Review Article

Linear Variable Differential Transducer (LVDT) & Its Applications in Civil Engineering

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Abstract: The presented report discusses the study of LVDT and its various applications in civil engineering. LVDT is the most preferred choice for the measurement of displacement, pressure, force, level, flow, and other physical quantities in engineering applications and in industries. Measuring displacement, settlements, deformations of slopes is a critical need in many structural processes, so some sensors are used for this purpose like potentiometer, capacitance picks, LVDT etc. The main aim of studying LVDT's is to find various other uses in structural processes advantageously which consumes less time and are more efficient. LVDT's when used with ETPFS's in a concrete beam can not only measure deflection of the beam but also cracks in it. LVDT has a wide range use in railways to measure dynamic displacement of rail bridges with advanced video based system. Because of its high sensitivity and high resolution LVDT's can detect vibrations in structures. Apart from dial gauges, using a LVDT is a primitive technique for obtaining deformation in conventional structural tests. Although there are certain advantages to using LVDTs, such as high resolution and accuracy, simple installation, and real-time logging ability, there are also some disadvantages, such as high cost, the inability to obtain the whole displacement field, and extra charges for data acquisition.

Keywords: LVDT, Deflection, Linear, Transducer and Loading

1. Introduction

A Linear Variable Differential Transducer (LVDT) is a displacement based transducer. It is a passive transducer used to measure displacement. LVDT is the most preferred displacement measurement transducer used in industries because of its simple design and proven reliability [1]. The major challenge faced in LVDT is linearity in limited stroke range. The performance of the LVDT is subjective to the transducer geometry, the influence of physical parameters on linearity and sensitivity [2].

As LVDT works on the principle of mutual induction between the primary and two secondary windings, the relation between the input and output of the LVDT is derived using the concept of mutually coupled circuits [3]. The output of the LVDT is voltage across the secondary windings, which are connected in series opposition. The flux linkage between the primary and secondary windings changes with the core position [4].

The output measure is based on the variation in mutual inductance between the primary winding and each of two secondary windings when the core moves due to subjected displacement [5]. The displacement to be measured is proportional to the position of the core which is extracted from the output voltage [8].
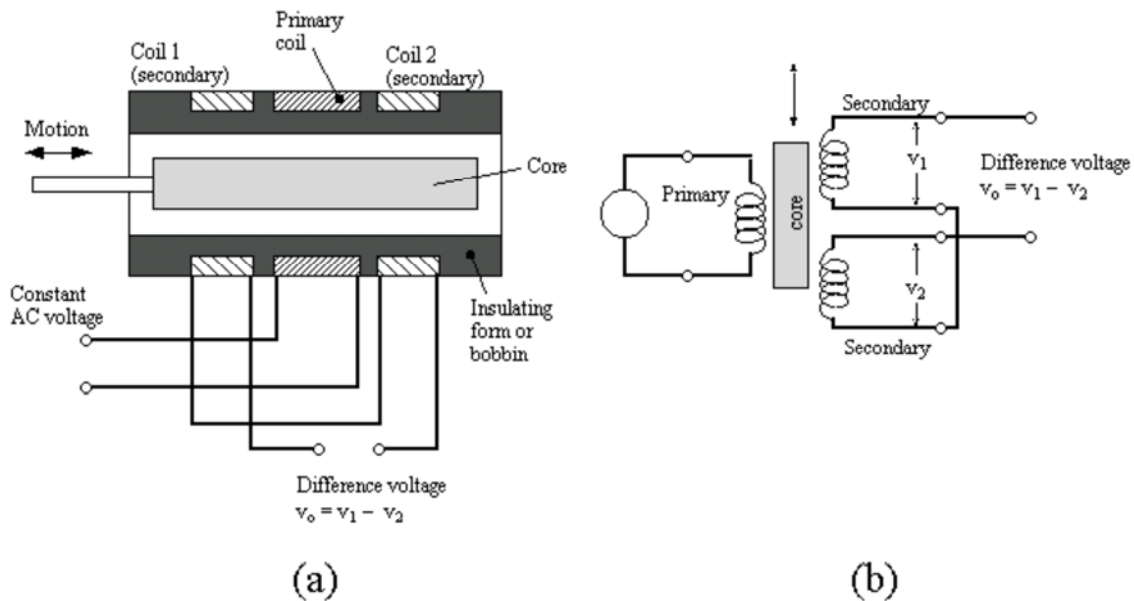
Figure 1. (a) shows construction of LVDT and (b) shows circuit diagram. [6].

2. Literature Survey

Ardalan Hosseini et. al. studied displacement values obtained from the PIV method precisely match the LVDT data; hence, load-displacement curves can be easily drawn for steel and RC beams subjected to flexural loading by means of the PIV technique. In this study, the impact of camera resolution on the midspan displacement of steel and RC beam specimens was investigated using two different types of digital cameras [i. e., a Nikon D80 with a resolution of 10.0 megapixels (3,87232,592 pixels) and a Canon 5D Mark II with a resolution of 21.0 megapixels (5,616 33,744 pixels)]. The results show that camera resolution has no significant effect on the accuracy of midspan displacements obtained from PIV analyses.

S. Balakrishnan et. Al, studied the surface settlements of the models during centrifuge tests were monitored with the help of Linear Variable Differential Transformers (LVDTs) wherein centrifuge model test on geogrid soil wall constructed with marginal backfill as backfill and reinforced with weaker reinforcement layers uniformly was found to experience excessive deformations very rapidly. The maximum crest settlement is 0.065 times and maximum normalized face movement is 0.033 times the height of the geogrid reinforced soil wall.

Santhosh K. V. et. Al. studied the analysis of available displacement mea-surement technique using an LVDT shows that only part of the full range of the input scale is used in practice wherein the measurement system needs to be recalibrated whenever the LVDT is replaced by another one having different number of pri-mary/secondary windings, dimensions of the coil, and on changing the excitation frequency or ambient temperature.

B. V. S. Vishwanandham et. Al. studied the lateral displacements of geotextile reinforced soil and surface settlement of slope using LVDT's wherein he determined the failure mechanism of soil surface using strain and settlement data.

Hongwei Wang et. al. studied that the maximum mid-span deflection increased significantly with the increase of explosive charge weight. However, with the increase of steel tube thickness, the maximum mid-span deflection decreased. As for the effect of cross sectional geometry, the confinement effect benefits circular CFST specimens more under axial loading rather than under lateral loading.

3. Theoretical Aspect

3.1. Construction of LVDT

An LVDT consists of a primary coil, two secondary coil and a moveable magnetic core. The primary and secondary coil are housed in a barrel, with moveable magnetic core rod which goes inside the barrel.

3.2. Method of Operation of LVDT on a CB

This section of the report describes how LVDT is employed to compute deflection of a CB's.

a. Firstly, measure the cross section and dimensions of the beam. Calculate its area and moment of inertia. Assume the Modulus of Elasticity of steel beam.
b. Then, move the LVDT mounting block on the beam and its support stand on the base to the designated position.
c. Tighten the setscrews and record the LVDT position with respect to the fixed end of the beam.
d. Move the weight support disk to the designated position on the beam. Record the distance from the disk center to the fixed end of the beam.
e. Set up the static test system as described above with the LVDT located underneath the beam at the designated location.
f. Turn on the power and record the digital readout from

the TIC-9000 Indicator. The Indicator can display from +0.200 to -0.200 digital readout in inches.

g. Applied a known weight slowly onto the disk located

near the end of the beam.
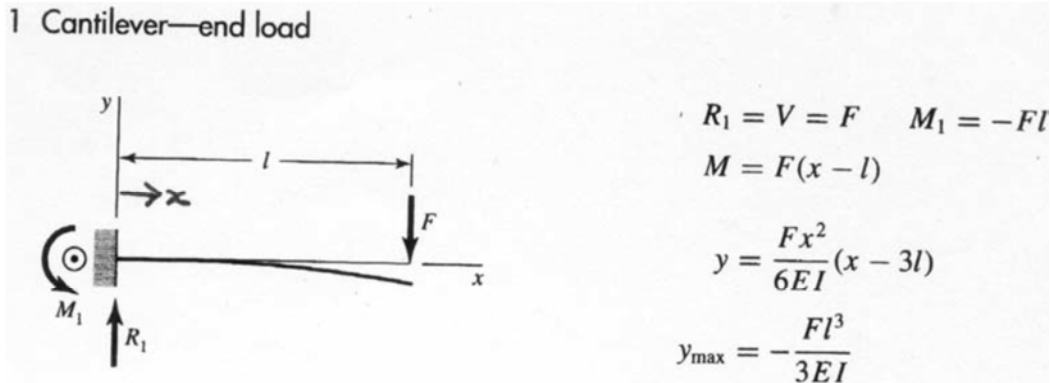
h. Record the readout from the Indicator.

Figure 2. *Analytical method to determine deflection of fixed beam at free end.*

4. Material and Methodology

4.1. Material

a. A mould with size of 150 mm×250 mm×2300 mm is used to contain the mixed cement paste and a plastic sheet is covered on the mould to prevent the evaporation of water.

b. The Ordinary Portland Cement (OPC), silica fume and sand are mixed together by a drum mixer for about 20 minutes.

c. The mould is removed after 3 days of casting. After that, the beams are stored at room temperature of 25°C for more than 28 days.

d. Four CBs are casted by using two grades of cement, 35 and 40, respectively. The water cement ratio of 0.67 was maintained.

e. The CBs with concrete strength of 35MPa and 40MPa are cured, respectively.

f. Furthermore, a LVDT sensor system is mounted at the bottom surface of CB to detect the deflection. [2].

4.2. Methodology

Here, four point flexural loading test is performed on the CB's and we measure the corresponding deflections by placing LVDT's at the bottom side of the CB's at various intervals.

4.2.1. Based on LVDT's Mounted over Entire Span

In this study, four point bend loading test is applied for all CBs. A Universal Testing Machine (UTM) -Instron 8800 is used for the loading test as shown in photograph of Figure 4 (a). The UTM has a minimum loading force of 0.01kN, however, a loading rate of 2kN/second is applied due to the higher strength of the reinforced CB. To fully monitor the health conditions of the full scale reinforced CB, the LVDTs, strain gauge, and TPFSs are used in this study. The configurations of the sensors installation are shown in Figure 4 [2].
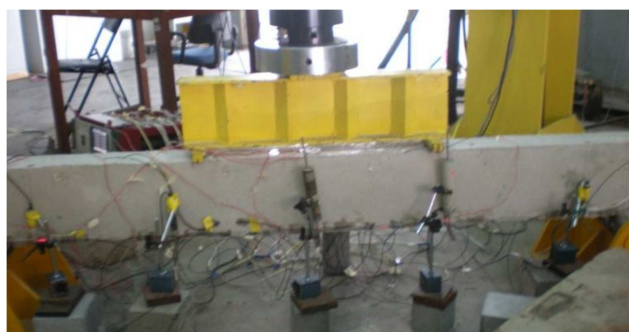

Figure 3. *(a) Four point loading test system for full scale reinforced CBs and sensors installation, (a) photograph of loading test for full scale reinforced CB.*
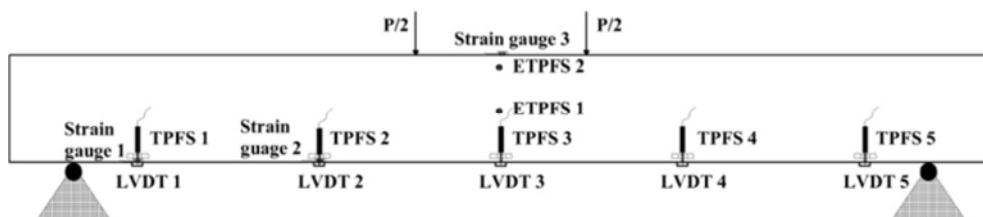

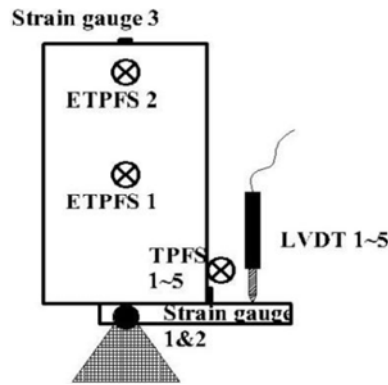**Figure 4.** *The placements of the strain gauges, TPFSs, and LVDTs.*

Figure 5. *Cross section view of the sensors installation [2].*

4.2.2. Based on LVDT Only at Mid-span

a. To evaluate displacement and strain fields of common bending tests one steel I-beam and two RC beam specimens were exposed to the four-point flexural test.

b. The beams were subjected to a four-point flexural load by means of a 2,000 kN displacement-control hydraulic jack. A LVDT was mounted at the mid span of each specimen to capture the load-displacement curves.
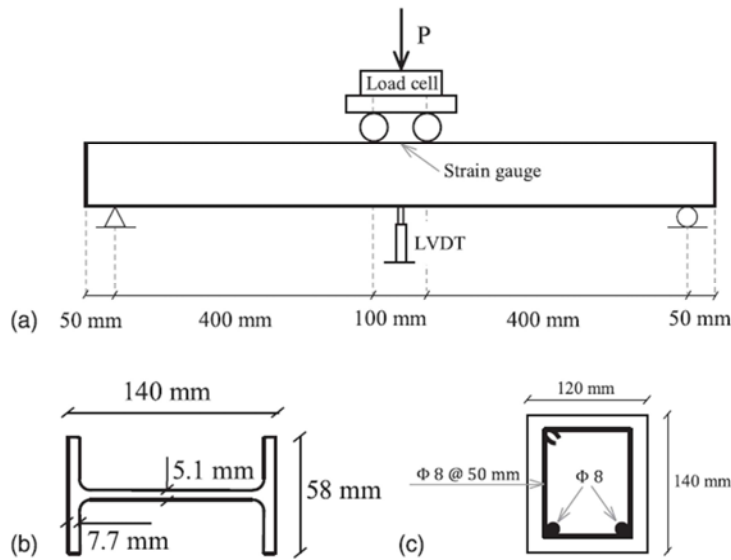

Figure 6. *(a) Beam specimens' dimensions and test setup: (a) test setup and loading arrangement; (b) steel I-beam; (c) RC beam [2].*
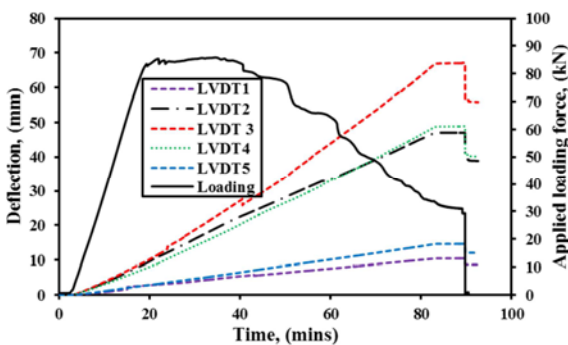

Figure 7. *Graph of deflection of LVDT's with respect to time under loading. [2].*

5. Results

5.1. Based on LVDT's Mounted over Entire Span

a. The four point flexural loading test was performed on an reinforced CB and a graph was plotted between time and displacement.

b. The curves of LVDTs share a same trend with that of the loading force history.

c. As known, the maxima deflection point occurs at the centre of the beam and this value becoming smaller with the point going closer to the support points. It is generally known as shown in Figure 7, maximum deflection of 10.5 mm for LVDT 3 and a minimum deflection of 2.4 mm for LVDT1.

5.2. Based on LVDT Only at Mid-span

a. Load-displacement curves for the steel I-beam, which were obtained from the PIV technique using 10.0- and 21.0-megapixel cameras in Tests T1 and T2, are shown in Figure 7. To evaluate the accuracy of the PIV results.

b. Load-displacement curves obtained from the LVDT readings are also plotted in Figure 7. Displacement values obtained from the PIV method match the LVDT precisely.
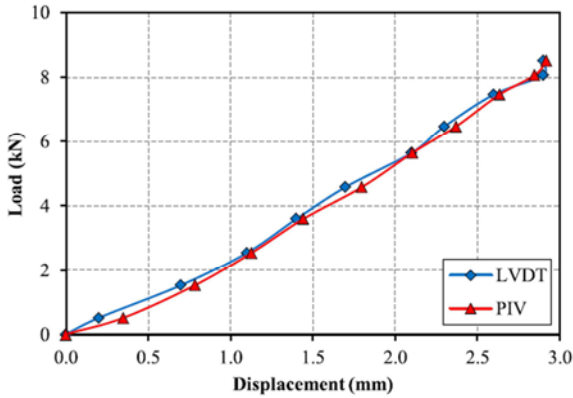
Figure 8. *Load-displacement curves for tested steel I-beam using LVDT and 10.0-megapixel camera (Test T1) [10].*
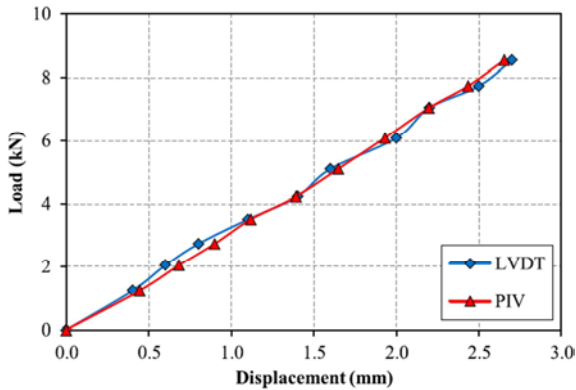

Figure 9. *Load-displacement curves for tested steel I-beam using LVDT and 21.0-megapixel camera (Test T2) [10].*

6. Conclusion

The minor different deflections between the LVDTs of 1 and 5, 2 and 4 may be due to the difference of the curing strength, structural, applied loading positions or LVDT systems on those monitored points. The beam deflection is monitored by LVDTs it is observed a maximum deflection of 10.5 mm for LVDT 3 and a minimum deflection of 2.4 mm for LVDT1. Displacement values obtained from the PIV method precisely match the LVDT data.

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Biography

Sarthak Joshi

He is currently pursuing B.E. from Prof Ram Meghe College of Engineering and Management, Badnera, India. His final year project is regarding the testing of the concrete pavement with the help of different instruments like straing gauges, thermoscouples, etc. He is the group leader of the project under the guidance of Prof. Shrikant M. Harle, Assistant Professor, Department of Civil Engineering.

Prof. Shrikant M. Harle

He is Assistant Professor, Department of Civil Engineering, Prof Ram Meghe College of Engineering and Management, Badnera, India. He has published more than 50 research papers in different International journals and conferences and filed few patents in Indian Government Patent system. He has completed B.E. in Civil Engineering from Government College of Engineering, Amravati, India in 2008. He has completed MTech in structural Engineering from National Institute of Technology, Rourkela in 2010. He is pursuing PhD from Sant Gadge Baba Amravati University, India. He is the author of few books in the field of Civil Engineering. He has around five years of experience in teaching field and three years in Larsen and Toubro Ltd, India.