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# STRUCTURAL HEALTH MONITORING OF THE COMPOSITE PLATE GIRDER IN A CANTILEVERED BUILDING

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## ABSTRACT

Health monitoring of civil infrastructures has achieved considerable importance in recent years, since the failure of these structures can cause immense loss of life and property. This paper presents the health monitoring of a plate girder of an observation tower located at Chennai. The observation deck was constructed over 94m above the ground level with concrete stem and large cantilever steel composite floor decks forming a bowl shape at the top. There are five floors, in which the fifth floor is having a butterfly shaped truss and each floor consist of 14 girders. The strains in the radial steel girders located at 102 m level due to upper floor construction were measured using electrical strain gauges. Readings were taken for a total duration of 500 days.

**Key words**: Health monitoring, Composite steel plate girder.

## INTRODUCTION

Structural Health Monitoring (SHM) for civil structures is becoming increasingly popular because of the opportunities that it offers in the fields of construction management and maintenance. SHM is defined as the use of in-situ, non-destructive sensing and analysis of structural characteristics in order to identify if damage has occurred, define its location and estimate its severity, evaluate its consequences on the residual life of the structure. SHM is also becoming more important because its ultimate target is the ability to monitor the structure throughout its working life in order to reduce maintenance requirements and subsequent downtime.

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Composite construction refers to any members composed of more than one material. The parts of these composite members are rigidly connected such that no relative movement can occur. Concrete and steel have to behave to act together with shear connectors. Concrete is stronger in compression than tension and steel is susceptible to buckling in compression. Composite construction aims to make each material perform the function it is best at or to strengthen a given cross section of a weaker material. The performance of a composite structure is dictated by the individual strength of concrete slab and steel girder as well as shear connection stiffness between the interacting elements. Full composite interaction is achieved when rigid connectors are used.

Jue et al.[1], investigated the shear behavior of partially encased composite I girder with corrugated steel web and concluded that encased composite girder have more shear strength compared to I girder because shear buckling in steel is restricted. Nakamura et al.[2], investigated on bending and shear strengths of partially encased composite I-girders and found the bending strength for partially encased girder model is 2.08 times higher and the shear strength is 2.98 times higher than the conventional steel I-girder model. Ahmed et al.[3], investigated on health monitoring of structures using statistical pattern recognition techniques. It was observed that the temperature has a significant effect on the values of strains. Lee et al.[4], did experimental study on structural performance of prestressed composite girder with corrugated steel plate web and found out that the girder with corrugated web had superior flexural performance. Hua et al.[5], did a continuous monitoring on a stress ribbon footbridge for two years. They were able to detect early structural damage with the help of dynamic monitoring system. Nardin et al.[6], studied the behavior of partially encased composite beams with stud bolts. They did a comparative study on encased I beam with studs in two positions. In one set studs were vertically welded in bottom flange and in another set they were horizontally welded on the faces of web. It was found that studs vertically welded in the bottom flange increased the bending strength of the encased beam. Kim et al.[7] experimentally studied the behavior of steel concrete composite bridge deck slab with profiled sheeting experimentally and numerically. It was concluded that the ultimate load capacity of the bridge deck having profiled sheeting is 220% greater than RC deck.

At present only little study has been made on structural health monitoring of buildings with composite plate girder and no literature is available for building with cantilever composite plate girder. Hence, a study is made on the behavior of the cantilever composite plate girder of the Signature Tower located at Chennai. This paper presents the strain behavior in composite plate girder located at 102 m.

## About the structure

The signature tower consists of RCC central core and four-floor deck systems which are made up of steel-concrete composite construction. The observation deck is located at 94m above ground level and cantilevering 17 m to 21 m from the center of the core. The floor deck system consists of total 14 numbers of deep plate girders in each floor. The field photo of the observation deck and plan of the deck system are shown in Figs. 1 and 2, respectively the details of the plate girder are shown in Table 1. The yield strength of the steel used for plate girder is 355 N/mm$^2$ and M40 grade concrete was used for the slab.


**Fig. 1: Field Photo: The observation deck**

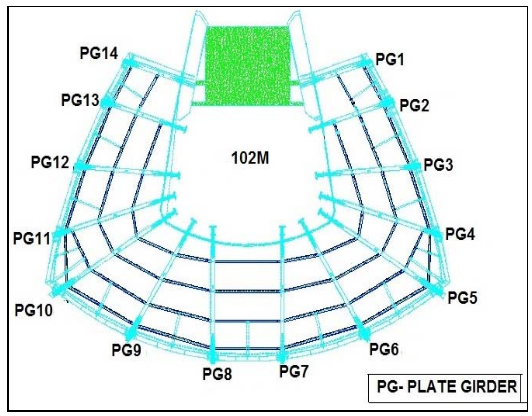


**Fig. 2: Floor deck at 102m**

**Table 1: Detail of plate girder**

| S. No. | Specification | | Length (mm) | Depth (mm) | Flange detail (mm) | | Web detail (mm) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | $b_f$ | $t_f$ | D | $t_w$ |
| 1 | PG2 | PG13 | 7732 | 700 | 300 | 32 | 636 | 17 |
| 2 | PG4 | PG11 | 11435 | 716 | 304 | 40 | 636 | 21 |
| 3 | PG6 | PG9 | 12615 | 716 | 304 | 40 | 636 | 21 |

The plate girders in the floor deck system are provided with huge anchorage plates at the end which in turn is encased with the reinforced concrete central core. Fig.3 shows the anchorage system.

**Fig. 3: Field photo: Anchorage system at 102 m**

## Instrumentation

The steel plate girder is provided with strain gauges across the depth to measure the strain. At level 102 m one strain gauge of strain gauge length 10 mm are fixed in the mid web and two strain gauges of gauge length 20 mm were fixed at the top and bottom of the flanges. Structural steel girder which is embedded with huge anchorage plate at the end of the girder is anticipated to go through maximum stress near the anchorage and therefore the strain gauges were fixed near the anchorage plates. The positions of strain gauges are shown in Fig. 4. Fig. 5 shows the strain gauges in the girder at site. Fig. 6 shows the data logger set-up in the site.

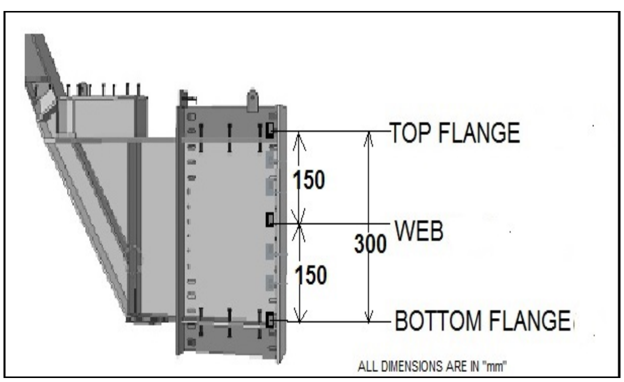


**Fig. 4: Position of strain gauge fixed in the plate girder**

**Fig. 5: Field photo: Strain gauges in the girder at site**

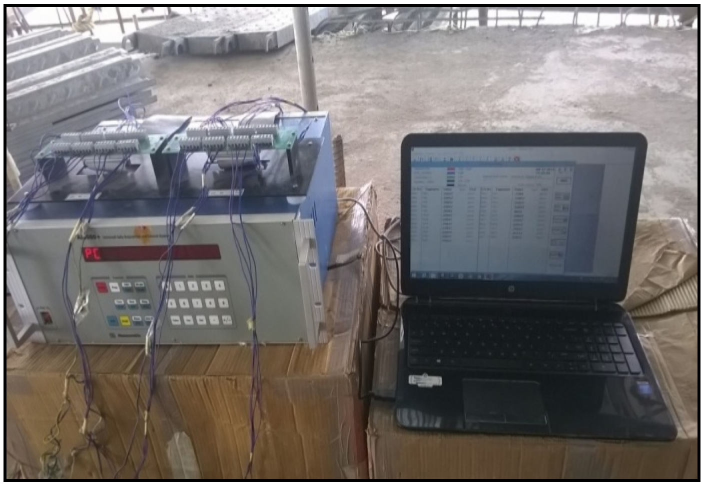

**Fig. 6: Field Photo:Data logger set-up**

## Details of strain in the composite plate girder at 102m level

The strain measurements obtained using strain gauges in the Girders PG 2, PG 4 and PG 6 are plotted. Fig. 7(a), 7(b) and 7(c) show the distribution of the horizontal strains in the flanges and in the web along the depth of the girder for the girders PG2, PG4, PG6.

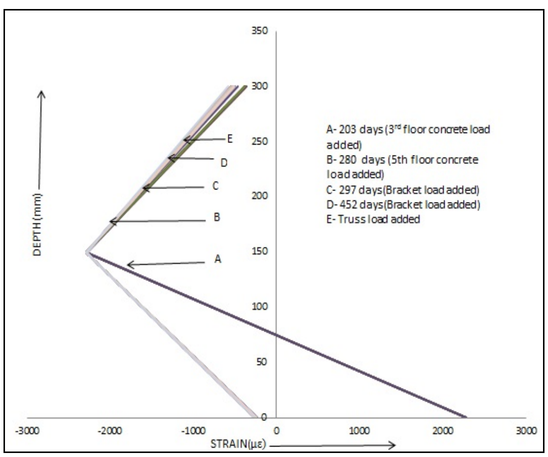


**Fig. 7(a): Strain variations accross the depth (PG2)**

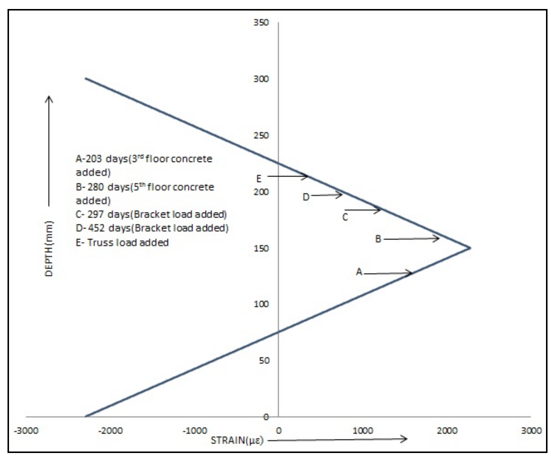


**Fig. 7(b): Strain variations along the depth(PG4)**

In the girder PG2, the maximum strain occurs at the bottom flange during the early stage of construction and it is in tension after 280 days. But the top flange is always under tension. In the girder PG4 the top and bottom flanges are in tension while the middle flange is in compression. In the girder PG6, the maximum tension occurs at the top and bottom flanges. The web portion of girder PG6 is also under tension.

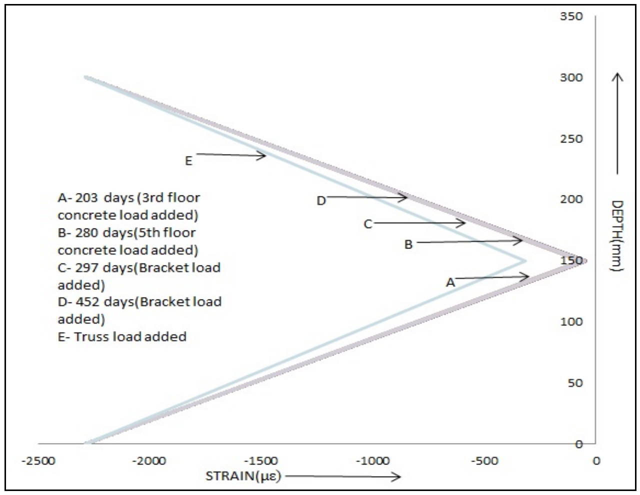


**Fig. 7(c): Strain variations along the depth (PG6)**

In Fig. 8(a), 8(b) and 8(c) show the strain measured on different days during the construction phase for the girder PG2. PG4, PG6.

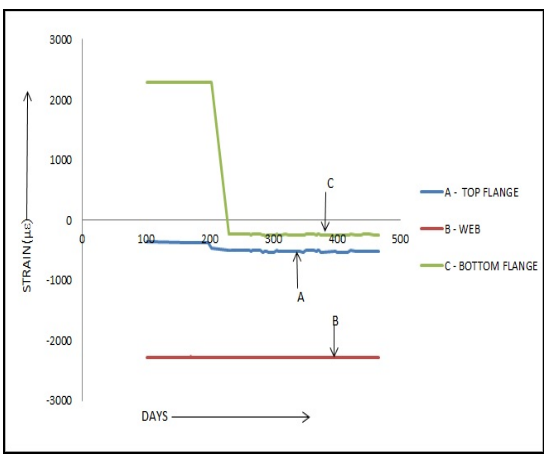


**Fig. 8(a): Strains measured in the girder during construction (PG2)**

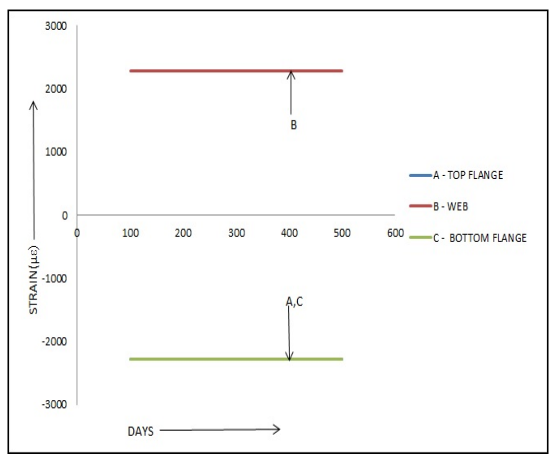


**Fig. 8(b): Strains measured in the girder during construction (PG4)**

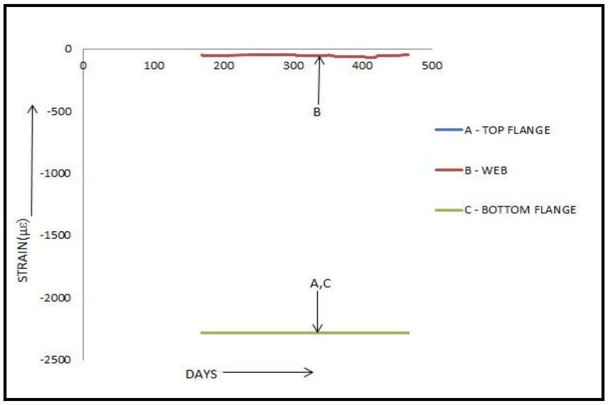


**Fig. 8(c): Strains measured in the girder during construction (PG6)**

## CONCLUSION

This paper presents the real time health monitoring of a Signature Tower located at Chennai. Strains in the plate girders of the floor deck located at 102m were measured using electrical strain gauges at different days. In the girder PG2, the maximum strain occurs at the bottom flange during the early stage of construction and it is in tension after 280 days. But the top flange is always under tension. In the girder PG4 the top and bottom flanges are in tension while the middle flange is in compression. In the girder PG6, the maximum tension occurs at the top and bottom flanges. The web portion of girder PG6 is also under tension. The strain distribution satisfy plain section remain plain. The longitudinal deformations and strain are due to bending and are also accompanied by shear deformation causing a different distribution of strain as strain happens in shear dominant beams.

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