Assembly construction quality detection based on dynamic characteristics of composite component

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Abstract. At present, composite slabs in our country have been widely used. There are few studies on the dynamic characteristics of assembled composite slabs in the existing literature. In this paper, the time history curve and amplitude spectrum of ribbed prestressed concrete composite slabs have been measured in the field, and the frequency changes in their dynamic characteristics have been analysed with YSV dynamic signal acquisition and analysis system. The reasons affecting the dynamic characteristics of ribbed prestressed concrete composite slabs are analysed, and the first six modal frequencies of ribbed prestressed concrete composite slabs are obtained, which lays a foundation for the construction quality inspection of ribbed prestressed concrete composite slabs.

1. Introduction

As a pillar industry of the National economy[1], the construction industry has contributed more than 5.7% to GDP, at present, composite floor is widely used in assembling monolithic concrete buildings (structures) because of its advantages of simple construction, clean production, labor saving, short construction period and superior crack resistance. Since the 1920s, concrete composite structures have been applied to bridges in foreign countries[2]. They have been tried to be used in buildings since the 1940s, and have been greatly developed in buildings since the late 1950s. The initial concrete composite structure is composed of cast-in-situ concrete slabs overlapped on steel or wood beams, and then developed into cast-in-situ concrete slabs overlapped on prefabricated reinforced concrete members or pre-stressed concrete members [3, 4]. In the past few years, many research scholars in Colleges and universities in China have carried out many theoretical studies and static load tests on concrete composite members. Yang Yunjun and Xue Weichen [5] Through full-scale model tests of two kinds of composite beams and cast-in-situ beam contrast beams under monotonic loads, the failure modes of composite beams, the overall working performance between prefabricated beams and prefabricated slabs, and the bending capacity of prefabricated and cast-in-situ slabs are studied. The theoretical research includes the research on the construction of composite beams, composite slabs and joints of assembled buildings [6]. The experimental research includes the loading test of composite slabs of assembled buildings and the loading test of beam-slab joints of composite structures of assembled...
buildings [7]. These scientific research work have achieved certain results, which provide some reference for the research of this paper.

2. Research method

2.1. Performance Characteristics of Concrete Composite Structures
The safety level of the building structure is level 2, the service life of the structure design is 50 years, and the composite floor is used on the first floor, the fourth floor and above. Concrete composite members can be divided into "one-stage members" and "two-stage members" [8, 9].

(1) Members subjected to force in one stage: before the precast concrete members are hoisted in the construction stage, reliable tool support or scaffolding are arranged in the construction floor, and precast concrete members are hoisted on the tool support or scaffolding [10]. Tool support or scaffolding bear the load in the construction stage. Precast concrete beam and slab members only play the role of formwork of cast-in-place concrete layer. After the cast-in-situ concrete layer reaches the required strength, the tool support or scaffolding are removed. The composite section formed by twice pouring concrete bears all the loads during the service period. The force of the whole section occurs once, thus constituting a "one-stage stress composite member".

(2) Members subjected to two-stage loading: no tool-type support or scaffolding is arranged on the construction floor during the construction stage. After the precast concrete members are hoisted in place, the precast reinforced concrete members are directly used as the formwork of the cast-in-place concrete layer and bear all the loads during the construction stage. The cast-in-place concrete layer on the precast reinforced concrete members is maintained to reach the design strength, and then precast steel is used. The composite structure composed of reinforced concrete members and cast-in-situ concrete layers bears the dead load and live load during the service period. The stress state of the composite section is generated by two stresses, which constitutes a "two-stage stress composite member".

2.2. Testing Method
For buildings, the response is usually output by sensors placed in different parts of the structure [11]. For the excitation equipment, because some heavy-duty excitation devices often affect the normal use of the structure under test, the test effect is not good. Many special excitation equipment are often limited by factors such as the inadmissibility of field test conditions [12]. As a natural way of excitation, the force hammer method in circumstance excitation has obvious advantages compared with the traditional modal identification method.

(1) Loose test conditions. The test can be carried out under normal working conditions of the tested components. Traditional methods often need to interrupt their functions or temporarily make the structure under test closed.

(2) No damage to the structure [13]. Compared with the heavy-duty excitation equipment, the use of artificial hammer excitation will not cause damage to the measured structure, and has less impact on the normal use function of the structure. It is an economical and applicable non-destructive excitation type.

(3) More truthful. When using the force hammer method in environmental excitation, the vibration response data are identified, which is more in line with the actual situation and boundary conditions of the structure in normal work.

Civil engineering structural monitoring includes laboratory test monitoring and health monitoring. This test belongs to structural health monitoring. At present, in the structural health monitoring of civil engineering, the common method to measure the overall deformation of the structure is to calculate the overall deformation curve by measuring the horizontal displacement, settlement, inclination and other data of the structure. When this method is limited by site conditions, some surveying work cannot be implemented, especially for tower structures, dams, bridges and other large buildings, the problem will be more obvious [14]. The dynamic characteristic test of composite components can be roughly divided into two kinds of excitation methods: force measurement method and force measurement method. This
experiment mainly uses the hammering method of unmeasured force to excite the vibration of composite components at specific positions, record the natural and residual frequencies of composite components, and analyze the test results to obtain the construction quality of composite components in assembled buildings. Among them, Liu Wenfeng [15] used hammering method to excite the main girder of viaduct Railway Bridge, and the test results were ideal. Xiahe [16] used hammering method to excite the pier. The natural frequency and residual frequency of the pier were analyzed through the response of the pier. Chen Xin [17] used single-point hammering method to excite the beam and measured the natural frequency of the multi-point response. The effect was very good.

2.2.1. Analysis of the Basic Theory of Modal Analysis. Modal analysis is a subject that studies the relationship among physical parameter model, modal parameter model and non-parametric model, and determines the theory and application of these system models by some means. In short, modal analysis [17] is a method based on vibration theory and aiming at modal parameters.

(1) The physical parameter model of a vibration system is determined by three characteristic parameters: mass, stiffness and damping.

(2) The modal parameter model of a vibration system is determined by three characteristic parameters: modal frequency, modal vector mode shape and attenuation coefficient.

(3) The non-parametric model of a vibration system is determined by frequency response function, transfer function and impulse response function.

Several basic assumptions of modal analysis [18] are as follows:

(1) Linear hypothesis: the dynamic characteristics of the structure are linear, that is to say, the output caused by any combination of inputs equals the combination of their respective outputs. The dynamic characteristics of the structure can be described by a set of linear second-order differential equations. In each modal analysis test, the linear dynamic characteristics of the structure should be checked first.

(2) Time invariance hypothesis: the dynamic characteristics of structures do not change with time, so the coefficients of differential equations are time-independent constants. Typical time-invariant problems may arise due to the additional mass of the motion sensor which has to be installed on the structure.

(3) Observability hypothesis: This means that all the data needed to determine the dynamic characteristics of the system that we care about are measurable. In order to avoid the observability problem, it is very important to choose the response degree of freedom reasonably.

(4) Reciprocity hypothesis: the response of point 2 caused by input at point 1 should be equal to that of point 1 caused by the same input at point 2. This assumption makes the stiffness matrix, mass matrix and damping matrix symmetrical.

Modal analysis takes two forms: time domain and frequency domain. Time domain modal parameter identification is based on impulse response function or free vibration response. Frequency domain parameter identification is to identify modal parameters by the measured excitation or response. Frequency domain method, which converts the measured excitation or response signals into frequency domain signals, still performs well in the case of strong noise, and is still the main method of modal identification. The main advantage of modal analysis is that it can directly, concisely and accurately reflect the dynamic characteristics of a complex structural system with fewer motion equations or degrees of freedom, thus greatly reducing the workload of measurement, analysis and calculation [19].

3. Modal parameter identification under ambient excitation by peak pickup method.

The frequency response function of building structure will peak at its natural frequency. Under the force hammer excitation, although the input energy cannot be determined systematically, the modal parameters of the structure can be identified by using the self-power spectrum of random response instead of the response frequency response function of the system. The peak picking method used in this research is based on this basic principle. When identifying modal parameters, because of the interference of surrounding construction noise, there are some errors between the peak value of the auto-power spectrum curve and the natural frequency of the building structure. When detecting and distinguishing
the natural frequency of the building structure, we need to refer to the following three points [17], taking into account the following three points. It is easy to understand the preprocessing of the measured data described below.

(1) The peak value of the self-power spectrum of each detection point of the building structure is located at the same frequency.

(2) There is a strong correlation between the detection points at the natural frequencies of building structures.

(3) The detection points of building structures are similar at the modal frequencies.

4. Experimental Device

This chapter includes PK prestressing concrete laminate (PK plate), truss laminate, prefabricated staircase, YSV8004-24 bit dynamic signal acquisition instrument, CA-YD-106 piezoelectric acceleration sensor, hammer, butter, laptop computer.

CA-YD-106 piezoelectric accelerometer is mainly located at the geometric center of the composite component. The sensor is arranged at the joint of concrete composite plate (PK plate), truss composite plate (YDB plate) and cast-in-place plate (LB plate) and coated with butter to increase the contact stiffness. This can ensure that the base of the whole accelerometer can be in good contact with the measured object, so as to make CA-YD plate rigid. 106 piezoelectric accelerometer is better bonded with the composite component, as shown in Fig. 3.3; figs. 3.4 and 3.5 are field diagrams for the start of field measurement. The piezoelectric accelerometer is placed on the top side of the completed concrete composite slab (PK slab) and truss composite slab; analogy with the requirement of the layout of relevant measuring points in the Technical Specification for Anti-corrosion of Ancient Buildings. When weighing the structure, any spindle side can be used for testing. Because the east-west direction of the building is symmetrical, the east side of the symmetrical axis is selected as the testing object. The layout of the measuring points of the building composite slab, truss composite slab and cast-in-place slab is shown in Fig. 1.

![Fig. 1 Layout of survey points of building composite slab, truss composite slab and cast-in-place slab](image)

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5. Test results and treatment analysis

The prefabricated part of the prestressing PK-7 plate is 3270 mm in length, 1000 mm in width and 30 mm in thickness, 120 mm after lamination is the same thickness as the ordinary cast-in-situ plate; the height of the "T" ribbed web is 35 mm, the width of the web is 80 mm, the width of the flange is 150
mm, the height of the flange is 30 mm, and two RB400 hot-rolled ribbed bars with 4.8 mm in diameter are embedded on the flange, and the thickness of the protective layer is 15 mm. The time-history curve, amplitude spectrum, peak frequency and frequency amplitude of the precast staircase with PK-7 measuring points on the 4th floor of the building 1 are as follows:

![Amplitude spectrum of pk-7 board measuring point on the 4th floor of the building 1](image)

**Fig. 2** Amplitude spectrum of pk-7 board measuring point on the 4th floor of the building 1

![Peak chart of measurement points of pk-7 board on different floors of the building 1](image)

**Fig. 3** Peak chart of measurement points of pk-7 board on different floors of the building 1

From Fig. 2, it is known that the frequency of the first main mode of the four-storey PK-7 board is 48.8281Hz. From Fig. 3, it can be seen that the peak values of each floor are similar. The average values of the 12 groups of data from the four-storey to the 15-storey different floors are 48.2518Hz. The frequencies of the first main mode of the four-storey PK-7 board measuring points fluctuate above and below their mean values. It can be seen that the fluctuation of the first mode of the four-storey PK-7 board shows a downward trend.

6. Conclusion

Through field monitoring, the first vibration frequency of two kinds of laminated plates is studied. From the analysis results, the vibration frequency from the bottom to the top, the vibration frequency has a slight downward trend. The main reason is that the strength and stiffness of post-poured concrete increase slowly with the development of time. The higher the bottom is, the higher the stiffness is and the higher the frequency is. In addition, the test results show the frequency fluctuation, in this study, the
fluctuation is not very obvious, basically less than 5%. The reasons for this fluctuation are not only the external and operational effects of the detection process, but also the structural characteristics of the structure itself. The following three aspects are analyzed in detail:

1) Noise interference: Firstly, the elevator of Building 1 # where the testing site is located is still working. When testing, there are still workers using the elevator to and fro, which has a greater impact on the testing results; secondly, while on-site testing, other units are still under construction, construction interference of other units and intermittent construction of some floors during noon break also exist in this unit, which is known afterwards. During the rush period, site workers will make use of the lunch break time to rectify some of the points that need improvement pointed out by the supervisor. Other units have the situation of rush time and overtime during lunch break time. Thirdly, the busy traffic on the Second Ring Road West and the continuous traffic will inevitably interfere with the detection. Although many interfering factors have been taken into account before the on-site inspection. Corresponding evasive measures have also been taken, but the impact of noise is still unavoidable.

2) Components have end defects and appearance defects: there are cross-working procedures in the process of stacking and hoisting, imperfect positioning measures or unreasonable positioning methods for components, and site workers damage components due to improper operation. As shown in Fig. 4, prefabricated panels lead to panels in the process of construction (left drawing) and stacking (right drawing). In the follow-up construction, special attention should be paid to the arrangement of construction procedures, early detection of possible operational problems of assembly structures in the construction process, relevant corrective measures should be taken, and operators should be notified to pay attention to standardized operation in the follow-up construction, and alert the potential problems of components in the construction process.

3) The influence of bonding interface of laminated slab: the laminated slab is different from the cast-in-place slab in structure, design and field construction. The laminated slab is formed by cast-in-situ concrete overlay on the prefabricated ribbed floor. The bonding interface between the prefabricated ribbed floor and the laminated layer is different from the integral cast-in-situ slab in structure. The prefabricated ribbed floor mainly passes through the protruding ribs and ribs. In addition, due to the existence of natural joints in the direction of the pre-stressed steel bar perpendicular to the prefabricated ribbed floor, the weak area of the bonding surface is prone to cause the stiffness degradation of the laminated slab when the post-poured concrete laminated layer is located.

Fig. 4 Defects of pk-7 plate on the 11th floor of building 1

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