# Stress Limitation of External Prestressing Tendons in Serviceability Limit State

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## Summary

The ultimate stress of external tendons sometimes controls the prestress design of a bridge. The ultimate stress of an external tendon can be expressed as the addition of the effective stress of the tendon and a stress increment in Ultimate Limit State. The effective stress is closely related to the stress limitation of the tendon in Serviceability Limit State. Theoretical research and experimental investigation were made at the Department of Bridge Engineering of Tongji University in order to get reasonable stress limitation of external tendons and make recommendation for bridge designers.
**Keywords:** external prestressing tendons; fatigue; stress variation; slip; stress limitation.

## 1. Introduction

The ultimate stress of external tendons sometimes controls the prestress design of a bridge. The ultimate stress $f_{ps}$ of an external tendon can be expressed as the addition of the effective stress $f_{pe}$ of the tendon and a stress increment $\Delta f_{pk}$ in Ultimate Limit State, i.e. $f_{ps} = f_{pe} + \Delta f_{pk}$. In AASHTO: $f_{ps} = f_{pe} + 105MPa$. So, the $f_{pe}$ is very important, which is closely related to the stress limitation $\sigma_{\max}$ of the tendon in Serviceability Limit State, while the stress limitation of the tendon in Serviceability Limit State is closely related to fatigue performance about the external prestressing tendon systems. Therefore, the fatigue evaluation about the external prestressing tendon systems becomes a subject worthy of consideration.

The fatigue research of external tendons in externally prestressed bridges in general can be divided into two branches: the one is the research of overall fatigue about tendons in the structure, the other is the research of local fatigue about tendons in the structure. The former can be analyzed and researched through the study of stress variation of external tendons under live load. The latter can be investigated through establishing a mathematical model for simulating the behaviour of the local slip at deviators, which could consider the friction between the strands and the sheathing under live load, to obtain the maximum slip. The fatigue experiment of the external prestressing tendon can be made according to the theoretical calculations.

## 2. Calculation model

For example, the calculation model of a 30 m simply-supported bridge with distance between deviators-to-span ratio of 0.4 is shown in Fig. 1. External prestressing tendon are seen as single member in the model. A rigid arm is added between the deviator and beam axis, while the rubber

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element, which can adjust the frictional coefficient between external tendon and deviator, is set in the node between the rigid arm and beam axis.

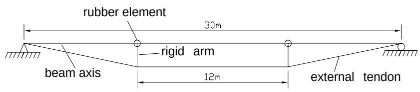

*Fig. 1: Calculation model of a 30 m simply supported bridge*

A non-linear computer program especially developed for externally prestressed concrete bridges can automatically record the stress variation of external tendons and the relative slip between external tendons and deviators.

In this paper, we analyzed and researched 184 situations according to different parameters in 24 externally prestressed concrete simply supported bridges(considering six kinds of spans and four kinds of depth-to-span ratios) and 61 ones of 3 externally prestressed concrete continuous bridges in order to get the stress variation of external prestressing tendons and the slip between external tendons and deviators under live load.

## 3. Calculation results

### 3.1 Stress variation of external tendons

The research about stress variation of external tendons under live load which reflected the overall fatigue behaviour is important part of fatigue evaluation about external prestressling tendons systems. From calculations and analyses we can know, for externally prestressed box girder bridges and internally ones, the stress variation of external tendons under live load is less obviously than that of internal ones. So the external prestressing tendons systems are better than internal ones according to the overall fatigue behaviour.

### 3.2 Slip between external tendons and deviators

The relative slip between external tendons and deviators in simply supported bridges is small, the largest value of which is no more than 0.4 mm. It is because the rigidity of simply supported bridges is big. The longer the span is, the more the slip is. The slip between the external tendons and the deviators in continuous bridges with the large span and the various layouts of external tendons is bigger: The maximum slip happens near the middle pier in continuous bridge with (80+140+140+80) m span, the value of which is 1.78 mm.


*Fig. 2: Sample and test devices*

## 4. Test research

The fatigue test on individually protected monostrands with 2 million cyclic loading was made at the Department of Bridge Engineering of Tongji University, the results of which are good and meet the criterion.

Conclusions