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Research Article

DEFORMATION MEASUREMENT IN A STEEL BRIDGE SYSTEM BY USING IMAGE PROCESSING METHOD

Zeynep FIRAT ALEMDAR[1], Senem BİLİCİ*[2], Fatih ALEMDAR[3]

[1] *Yıldız Technical University, Dep. of Civil Eng., Esenler-ISTANBUL;* ORCID:0000-0002-0793-8582
[2] *Istanbul Aydın University, Dep. of Construction Technology, ISTANBUL;* ORCID:0000-0002-9698-8900
[3] *Yıldız Technical University, Dep. of Civil Eng., Esenler-ISTANBUL;* ORCID:0000-0002-8752-0310

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ABSTRACT

In this study, the digital photogrammetry method is described to measure displacements in the experimental mechanics without applying digital sensors to the specimens is described. This optical method uses a camera, a computer with frame grabber board and image analysis methods within the MATLAB Image Processing Toolbox. The displacements at the surface of the test specimens are obtained by the analysis of the movements of special dots painted on the specimen before testing. The image analysis algorithm makes it possible to automatically track the motions of the dots and compute their centroid coordinates in a sequence of images. The aim of the study is to determine the vertical deformation of the steel bridge during testing and to compare with the results obtained from both a traditional instrument and a finite element analysis.
Keywords: Steel bridge, deflection measurement, digital image processing.

1. INTRODUCTION

Mankind can react by perceiving the events surrounding it through its ability to see. The visual function sends information to the brain about the described properties of the object (color, size, position, etc.) and perception is possible with the visual center herein. In today's image sensing technologies, improvements have been recorded with reference to this visual perception system in human physiology. Image processing is the attempt to perform the operations performed by the human vision system in a computer environment. Image processing methods include many processes such as acquiring, digitizing, segmenting, improving, classifying, recording and recalling of images. In image processing, various studies are carried out on the image of the object and they provided information which could not be obtained in abstract ways, and the object of application of the image processing technology has improved accordingly [1].

Image processing is also used to process or enhance existing images that have already been recorded. Image analysis systems are used with the software and the received image is analyzed on segments of second. Image analysis plays a key role in the development of intelligent systems and the main purpose of research on intelligent systems is to develop systems that can perceive reason, move and learn.

* Corresponding Author: e-mail: senembilici@aydin.edu.tr, tel: (212) 383 52 00

Digital images form the main part of the imaging methods. The images in real life, which have been converted into a digital picture, are processed as an input picture and a new picture is created as a result of the change of the picture properties and its image. Digital images are usually obtained using industrial cameras. The images are transferred from the camera to the computer and analyzed using commercial software developed for this purpose or developed by the user [1].

Literature research indicates that image processing method in recent years has a wide use in engineering subjects. Some of the works conducted are summarized below.

Austrell et. al. [2] evaluated deformation and strain in mechanical test pieces without applying any sensors to the test member. The image processing algorithm automatically monitors the movement at the points and calculates the coordinates at the average of the points according to the order of the images. This method uses the shape functions in the finite elements to calculate the deformations in the intermediate locations and the surfaces of the strains. Automatic detection of points in the first picture saves time. This method can be implemented better when grid systems are drawn on the test sample.

Whiteman et.al. [3] used digital photogrammetry to measure deformations in reinforced concrete beams during destructive tests. Three-dimensional measurement of displacement components, unlimited measurement range, and reducing non-linear systematic errors most are some of the advantages of this method. The results were obtained from various tests on different beams. The measurements obtained from the photogrammetry and displacement transducers were compared.

Onat [4] studied the potential behavior of the concrete before failure by using image processing methods. For this purpose, 50x10x10 cm rectangular prismatic fiber concrete specimens were prepared and then subjected to three point bending tests. The deformation values corresponding to the loads applied were measured with a comparator. In addition, during the experiment, the samples were recorded with high resolution digital camera and images were obtained. These images were processed with the software encoded in the MATLAB program. The resulting deformation values were compared with the values obtained from the comparator simultaneously.

In his work, Kılınç [5] obtained scanned electron microscope photographs of the holes formed at different diameters and depths on the steel samples, then found the depths in pixels with the help of the MATLAB program and examined the samples. The steel specimens are left in corrosive environment and the depths were then calculated with the MATLAB program after the photographs of the holes were taken with scanning electron microscope. Depth values determined using the image processing method and the actual groove depth values were compared and it was concluded that the actual groove depths can be obtained with a maximum relative error of 6.5%.

Çomak et.al. [6] investigated the possibility of using image processing methods in concrete technology especially in the field of civil engineering. It was concluded that the studies on the image processing methods for the determination of the concrete properties and the evaluation of the parameters have increased.

Fırat Alemdar et.al. [7] studied the location of nonlinear response in structural systems under different loadings. The deformation data was obtained from the plastic regions of the columns during response to strong motion events while investigating the seismic performance of a four span large-scale bridge system. A photogrammetry method was applied using grid lines to the top and bottom surfaces of the columns in order to record and analyze deformations in the plastic regions. The deformations and rotations of the reinforced concrete bridge column under dynamic loading were investigated and compared with the results obtained from conventional test equipment. The photogrammetry method has succeeded in tracking the deformed shape of the plastic parts alongside the lateral and vertical displacements of the points on the surface drawn using reference lines, but the results of secondary calculations such as column rotations have achieved a limited success.

Şahin et.al. [8] have compared the cross-sectional areas of the steel samples subjected to the tensile tests by measuring the areas using conventional measurement methods and image processing methods. The ductility is determined by processing the section images taken at the rupture stage and the values obtained from the both methods were compared. As a result, the average error margin between the two measurements was calculated as 29.74%.

Henke et.al. [9] applied the digital image processing method to improve the system of measuring building deformation in a simple, accurate and economical way. The selected points of the building are recorded by electronic cameras at regular intervals and their locations are measured by digital image processing method. In this case, the target points used the light emitting diodes (LED) and the cameras used for the measurement also operate in the infrared range; which means that the image quality is not affected by the illumination conditions. Laboratory tests have indicated that the application of this method makes it possible to set targets in millimeters at certain distances for building systems. In the study, a structure with a wide span timber roof element was considered and the movement of all three points of the four main beams was measured by digital image processing method.

2. MATERIALS AND METHODS

2.1. Steel Bridge System

In this study, a video recording was taken during the vertical loading of the steel bridge system prepared within the scope of 'International Student Steel Bridge Competition' organized by Boğaziçi University. The video was converted into photographs as 1 in a second using the image processing method and the vertical displacement in the middle section of the bridge was calculated by the MATLAB program.

Geometrical Properties of the Bridge

The steel bridge used in this study has a total length of 6.3 m and a height of 1.98 m (Fig. 1). The steel material used in the bridge is A37 Steel, and the pipe profiles used are of φ40 mm and φ15 mm. The properties of the steel material used are provided in Table I.

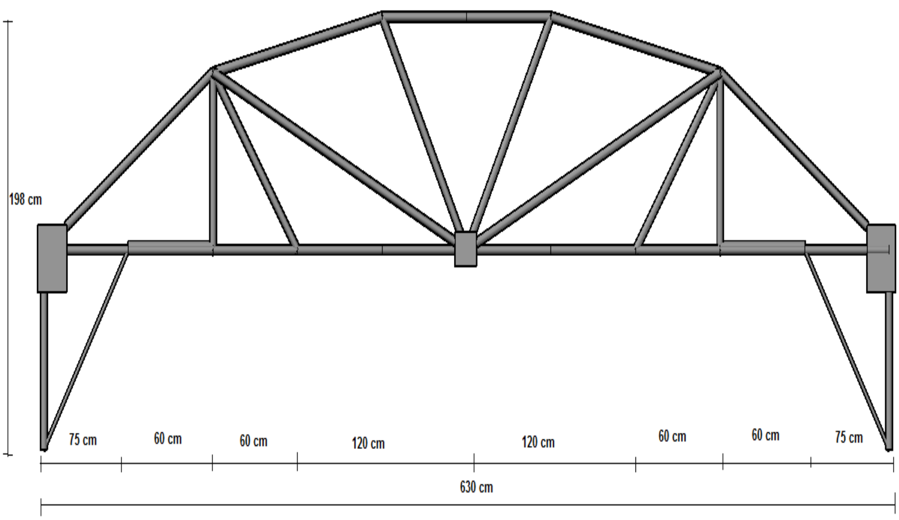

Figure 1. Front view of steel bridge designed in AutoCAD program

Table 1. Mechanical properties of steel

Minimum tensile stress (MPa)	360
Maximum yield stress (MPa)	235
Elasticity Modulus (MPa)	200000
Density (kg/m^3)	7850

The Loading Test

In vertical load application; three loading boards (weighing approximately 25 kg) with a total length of 1.5 m have been installed in the center of the bridge, at the right and left centers. As shown in Fig. 2, a load of 250 kg was placed on the right side of the bridge in a symmetrical manner with respect to the midpoint of the bridge, and a load of 1000 kg was placed on the middle point of the bridge [10].

Figure 2. Loading stage

2.2. Vertical Deformation Results

The position of the special point on the bridge was marked as the reference point in Figure 3 and the image processing steps were followed. The images obtained from the video taken during the experiment under vertical loads had a resolution of 1440x1080 and 29 images/second were recorded. In MATLAB, the vertical displacement values of this special point were obtained throughout the experiment. Since these values were in pixels, they were required to convert into millimeters. The distance between two points in millimeters, of which we know the length in the sample, was determined as the distance in pixels from the images. The data received in pixels from the image processing method was multiplied by the ratio of these values (actual length / pixel value) to convert them into millimeter. The amount of time that each photo was taken was calculated as the ratio of the total video duration calculated in seconds to the total number of photos.

Figure 3. Reference point marked in the steel bridge

The displacement value measured by LVDT for the steel bridge was 3.47 mm, and the final displacement value obtained by the image processing method was 3.6 mm (Fig. 4). The error rate is (3.6-3.47) /3.47=0.037. The error rate is very low and the value is close to real one. The reason for the fluctuations in the displacement graph is that when loads are placed on the loading boards during the experiment, vibrations appear on the bridge and continue until the end of loading.

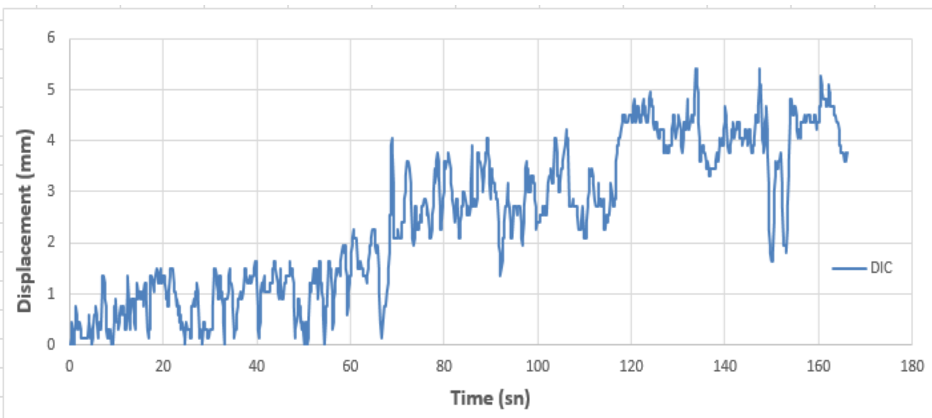

Figure 4. Displacement of reference point marked in the steel bridge

2.3. Analysis of Steel Bridge with Finite Elements Program

The steel bridge was modeled with the SAP2000 Finite Element (FE) Program and analyzed according to the loading experiment (Figure 5).

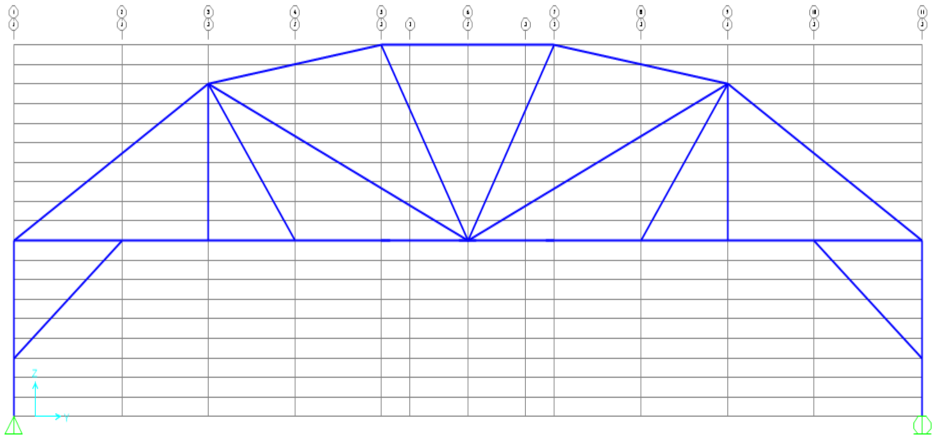

Figure 5. FE model of the steel bridge

According to the result of FE analysis, the vertical displacement value at the midpoint of the bridge is 2.43 mm (Figure 6). The displacement value obtained in the loading test is 3.47 mm. The error rate of the result is calculated as (3.47-2.43)/3.47=0.29 (29%). The reasons of high error ratio are that the bolt elements used in the connections of profiles cannot be modeled while modeling the steel bridge in the SAP2000 program and the internal stresses occurred in the welded regions due to temperature effects cannot be taken into consideration during modeling.

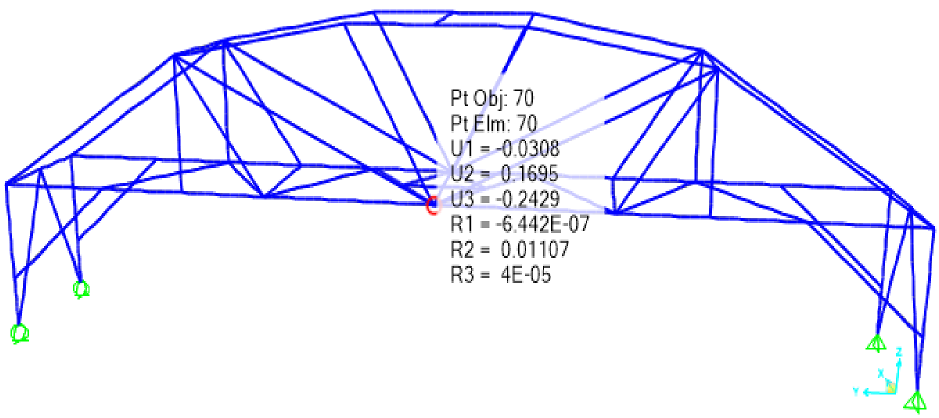

Figure 6. Displacement values in FE model

3. RESULTS

The steel bridge test used in the study was conducted within the scope of the competition at Boğaziçi University and it was not possible for us to approach the bridge during the test.

Although the sunlight affected the quality of the video, the results from the image processing method reflect the reality and the error rate is 3.7%. The error ratio is found to be 29% from FE analysis of the model.

The following results are drawn from the experimental and analytical works performed:

• The image quality of the camera used for video recording during the experiment, the amount of light in the environment where the experiment is performed and the recording distance are of great importance to obtain accurate results from image processing method.

• Special care must be taken to avoid shading of the sample surface as each pixel image on the sample will affect the numerical results. In such cases, it is necessary to clean the surface by removing roughness that may form shadow.

• Deformation measurement with image processing method offers many advantages over other classical methods. In general, measurements can be made without direct contact with the material surface and the measurement accuracy can be adjusted according to the application and resolution of the camera system.

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