GU J Sci, Part A, 7(4): 106-111 (2020)

Gazi University

Journal of Science

PART A: ENGINEERING AND INNOVATION

http://dergipark.gov.tr/gujsa

Araştırma Makalesi Research Article

A Load Cell Design that can be utilized for The Testing of Reinforced Concrete Members

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Keywords

Load cell.
Strain gauge.
Calibration.

Abstract

Load cells are widely used for the experiments conducted in structural mechanics. However, since it is a high technology product, supplying load cell is very costly. Therefore, the need for different types and capacities of load cells specific to each experimental study may cause the funding allocated to the research to be exceeded. In the current study, single directional load cells were produced by significantly, almost 90%, reducing the cost and these were tested in an experimental research on reinforced concrete members. The results indicated that produced load cells could take measurements with sufficient accuracy and stability.

Cite / Alıntı

Özbek, E. & Aykaç, B. (2020). A Load Cell Design that can be utilized for The Testing of Reinforced Concrete Members. *GU J Sci, Part A*, 7(4): 106-111.

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Article Process / Makale Süreci

Submission Date/ Başvuru Tarihi	17.06.2020
Accepted Date / Kabul Tarihi	09.12.2020
Published Date / Yayım Tarihi	15.12.2020

1. INTRODUCTION

One of the most basic measurements needed both in scientific field and daily life is force measurement. As known, in this way, calculations including weight, pressure, acceleration, torque, work, and energy can be made. For this reason, various devices have been designed and manufactured in order to measure the force as accurately as possible. With the rapid development of technology in the last fifty years, a demand has arisen for a device that can transfer the measured force data to the computer in terms of electrical signals. Studies have shown that load cells are very successful in meeting this demand.

Nowadays, load cells are widely used in the aerospace (Jenkins and DeAngelis, 1997), mechanical (Muller et al. 2010; Kluger et al. 2016), transportation (Faruk et al. 2016), automotive (Lin et al. 2020), and structural engineering applications. In the field of structural engineering; it is especially adopted in experimental studies on real structures (Tumialan et al. 2014a, b) and laboratory specimens (Aykaç et al. 2019; Özbek et al. 2019). Load cells are high technology product, and thus supplying load cell is very costly. In fact, know-how ratio on this product is high. In other words, commercial firms sell knowledge rather than materials or workmanship. Therefore, the high demand for different types and capacities of load cells in structure laboratories may not be met due to the limited funding. Moreover, since load cells of certain types and capacities are only commercially available, most of the time, the fully compatible ones may not be found. On the other hand, load cells capable of very precise measurement are not required in structural engineering.

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The authors experienced the aforementioned problems and produced their own load cells to overcome these issues. Produced load cells, a total of four, were tested more than twelve times in an experimental research conducted on slabless reinforced concrete staircases (Kaya, 2020). The results showed that the load cells could take measurements with sufficient accuracy. Additionally, cost of these load cells were almost 90% lower than the commercially available equivalent ones, and still they could collect data in a stable manner.

The present study shares the design, production, calibration, testing, and utilizing of these load cells in detail. The main principles and approaches adopted here are intended to guide researchers who are willing to produce their own load cells.

2. METHODS

2.1. Design

Four identical canister style load cells were produced within the scope of the study. Main body of the load cell was shown in Figure 1. Nominal capacity of the load cell was assumed as 75 kN and this value achieved as follows. Selected steel grade for the main body was S235, produced in accordance with the TS EN 10025-2 (TSE, 2006). S235 is the commonly used low cost structural steel which has a yielding strength (f_y) of 235 MPa. Load cell was designed based on the provisions in ÇYHY (2016). Accordingly, modulus of elasticity (E_s) of steel was taken as 2×10^5 MPa. Minimum dimensions were determined in order to obtain both light weight and economical design. Initially, intended capacity 75 kN was multiplied by a factor of 1.67 for the allowable stress design (ASD) method (ÇYHY, 2016). Result divided by f_y to obtain minimum cross-sectional area (A_g) of 533 mm^2 without considering buckling. Tubular shaped section was adopted for the main body. This kind of shape helps load cell to be mounted on the experimental set-up in many ways and also increases the moment of inertia. Thus, tubular shape having an outer diameter of 40 mm and a thickness of 10 mm (A_g = 550 mm^2) was selected for the net section of load cell body (Figure 1).

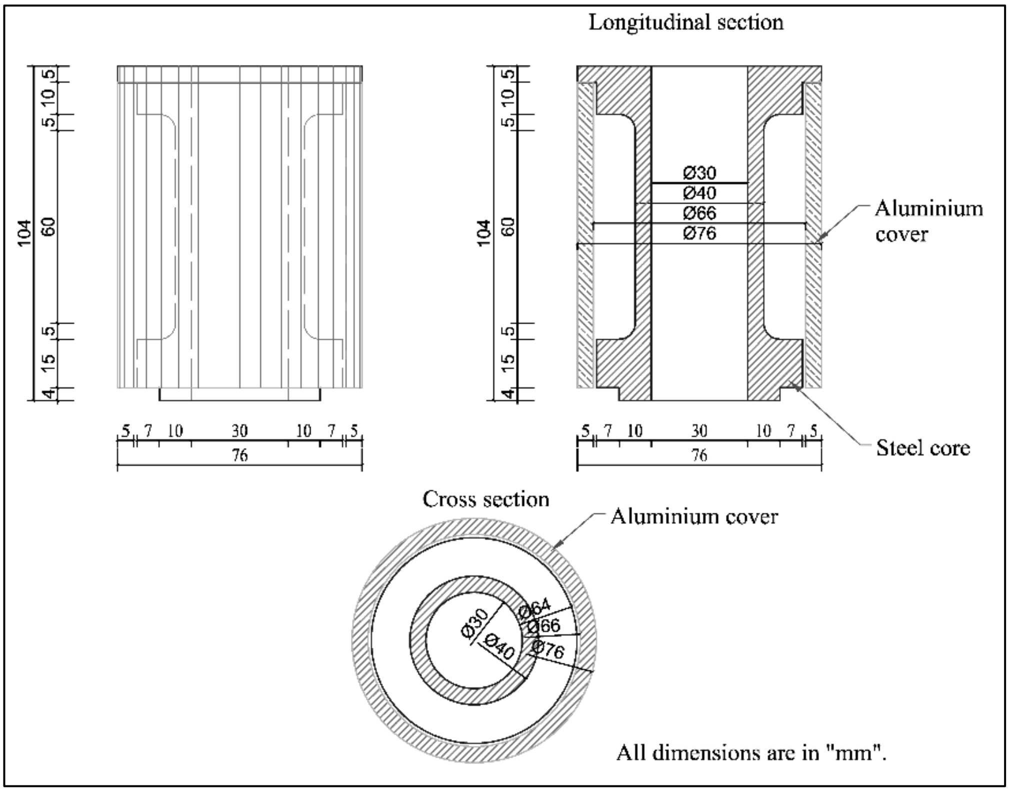

Figure 1. *Dimensions and details of the load cells*

The clear height of the main body should be as short as possible to be buckled in the inelastic region, but also as high as to ensure that the stresses are uniformly distributed in the central region. As a rule of thumb, clear height was selected as the two times of the diameter of tubular section (70 mm). This diameter was measured from the centerline of the wall. The design, in this form, was checked for the global buckling (ÇYHY, 2016) and still was seen capable of resisting a load of 75 kN. Both ends were assumed as pinned for a conservative approach. The shape also checked for local buckling (ÇYHY, 2016) and it was found to be non-slender. Consequently, the height, diameter and wall thickness of the tubular shape was designed as 70×40×10 mm, respectively (Figure 1).

Sufficiently large and stiff regions were formed at both ends of the steel shape for a proper loading. Shoulder fillets were also formed at the transition regions to reduce stress concentrations (Figure 1). This design, considering compression forces, is also safe against tensile forces. In other words, load cell can measure tension forces in addition to compression forces.

2.2. Production

Steel shape shown in Figure 1 was monolithically manufactured in lathe machine. Wheatstone bridge circuit was used to set up a linear relationship between the electrical signals and the deformation of load cell. Full-bridge circuit was formed on the steel core by a total of four strain gauges as shown explicitly in Figure 2. Metallic strain gauges were commercially available with a nominal resistance value of 120Ω and a gauge factor of 2.0. Special care was taken to mount strain gauges properly on to the load cell. A template was prepared for a clear orthogonal layout. Adhesive recommended by the manufacturers were used to connect strain gauges to the steel core. Solder was utilized for the necessary connections on the circuit. Necessary isolation measures were taken to avoid short circuit. Finally, the cover made of aluminium pipe, outer diameter of 76 mm and a wall thickness of 5 mm, was mounted to protect the electrical circuit and device. Connection type of this cover allows steel core to deform without restrictions. In other words, aluminium cover was only fastened from the lower end. These steps were illustrated in Figure 3, respectively.

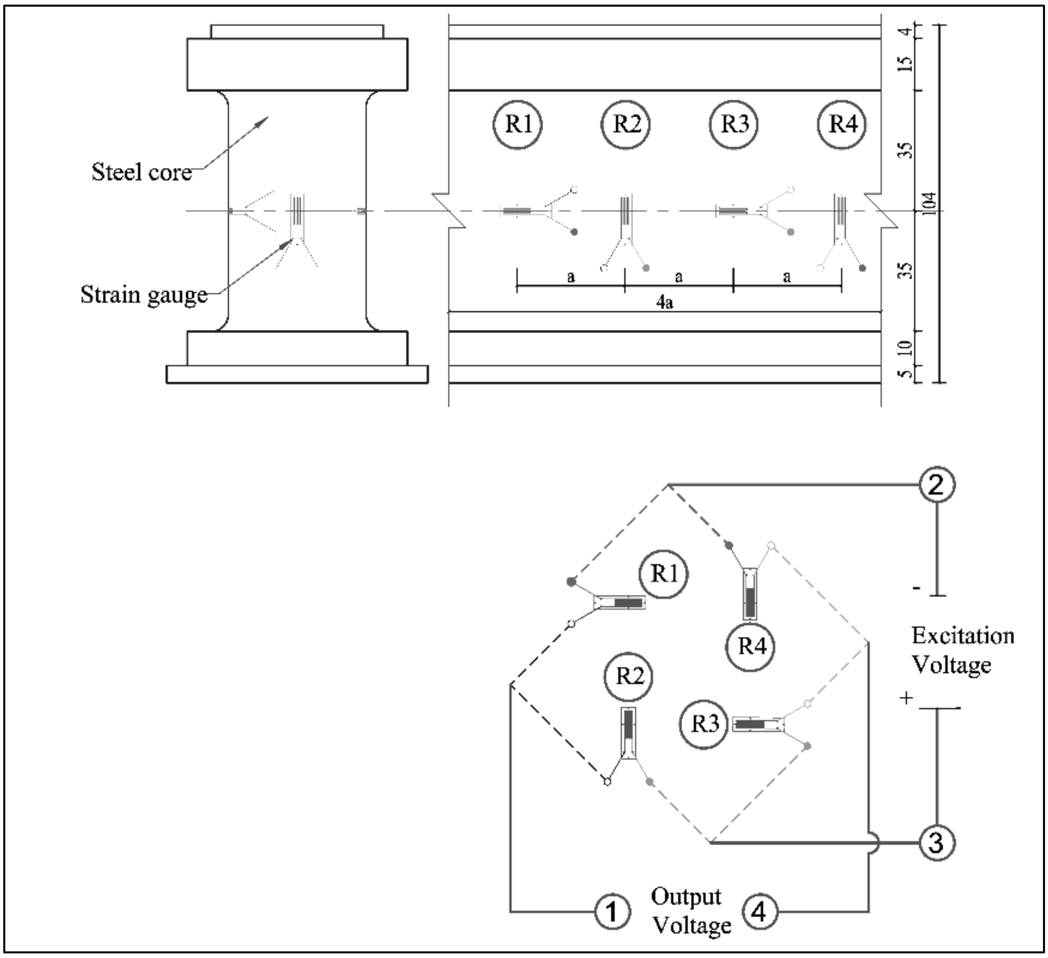

Figure 2. *Instrumentation and full-bridge circuit*

Figure 3. *Load cell production steps*

2.3. Calibration and Testing

Signal conditioning and data acquisition system (SCDAS) for PC-based applications illustrated in Figure 4 was utilized for converting output voltage into load data. Excitation voltage of 5V was adopted for the load cells. Shielded twisted-wire cable was used for the connection of load cell and SCDAS to reduce electrical noise from affecting the signals. Load cells were calibrated via the help of precise CBR test machine with a load ring. Load cells were calibrated by 7.5 kN intervals while loading up to the design load of 75 kN. Thus, measurement errors that could be resulted from non-linearity and hysteresis properties of load cell were mitigated. Afterwards, load cell output readings were verified at least three times both by increasing the load from zero, and decreasing the load from ultimate value.

Figure 4. *Signal conditioning and data acquisition system (SCDAS)*

2.4. Utilizing Load Cells

A total of four identical load cells produced in this way were tested in an experimental research conducted on slabless reinforced concrete staircases (Kaya, 2020). Load cells were mounted on the hydraulic jacks as illustrated in Figure 5. Thus, these load cells were used extensively within the scope of the research consisting of 12 specimens. Applied loads individually could be detected with a sufficient accuracy, response time, and stability at room temperatures throughout the experiments. Moreover, compatibility of load cells with the SCDAS was quite decent. Load-displacement curves could be plotted without any problem with the collected data at the end of each experiment.

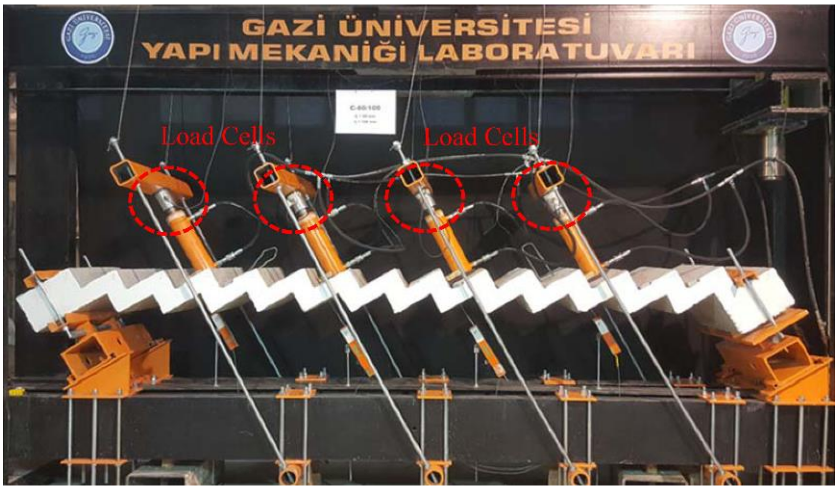

Figure 5. *Utilizing of load cells in the experimental set-up*

3. CONCLUSIONS

In this research, single directional load cells were produced while reducing the cost almost 90%. The design, production, calibration, and testing of these load cells were explicitly defined. They were also utilized in an experimental research on reinforced concrete members. The main principles and approaches adopted in the procedure are intended to guide researchers who are willing to produce their own load cells. Precise and absolute judgements should be avoided, since the results are rely on relatively few data.

Load was measured with a sufficient accuracy, response time, and stability at room temperatures via the load cells produced. The load cells produced in accordance with the proposed method can be used for the experimental research on any reinforced concrete members in which quasi-static loading is preferred.

One of the load cells was unintentionally dropped on the hard floor from 1 m height during the experiment. Developed aluminium cover was able to protect load cell from breaking down. This kind of cover is highly recommended for these load cells.

CONFLICT OF INTEREST

The authors declares that, there is no conflict of interest regarding the publication of this paper.

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