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Study on the Main Influence Factors of Traffic Loads in Dynamic Response of Submerged Floating Tunnels

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Abstract

As the main variable loads during the service stage of Submerged Floating Tunnels (SFTs), traffic loads is an important part in the studies of SFTs' dynamic response. On the basis of the characteristics of moving vehicles and the structural characteristics of SFTs, this paper puts forward the calculation formula of traffic loads, with a comprehensive consideration of different influencing factors. In this paper, in order to obtain the degrees of influence of such factors on the calculated values of traffic loads and the dynamic response of SFTs and the weight of each factor, the author uses the orthogonal experiment method and the analytic hierarchy process, combining them with a simulation of the finite element software. It is expected to provide reference for related researches on SFTs.

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Keywords: Submerged Floating Tunnels; Traffic Loads; Influence Factors; Dynamic Response; Weight

1. Introduction

Over the last decades, due to the great improvements in offshore and deep-sea technologies, there are several preliminary designs and feasibility studies about SFTs that have been proposed. In particular, some researches have obtained significant results on the dynamic response of SFTs.

When we study on the dynamic behaviors of SFT structures, we also need consider the interaction of external incentive loads (such as wave loads [1], ocean currents [2,3], tension of anchor cables [4], earthquakes [5,6], tsunamis, etc.). Concerning the internal incentive loads, the structural vibration caused by traffic loads has great influences on

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the safety of tunnel structures, regardless of the traffic loads from cars or trains in SFTs during the service stage. On the other hand, research on the traffic loads of SFTs is rather limited, however, due to the following reasons:

- Traffic loads has less influence on the dynamic response of SFTs compared with other loads;
- SFTs are similar to bridges in several aspects, and the studies of bridges' traffic loads are under rapid development. The achievements of such studies can be used as references, suggested by some scholars.

Actually, the traffic loads of SFTs and bridges are different though, so we should bring out an appropriate method to study SFTs' traffic loads, while considering the characteristics of SFT structures and traffic loads in them. In this paper, based on the studies of bridges' traffic loads and a comprehensive consideration of different influence factors, we put forward a calculation formula of traffic loads in SFTs. Furthermore, we analyze the weights of influence factors in traffic loads, expecting to provide references for related researches in this field.

2. Calculation method of traffic loads

2.1. Analysis of the main influence factors of traffic loads

According to the previous research results of bridges, traffic loads concerns vehicle structure and speed, road roughness, internal incentive loads, etc. We need study the influence factors of traffic loads in SFTs at first, and then put forward the calculation formula of traffic loads taking into account these factors. We consider the following main factors:

(1) Vehicle structure

The influence of vehicle structure on traffic loads is reflected on the weight of vehicle and the variation of traffic loads due to the vibration of the suspension system during moving [7]. Vehicle weight is a static but constant load. The vibration of the suspension system concerns the damping and the stiffness of the wheels and suspension. We can adopt the professional parameter "unsprung mass" as the index to simulate the dynamic loads in the calculation formula of traffic loads.

(2) Vehicle speed

Vehicle speed is an important factor affecting the vibrations of bridge structures and vehicles. According to previous studies, bridges' vibration is variable when vehicles are moving on the bridges with different speeds. It is not true that when the speed is faster, the vibration is more violent. Actually, the bridges' vibration is the most violent at certain range of speeds. Under the condition of different speeds, the place with the most violent vibration of structure will change.

Therefore, we take the speed factor into the formula of traffic loads, which is considered as an influence factor on traffic loads. In addition, vehicle speed would affect the dynamic response of SFT structures due to the interaction between the vibration of vehicles and that of tunnel structures.

(3) Road roughness

In SFT structure, it is impossible for road surface to be at an absolute level, and the pavement unevenness is called road roughness. Road roughness also causes the vibration of vehicles when moving through the tunnel structure, which then causes the vibration of tunnel structures. Therefore, there exists a coupling relationship between them. Road roughness is one of the main reasons that cause the vibration of SFT structures under traffic loads.

In order to study the influence of road roughness, we can analyze it by using the random vibration theory. The most effective method is the analysis of the power spectrum. The power spectral density function (or road roughness) is the mean square deviation of the measured values of road roughness in a unit of frequency. It is named mean square spectral density function as well. This paper will transfer the defined power spectral density function to road roughness, so as to simulate the different degrees of road surface.

(4) External incentive loads

According to the existing research results, the external environmental loads of SFT structures consist of wave loads, ocean currents, eddy currents, tide, etc. Of these loads, wave loads has the greatest influence on the dynamic response of tunnel structures, so it is considered part of the external incentive loads in this paper.