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A Simulation Device for Concrete Members Served in Marine Environment

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Abstract: To study the durability of reinforced concrete members served in marine environment, a simulation device to test the service performance of concrete members under the coupling effect of load and environment is developed. The device includes sustained load system, marine environment simulation system and bearing capacity testing system. The self-balanced system is applied to impose a constant sustained load, the underwater zone and tide zone of marine are simulated through the fluctuation of the salt water and remaining load bearing capacity is tested with the help of a perforated support. The device does not need loading reaction frame so it occupies little space and can test the component of any size and of any load ratio. Test shows it can truly simulate the service performance of marine structures under the coupled effect of load and environment. The device solved the deficiencies of commonly used existing technology.

Key words: Long-term load, marine environment, service performance, simulation device

INTRODUCTION

To study the durability and service performance of concrete structure and its members under the action of double or multiple factors systematically is one of the most important scientific and theoretical problem in the field of civil engineering currently (Malumbela *et al*., 2009a; Ballim and Reid, 2003). The vertical load-bearing structures in the marine environment such as steel reinforced concrete columns and bridge piers are generally in three states, namely, underwater zone, fluctuation zone and salt fog zone. At the same time they must bear the load from the up structures. Therefore, to study the durability and life prediction of concrete members served in marine environment, a test device to accurately simulate the service state of column or bridge pier under the effect of load and environment must be developed first (Yoon *et al*., 2000).

At present, the commonly used technology for durability test is an environmental simulation chamber. The existing technology has following deficiencies. First, it does not consider the influence of load, while the actual component works with load. Second, artificial environment simulation chamber is difficult to simulate the underwater, tide and the salt spray zone simultaneously. Third, the existing technology cannot measure the residual bearing capacity of components while they are in a state of working. The existing technology applies reaction force to component by putting two or more component in reaction frame. To measure the remaining bearing capacity, the load device must be removed. Moreover, the existing technology is all about beam test (Malumbela *et al*., 2009b, 2010; El Maaddawy *et al*., 2005; Vidal *et al*., 2007; Ballim *et al*., 2001). The static test conducted after removing load is entirely different from the actual situation, just like we can't ensure that all people can be evacuated from the building when earthquake happens. The destruction of structural is the result of joint action of working load and accidental load. For this reason, the degeneration and decay law of service component over time as well as its ability to resist accidental damage under the effect of load and environment, namely under normal working conditions are more concerned.

DEVELOPMENT OF DEVICE

Objective: To solve the deficiencies of existing technology, this study is to provide a kind of simple, easy to operate and small size device which can measure whole-life service performance and time-varying residual bearing capacity of reinforced concrete column or pier under the effect of load and marine environment.

Method: Fig. 1 is a schematic structural diagram of the device. The simulation device for concrete members serving in the marine environment, includes reinforced concrete column with prepared hole, tensile reinforcement, fastener, anchor, perforated load support, solution tank, testing machine, water inlet pump, water outlet pump, water inlet pipe, water outlet pipe and controller. The fluctuation height and length of corrosive solution in tank

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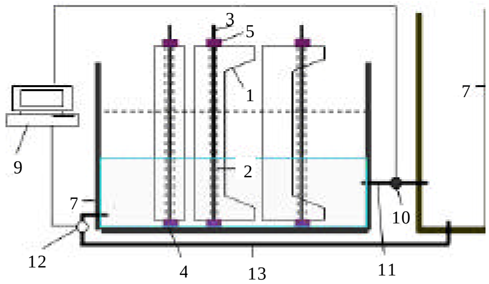

Fig. 1: Schematic diagram of test device

is achieved by controlling the flow rate of the pump. There is a hole in the center of the load support. The hole is greater than the diameter of the fastener and the anchor so that the fastener and the anchor is unconstrained by load support, the fastener and the anchor can move freely in the longitudinal hole of the load support when second loading imposed.

In Fig. 1 and Fig. 4, 1 is a reinforced concrete column or pier, 2 is prepared hole, 3 is tensile reinforcement, 4 is fastener, 5 is anchor, 6 is perforated load support, 7 is corrosive solution tank, 8 is reaction frame, 9 is controller, 10 is water inlet pump, 11 is water outlet pipe, 12 is water outlet pump, 13 is water outlet pipe.

The common steps for application of the device are as follows. first, put the tensile reinforcement into the prepared hole of column with one end of the tensile reinforcement fixed at fastener and the other end of the tensile reinforcement fixed at anchor. Second, pull the tensile reinforcement from end of the anchor and then fix it when design load is met. Then place the column with applied load into the corrosive solution tank. After the corrosive age achieved, get the column out of the solution tank and put perforated load support at both ends of the column and finally apply ultimate load to the column, the remaining bearing capacity of the column therefore can be obtained.

Beneficial effects: The beneficial effects of this device are as follows:

- This device does not need loading reaction frame so it can meet any size of component and any need of load ratio. It can truly simulate the actual working state of the reinforced concrete components in marine environment, including load, underwater and tide zone
- The test device is small in size and occupies little space, so existing durability test equipment such as freezing and thawing test machine, carbonation tank, artificial environmental simulation chamber can be fully used to simulate the real work state of components and research the mechanical property of reinforced concrete members under the coupling effects of environment and load
- The mechanical properties such as continuous stress-strain, load-deflection and residual bearing capacity of the concrete column with the working load can be directly tested without need to uninstall the device. Loading device has no binding effect on the secondary load which can fully reflect the life service performance and residual bearing capacity of reinforced concrete columns under the coupling effects of load and environment. The test results of column fully reveal the failure mechanism in the whole process and reflect failure process of column in actual working condition

APPLICATION OF DEVICE

The implementation of device includes three stages, namely, applying sustained load, simulating marine environment and testing the remaining capacity, the specific detail as shown in Fig. 1-3. Three phases are indispensable to achieve full life service performance and residual bearing capacity of reinforced concrete columns under the coupling effects of load and environment. The following specific example illustrates the application of the device:

- Produce the reinforced concrete columns according to the requirements of test plan. The cross-sectional dimension of column in this example is 120×120 mm with height of 750 mm, the reinforcement of column is 4ϕ10, stirrups is 6 @ 50-100, the concrete cover is15mm, the length of bulge flange is 120 mm, the eccentricity is 0 mm, 25 mm and100 mm, respectively and a 32 mm diameter hole is reserved at the eccentricity point
- Pass a 25 mm diameter stainless tensile reinforcement through the reserved hole of column, then fix the fastener on the end of tensile reinforcement and fix the stainless fastener on the other end. Finally apply the sustained load on column by center-holed-jack based on calculated results of bearing capacity of columns showing Table 1. Given stiffness degradation and stress relaxation of column due to the rebar corrosion under the coupling effects of load and environment, 5% extra-tension force is applied on the column. When tensile force meets the design

Fig. 2: Applying the sustained load

Fig. 3: Simulation of marine environment

Table 1: Loading program and test results

Eccentricity/ (mm)	Calculation of ultimate bearing capacity/(kN)	Load ratio/ (%)	Sustained load/(kN)	Remaining bearing capacity/(kN)
0	330	0	0	330
		30	100	190
		60	200	60
25	235	0	0	235
		30	70	140
		60	140	180
100	67	0	0	67
		30	20	40
		60	40	14

value, sustain the loading for 3 minutes and then fix anchor. The detailed implementation process can be seen in Fig. 2

- After applying sustained load to the component, place the component in a corrosive solution tank filled with 5% sodium chloride. The tidal fluctuation of marine is realized by controlling the rate of flow as shown in Fig. 3
- 360 days later, remove the column from the tank. As shown in Fig. 4, wear perforated load support to fastener and anchor, then dispose force sensor, jack on steel structural counterforce frame in turn and finally apply load to component until structural fail. The detailed test results are shown in

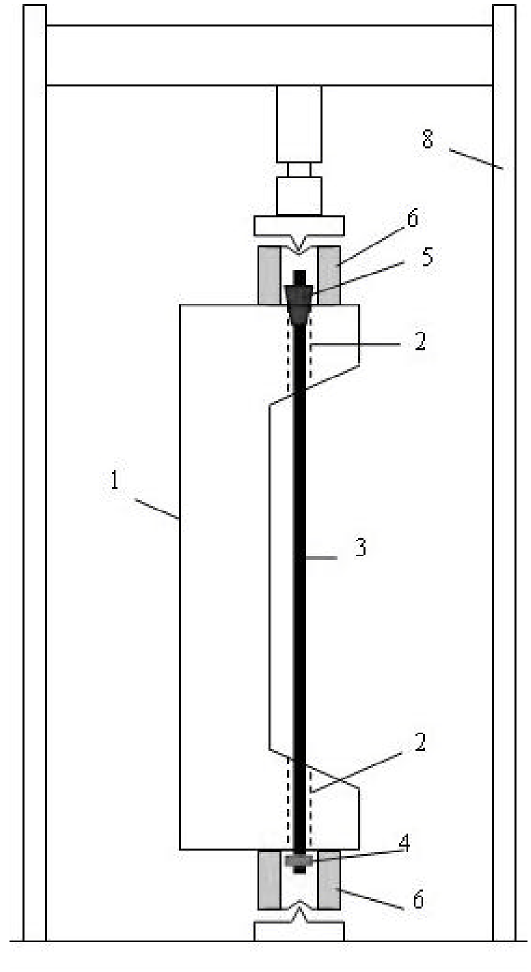

Fig. 4: Measurement of remaining bearing

Table 1. It can be seen from Table 1 that the coupled effects of load and environment accelerate the degradation of component performance

CONCLUSIONS

To study the durability of reinforced concrete members served in marine environment, a simulation device to test the service performance of concrete members under the coupling effect of load and environment is developed. The system of device includes sustained load, the simulation of marine environment and testing of the residual bearing capacity. Accordingly, the implementation of the device includes three phases, namely, imposing of sustained loading, simulation of marine environment and test of remaining bearing capacity. Three phases together fully realize the simulation of whole life of reinforced concrete columns under the coupling effects of load and environment. The service performance and remaining bearing capacity of the test results can fully reflect the failure mechanism of column in whole process of actual working condition.

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