www.wordlyknowledge.uz Volume: 1, Issue: 2, 2023

Structural Deformation Monitoring and Analysis of Highway Bridge Using Accurate Geodetic Techniques

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ANNOTATION: As the new materials and technologies are increasingly applied to construction of civil infrastructures such bridges, dam and tunnels, the need for structural monitoring systems, maintenance and restoration becomes more important and vital. Bridges are widespread in every society and affect its human, social, economical and cultural aspects. Measurements and monitoring of the structural deformation of highway bridges have an essential role in structural safety. This paper investigates an integrated monitoring system for estimation of the deformation behavior of one of the important reinforced bridges in Egypt. The applied data for analysing the deformation of any structure from geodetic observations are the coordinates of several monitoring points distributed on the structure itself.

KEY WORDS: Bridges, Monitoring, Statistical Tests, Transformation, Deformation.

INTRODUCTION: Structural health monitoring is the term that describes the range of systems implemented on various civil infrastructures, which inform operators whether the structural deformation is the same as those the structure was designed to tolerate or not [1]. The demand for structural health monitoring systems for bridges has grown over the last few decades [2]. In order to know the safeties of bridges, monitoring their real-time displacement and recording their fatigue history are very important.

The measuring techniques and instrumentation for geometrical monitoring of structural deformations have traditionally been categorized into two groups according to the two main groups of professionals who use the techniques [3]:

1) Geodetic surveying, which includes Global Position System (GPS), close range Photogrammetry, terrestrial surveying (leveling, theodolite, total station and very long base line interferometer) and satellite laser ranging.

2) Geotechnical structural measurements of local deformations using tilt meters, strain meters, extensometers, joint meters, laser distance gauge method, etc.

Each type of the measurements has its own advantages and drawbacks [1]. The acceleration integration method integrates the acceleration, which is measured by acceleration gauge, to obtain the displacement. But its error is relatively large. The laser distance gauge method is often influenced by the weather. Furthermore, the geotechnical structural measurements often need to stop the traffic, which brings a lot of costs. So these methods are suitable for some structures whose survey distance is relatively short and the displacement is relatively small. But to structures such bridges, these methods are difficult to use. Geodetic surveys, through a network of points interconnected by angles and distances measurements, usually supply a sufficient redundancy of observations, for the statistical evaluation of their quality and for detection of errors [4] [5].

They give global information on the behavior of the deformable object. Recent advances in technology have made it possible to use accurate surveying equipments to measure and monitor the deformation of structural members. The emergence of reflectorless accurate total station allows working without special reflectors (prisms). It is now possible to measure without long and

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tedious search of prisms to lift the reflector under the roof of buildings. The principle of work of reflectorless total station is the same as that of a simple total station [6]. The surveillance of an object involved in a deformation process requires the object as well as the process to be modeled. Conventionally, geodetic modeling the object (and its surrounding) means dissecting the continuum by discrete points in such a way that the points characterize the object, and that the movements of the points represent the movements and distortions of the object. This means that (only) the geometry of the object is modeled [6]. Furthermore, modeling the deformation process means conventionally to observe the characteristic points in certain time intervals in order to monitor properly the temporal course of the movements. This means that (only) the temporal aspect of the process is modeled. Nowadays, for the analysis and the interpretation of structural deformations, different deformation models have been developed [7].

In deformation monitoring studies, these models include static, kinematic and dynamic models. Static model that is not dependent on time provides the determination of deformations on the characteristic points of the area or the structure, which is monitored. In this paper, statistical tests of geodetic observations using F-Fisher criterion with a confidence level of 98% were applied. Kinematic models allow estimating the velocity and even the acceleration (by building double differences) of monitoring point movements. The intention of kinematic models is to find a suitable description of point movements by time functions without regarding the potential relationship to causative forces. In Egypt, there are many highway bridges with different lengths and widths which have a great effect on Egyptian life and economy. These bridges were constructed from different materials such as reinforced concrete, steel and wood. In this paper, studying the deformation behavior of one of the most important bridge in Delta Egypt is presented.

The used data for analysis the structural deformation of the studied bridge are the coordinates of monitoring points (targets). The coordinates of these points were calculated depending on the occupied stations coordinates. So any deviations in coordinates of control points between original and repeated observations epochs will affect the coordinates of monitoring points and consequently affect the values of structural deformation.

To overcome this great problem, four reference stations were selected not far the studied bridge and fixed in stable soil. The resulted deviations (differences) of these reference stations coordinates between epochs were very small and didn't mean that these points were moved or deformed. In geodesy, there are no identical coordinates of points between two epochs of observations [2].

The deviation in coordinates resulted from systematic errors in observations (temperature, air pressure, instrumental errors, and observations in different times of day… etc.). Then the following steps were done: 1) Carrying out transformation of reference stations coordinates from any other epoch of observations (second, third, fourth…) to the coordinates of the first epoch of observations by using seven parameters transformation to find these parameters.

2) Depending on the resulting parameters of transformation, the coordinates of all monitoring points of the other epochs of observations (second, third and fourth) were transformed to the system of coordinates of the first epoch of monitoring process. By this way, any small deviations in the monitoring points coordinates were removed.

Statistical tests are widely used to determine if a given quantity (coordinates of points in first epoch observations) is compatible with, or significantly different from, some other quantity. Statistical tests on the residuals would determine which of the above statements is supported by the data. For network adjustments, statistical testing is widely used for data quality assessment. So

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the statistical tests can be used to detect whether there are any significant coordinates differences between each two epochs of observations. This model of the observations analysis does not consider the time intervals between the observations nor the factors responsible for the deformation—explicitly.

Conclusions: Based on the results obtained, the following conclusions can be summarized: 1) The proposed geodetic monitoring techniques can provide valuable data on the deformation of the structural members and movement of structures such as highway bridges. The accuracy of the monitoring target coordinates will be improved if the two total stations are applied instead of using one total station only. 2) Application of seven parameters transformation technique is an effective method for determining the values of deformation of structure because it can remove the systematic errors of observations between the two successive epochs; 3) Achieving the required accuracy for geodetic monitoring technique of highway bridge is based on the following factors: a) The used instruments specifications (Instrument resolution, data collection options and the proper operating instructions). b) The field observing and modeling procedures. Measurements and adjustment techniques of the network have direct influence on the detection of monitoring point's displacements; 4) All the recorded noise levels in all places around the studied highway bridge are much more the permissible limits according to the Egyptian law of environmental and world organizations limits; 5) Statistical test using F-Fisher criterion with a confidence level of 98% can be used to identify the values of deformation for any structure such as bridge between any two epochs of observations.

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