Engineering Structures 165 (2018) 386–395

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

# Vibration performance of arch prestressed concrete truss girder under impulse excitation

Liang Cao[a], Jiepeng Liu[b,*], Y. Frank Chen[c]

[a] School of Civil Engineering and Architecture, Nanchang University, Nanchang, China
[b] School of Civil Engineering, Chongqing University, Chongqing, China
[c] Department of Civil Engineering, The Pennsylvania State University, Middletown, PA 17057, USA

ARTICLE INFO

*Keywords:*
APT girder
Vibration performance
Impulse excitation
Shape function
Modal decomposition method

ABSTRACT

In this study, laboratory testing and theoretical analysis were carried out to investigate the human-induced vibration issues for a relatively new structural form, i.e. the arch prestressed concrete truss (APT) girder system. Ambient vibration was performed on the APT girder to capture its natural frequencies, damping ratios, and mode shapes. The APT girder system possesses high frequency and low damping. Heel-drop and jumping impact excited by a single person and dual persons were considered to evaluate the vibration performance and peak acceleration distributions for the APT girder system. The mid-span of the APT girder was selected as the key location for the vibration evaluation. It is found that the additional tester contributes to the acceleration attenuation. A reasonable shape function for the APT girder was proposed. The validity for the fundamental natural frequency was verified. The theoretical accelerations determined by the modal decomposition method with the proposed shape function agree generally well with the test results.

## 1. Introduction

Driven by the rapid development in material science and construction technology, a building system with large span and light-weight floor, such as prestressed cable reinforced concrete truss floor [1], composite cable supported beam-structural slab floor system [2], hybrid composite floor plate system [3], and flat plate-voided concrete slab [4], has emerged as a desirable choice. Low damping and vertical natural frequency are the two main characteristics for this kind of floor systems [5–7]. Therefore, the floor is likely to subject to near resonant excitation due to the human daily activity, such as walking, hopping, or jumping, which may disturb occupants [8] or an equipment and even present a concerning issue on vibration serviceability. To avoid the potential vibration problems, several design specifications have proposed some threshold values to evaluate the floor vibration serviceability [9–12].

The arch prestressed concrete truss (APT) girder shown in Fig. 1 is a relatively new structural form, consisting of upper chord, arch chord, prestressed lower chord, web members, floor, and columns. Compared with the traditional prestressed concrete structure, the self-weight of girder is considerably reduced and the compressive strength of concrete is fully utilized. Therefore, it is suitable for large span structures such as bridges, gymnasia, airports, open-space offices, and factory buildings [13]. Yu studied the static performance and proposed a simplified calculation model for a factory building with APT girders [13]. However, the vibration serviceability issue for APT girders requires further studies as some natural frequencies of the APT girder may be close to the dominant response spectrum corresponding to a common human activity. A comprehensive research was thus undertaken to investigate the vibration serviceability issues for the APT girder.

The research techniques that have been used to evaluate the human-induced vibration include experiments [14–17], numerical analysis [18,19], and analytical method [20–22]. The first two techniques are most common. However, a justified analytical method would be more useful to practicing engineers. In this study, both experimental and analytical methods were used to capture the vibration characteristics of a large span APT girder under the impulse excitation (heel-drop and jumping). The objectives of this research include:

- To capture the modal properties of the APT girder using the ambient excitation.
- To discuss the peak acceleration, and acceleration distribution due to the impulse excitation (heel-drop and jumping), and the tester's effect on them.
- To derive an analytical formula for predicting the accelerations for the APT girder under heel-drop and jumping based on the modal decomposition method.

* Corresponding author at: School of Civil Engineering, Chongqing University, Chongqing 400045, China.
*E-mail address:* liujp@cqu.edu.cn (J. Liu).

https://doi.org/10.1016/j.engstruct.2018.03.050
Received 31 July 2017; Received in revised form 17 March 2018; Accepted 19 March 2018
0141-0296/ 

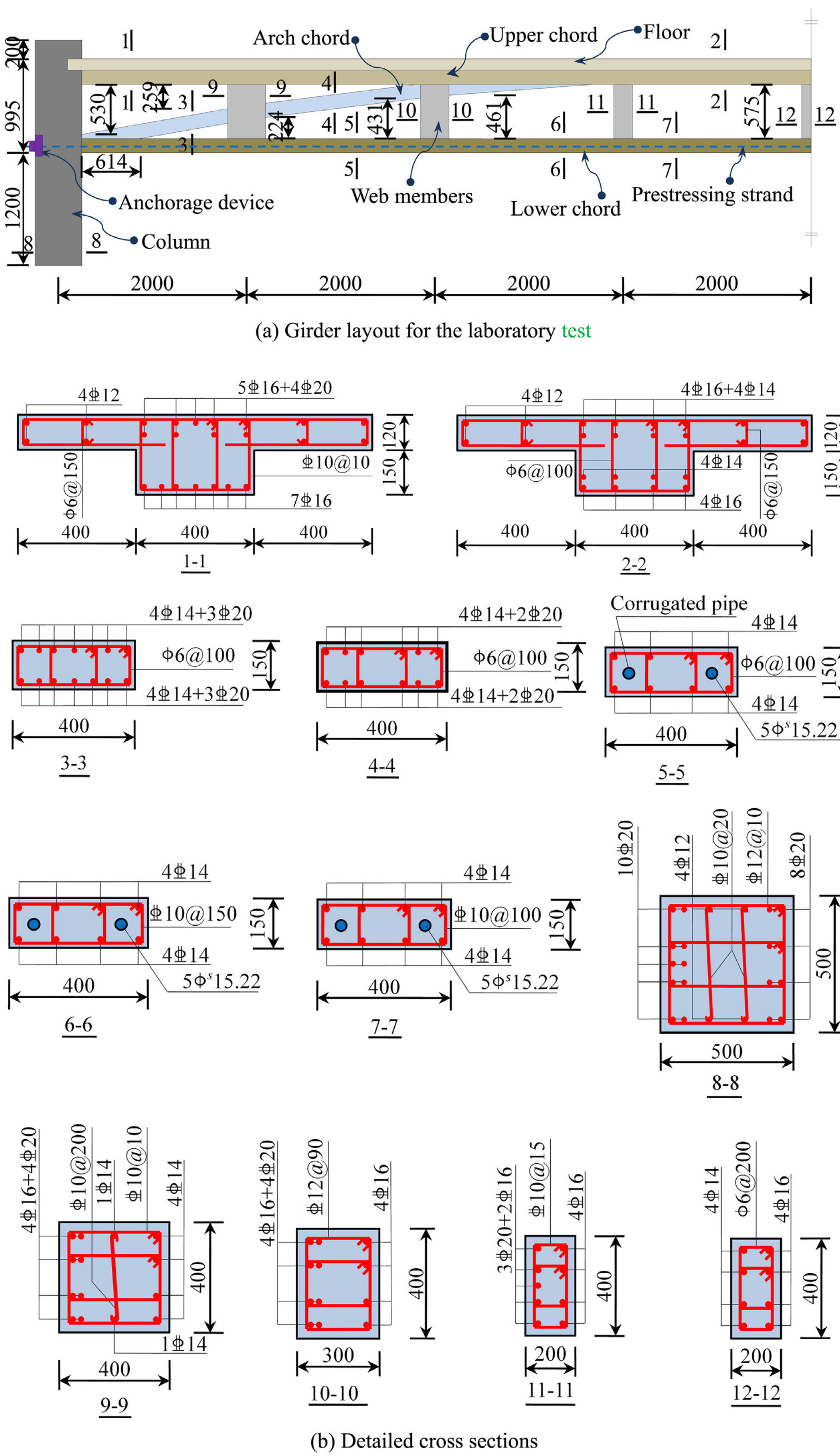


**Fig. 1.** The APT girder (mm). Note: Symbols "ϕ", "Φ" and "ϕˢ" represent different levels of rebar.