore, the strain warning threshold of steel structure members is 1000με.

(3) Early warning threshold of structural vibration acceleration

Structural vibration acceleration information is the most direct vibration response information of the dock structure, and the peak value of vibration acceleration can be used for the safety assessment of the structure. When determining the structural vibration acceleration warning threshold, according to the "China Earthquake Parameter Zoning Map" (GB18306-2015) for each region of the country, the local basic intensity corresponding to the seismic acceleration is set as the structural vibration acceleration threshold, such as the structural vibration acceleration warning threshold for the Tanggu area of Tianjin is 0.15g.

5. Conclusion

In the past, wharf management emphasized on construction rather than maintenance, which resulted in aging and fatigue problems before reaching the design life due to aging materials, seawater erosion, overload operation and natural disasters. Modern wharf management requires a comprehensive development from pure "construction" to "construction, management, maintenance and utilization", which puts forward higher requirements for wharf health monitoring and diagnosis technology. The research of dock structure health detection and information processing technology can improve the technical ability level of health monitoring, detection and evaluation of port terminals, strengthen the regular maintenance of port terminal facilities, and save maintenance costs. Terminal structural health monitoring technology comprehensively utilizes modern intelligent sensor technology, remote wireless transmission technology, signal analysis and processing technology, structural vibration theory and finite element numerical analysis, etc., to carry out long-term, continuous and real-time health monitoring of port terminal structure, and assess the structural safety based on the monitoring information, so as to guide the normal operation and maintenance of the terminal. The research on terminal structure health detection and information processing technology comprehensively improves the informationization and intelligentization level of the port.

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