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TITLE: METHODS OF MONITORING DEFORMATIONS IN ENGINEERING STRUCTURES.

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METHODS OF MONITORING DEFORMATIONS IN ENGINEERING STRUCTURES.

ABSTRACT

This scientific article explores the objectives and fundamental principles of engineering geodetic surveys to detect structural deformations, identify the types and causes of subsidence and displacements, and analyze the monitoring processes for deformations in buildings and structures. It presents a methodology for predicting the movement of structures by accurately determining their deformations, displacements, and potential failures using high-precision geodetic techniques. The study assesses the current geodetic methods for monitoring deformations in hydraulic structures, draws conclusions on the most effective approaches, and provides suggestions for future research.

Keywords: deformation, tilt, draft, rotation, leveling, roll.

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INTRODUCTION

Deformations in buildings can occur under constant and alternating loads. These deformations are localized when there are movements, rotations, or displacements of structural elements or the entire building. Deformations can be categorized into residual deformations, which remain after the load is removed, and elastic deformations, which disappear once the load is lifted.

Buildings and structures are susceptible to various deformations due to design characteristics and the continuous influence of anthropogenic and natural factors. Deformations refer to changes in the spatial position of buildings and structures. Downward movements of these structures or their parts are termed settlement, while upward movements are known as heaving. Lateral movements or shearing can also occur.

The settlement of buildings and structures stabilizes over time, eventually fading and stopping. Improper placement can lead to tilting, twisting, distortion, and tearing of the structure. Horizontal plane movements are often caused by external pressures such as water, wind, and soil.

Tall structures are particularly prone to bending and deformation due to factors like precipitation, uneven solar heating, and wind loads.

The objective of geodetic observations is to obtain precise numerical data describing the absolute values of positions and deformations to implement measures that prevent potential damage. There are three types of observations: systematic, urgent, and special. Systematic observations are conducted according to a predetermined schedule. Urgent observations are performed when there is a significant deviation from the normal deformation state. Special observations are employed to ascertain the causes of deformations.

A critical aspect is establishing the required accuracy of geodetic measurements. The accuracy is defined in relevant normative documents as the mean square error. For instance, permissible errors in determining settlement should range from 1 mm to 5 mm, depending on soil conditions. Horizontal displacement measurements of building components should have a standard deviation between 1 mm and 15 mm, while measurements of building tilts should be conducted with a standard deviation not exceeding 0.0001 times the height of the building walls.

Sedimentation markers are placed on the foundations around the building's perimeter, with their positions marked on the walls and fixed with permanent colorful stamps. Leveling is used to determine the general slope characteristics for different sections of the building.

The subsidence of buildings and structures can be assessed through various precise geodetic methods, including geometric leveling, trigonometric leveling, hydroleveling, microleveling, and photogrammetric techniques such as photogrammetry and stereophotogrammetry.

Among these, high-precision geometric leveling is the most widely adopted method in practice. This technique involves periodically measuring the absolute heights of installed benchmarks (rappers) to monitor deformations. These benchmarks, labeled as 1, 2, 3, ..., 20 (see Fig. 1), are routinely measured to detect any subsidence or movement over time.

Deformation markers (also known as sediment markers) are installed on load-bearing columns of buildings and structures at intervals of 6 to 12 meters or 12 to 24 meters, both externally and internally.

Figure 1. (a) Placement of benchmarks (sediment markers), level crossings and (b) construction of marks

These markers are placed along at least three horizontal and vertical axes, with a minimum of four markers installed along the perimeter. The top of the deformation marker should be positioned at least 3-4 cm away from the wall or column surface.

When installing these markers, considerations should be given to accessibility and the feasibility of installing a leveling instrument. A straightforward and dependable design involves using a metal bracket, which can be either embedded into the wall at a specific angle or welded onto a metal column or plate anchored within the wall. This design ensures accurate alignment of the leveling instrument with the marker (see Fig. 1, b).

At greater distances, such as from Benchmark Rp 3 to sediment marker 14 and from Benchmark Rp 2 to sediment marker 19 (Fig. 1), auxiliary benchmarks B1, B2, ... Bn are established. Sediment deposition is monitored periodically on a quarterly, semiannual, or annual basis until sediment stabilization is achieved, defined as an annual sedimentation rate of 1-2 mm.

Leveling. Leveling is a crucial aspect of deformation monitoring. Electronic (digital) levels designed for this purpose incorporate special bar code lines, with RAB and BAR codes utilized for encoding. These devices boast automatic scale reading capabilities, eliminating the need for measuring horizontal distances and performing redundant calculations between leveling points. The measured values are promptly displayed on the level's screen. Some digital levels even facilitate in-field processing and leveling transitions.

However, it's important to note that digital levels, like all instruments with compensators, are susceptible to vibrations and strong electromagnetic fields, especially when operating near power lines, exposed conductors, transformers, bus bars, and similar sources, as these can potentially damage the electronics. Among the contemporary digital levels available, devices from the DiNi series stand out (see Fig. 2).

Figure 2. Digital level DiNi 03

For SDL 30/50 levels, fiberglass, aluminum, or invar laths equipped with a specialized RAB code are employed. Conversely, for DiNi 0.3/0.7 levels, invar, folding, or telescopic laths featuring a dedicated bar code are utilized.

In situations where the benchmark marks are elevated (as depicted in Fig. 3, b), a tape measure is employed while the leveling instrument remains stationary.

Figure 3. Alignment scheme using an iron tape measure

High-precision geometric leveling effectively addresses the challenge of determining the precise positions of buildings and structures. However, in confined spaces such as basements, workshops, and other enclosed areas, the feasibility of geometric leveling using BAR-code and RAB-code DiNi03 instruments may be severely restricted.

Processing of leveling results

ccording to the observations of each cycle, the absolute balance of deformation marks is calculated, on the basis of which the absolute position, subsidence rate, structure deformation, structure bending and deformation graph are calculated.

Absolute sediment of individual marks S $_i$ is determined by the following formula

$$S_i = H_i - H_1, \qquad (3)$$

here: H_i va H_1 are the height of the mark in i -th and first cycles.

The sediment speed is determined by the following formula

$$v = \frac{S_{mid}}{T} \qquad (4)$$

where S_{mid} - is the mean location of the structure during the observation period T.

If v = 1-2 mm/year, then the condition of the structure will be regarded as sustainable.

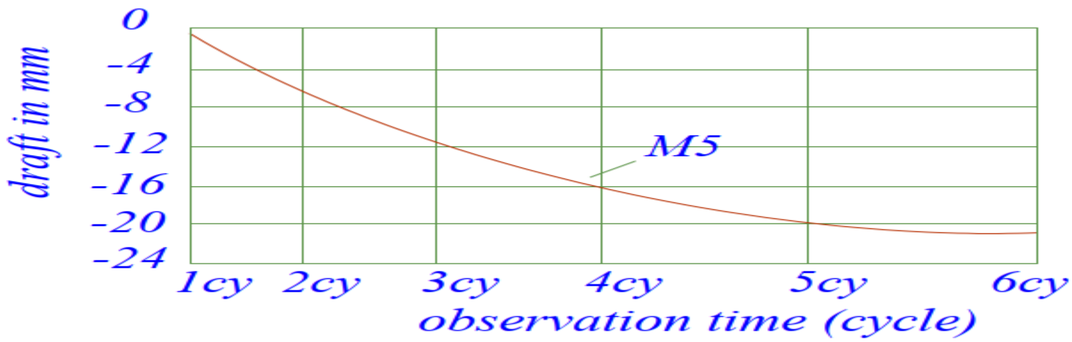
Bending (crane) is caused by the uneven location of the foundation,

as a result, the building tilts in one direction:

$$K = \frac{\Delta}{l} \qquad ((5)$$

bu yerda Δ- the difference in the location of the extreme marks along the axis of the structure, L – distance between the marks.

Torsion occurs as a result of the uneven location of the foundation, which



causes buildings to bend downward or convexly upwards:

$$f = \frac{2S_2 - (S_1 + S_2)}{2l} \qquad ((6)$$

where S_1 and S_3 are the extreme marks of the considered part of the straight line; S2 - average project of the site; L is the distance between the extreme marks. According to the results of observations in each cycle, graphs of sediment are made (Fig. 4).

Figure 4. A graph of sediment over time in cycle M5.

From these graphs, for example, it is possible to determine the estimated time for stabilization of buildings. Figure 4. Time graph of M5 deformation.

MAIN PART

To assess deformations according to technical specifications within the architectural ensemble of the Registan madrasah "Tilla-Kori," a comprehensive geodetic investigation was conducted.

This investigation focused on determining the precise positioning, deformations, and displacements of structures within the Tilla-Kori madrasah complex.

Various geodetic measurements were employed to address practical challenges. A 2nd-order leveling survey spanning 5 kilometers was utilized to ascertain structure settlements. This survey was conducted using the Trimble

DiNi03 high-precision electronic leveler, a digital instrument renowned for its accuracy.

The Trimble DiNi03 electronic leveler ensures exceptional precision, boasting an RMS error of merely 0.3 mm over a 1-kilometer leveling path. To facilitate the survey, a three-meter digital code relay was employed.

The calibration and alignment of the leveler and aiming marks adhered strictly to the guidelines outlined in the "Instructions for Leveling of 1st, 2nd, 3rd, and 4th Orders," ensuring methodological consistency and accuracy throughout the investigation.

OBSERVATION METHOD

The 2nd-order leveling was executed following the prescribed methodology and adhering to the tolerances outlined in the "Instructions for Leveling of the 1st, 2nd, 3rd, and 4th Orders."

The leveling procedure involved both forward and backward measurements employing the "merge" method. The accuracy of the leveling results was assessed by comparing the relative heights obtained from forward and backward measurements.

Allowable discrepancies between forward and reverse leveling were determined using the following formula:

$$\mathbf{n_{rux} = +/- 5\ mm.}$$

The 2nd-order leveling is conducted in the configuration of a closed polygon. Table 2 presents the relative height error limitations for the closed polygon across various cycles.

Table 2

Name of vertices of a closed polygon	Length, km	Measured relative height, mm	
		1 cycle	2 cycle
Mark 4481 Mark 5144	5	1.0	2.4

Analysis of vertical displacements of foundations based on leveling results.

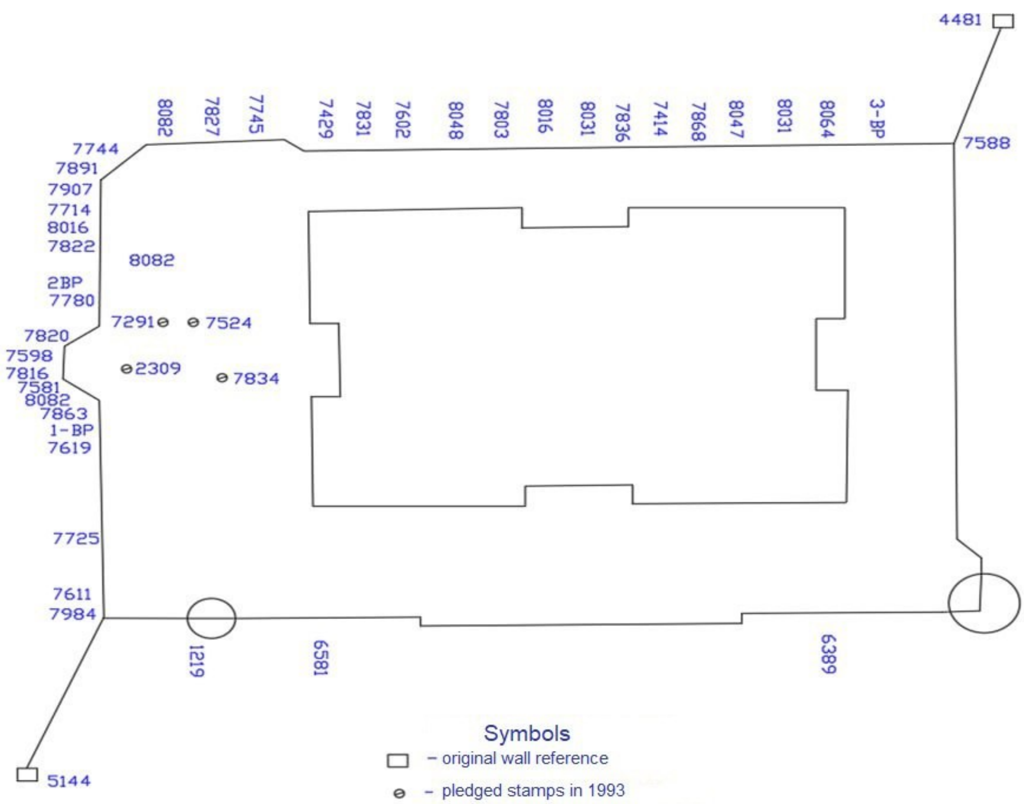
Two cycles of leveling at the 1st and 2nd orders have been successfully executed and concluded. Through careful examination of repeated height measurements, it is possible to confidently ascertain the vertical displacements of the buildings over the surveyed period.

Significant vertical shifts in the foundation of the building are evident in the wall markers, specifically marks 8024, 7725, and 7614 installed at the Tilla-Kori madrasa (Fig 5).

Despite the ongoing incline of the southwest tower of Tilla-Kori, there is minimal change observed in the height of the wall markers.

Figure 5. Placement of leveling marks in Tilla-Kori madrasa buildings

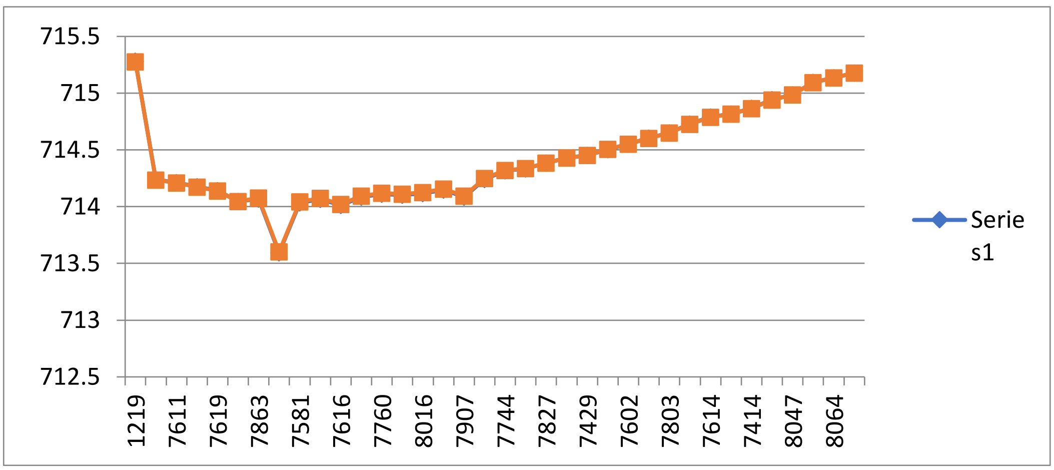
Comparative atalog of elevations of leveling marks



T.r.	Wall sign numbers	With 2 cycles N	1 cycle N	Difference n
1.	1219	715.282	715.278	0,004
2.	7984	714.238	714.235	0,003
3.	7611	714.212	714.210	0,002
4.	7725	714.176	714.174	0,002
5.	7619	714.142	714.140	0,002
6.	1vr	714 047	714 045	0,002
7.	7863	714 068	714 077	-0,009
8.	1326	713.593	713.602	-0,009
9.	7581	714 034	714 042	-0,008
10.	7598	714.065	714 074	-0,009
11.	7616	714 012	714 020	-0,008
12.	7820	714 085	714 094	-0,009

13.	7760	714.111	714.120	-0,009
14.	7822	714.103	714.112	-0,009
15.	8016	714.116	714.124	-0,008
16.	7714	714.147	714.155	-0,008
17.	7907	714 086	714 093	-0,007
18.	7891	714.240	714.249	-0,009
19.	7744	714.318	714.321	-0,003
20.	8028	714.334	714.337	-0,003
21.	7827	714.384	714.386	-0,002
22.	7745	714.429	714.431	-0,002
23.	7429	714.452	714.454	-0,002
24.	7831	714.504	714.506	-0,002
25.	7602	714.552	714 550	0,002
26.	8048	714.604	714.602	0,002
27.	7803	714.651	714.649	0,002
28.	8061	714.728	714.726	0,002
29.	7614	714.79	714.788	0,002
30.	7836	714.818	714.816	0,002
31.	7414	714.867	714.866	0,001
32.	7868	714.943	714.942	0,001
33.	8047	714 986	714.985	0,001
34.	8031	715.095	715 094	0,001
35.	8064	715.137	715.135	0,002
36.	3vr	715.178	715.178	0
37.	7588	715.452	715.452	0

Vertical profile of the northern and western walls of Tilla-Kori Madrasa



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Ứng dụng dữ liệu viễn thám đa cảm biến để thành lập bản đồ lớp phủ đất tại hệ sinh thái rừng ngập mặn Cần Giờ, TP. Hồ Chí Minh

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Tóm tắt:

Nghiên cứu này trình bày cách tiếp cận tích hợp dữ liệu đa phổ Sentinel-2, siêu phổ PRISMA và radar COSMO-SkyMed (CSK) nhằm xây dựng bản đồ sử dụng đất/lớp phủ đất (LULC) cho hệ sinh thái rừng ngập mặn Cần Giờ. Phân tích được bổ sung bằng các biến sinh học (LAI, FAPAR) và thư viện phổ thực địa để tăng cường khả năng tách biệt thảm thực vật và các bề mặt có tính chất phổ tương tự. Mô hình pha trộn phổ tuyến tính (Linear Spectral Mixture Model – LSMM) được áp dụng cho dữ liệu PRISMA nhằm giải quyết hiện tượng trộn phổ phổ biến trong môi trường ven biển. Dữ liệu CSK được dùng để nhận dạng khu vực đô thị và ao nuôi thủy sản. Kết quả phân loại cho độ chính xác tổng thể 88% (Kappa = 0,83), cho thấy hiệu quả của cách tiếp cận đa cảm biến trong mô tả cảnh quan dị thể. Phương pháp này có tiềm năng áp dụng cho các nhiệm vụ siêu phổ thế hệ mới.

Từ khóa: *Viễn thám đa cảm biến, mô hình pha trộn phổ tuyến tính, sử dụng đất/lớp phủ đất, siêu phổ.*

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Multi-sensor remote sensing for land cover mapping in the Can Gio mangrove ecosystem, Ho Chi Minh City

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Abstract:

This study presents an integrated approach utilizing multispectral Sentinel-2, hyperspectral PRISMA, and Synthetic Aperture Radar (SAR) COSMO-SkyMed (CSK) data to map land use/land cover (LULC) patterns in the Can Gio mangrove ecosystem. The analysis is supplemented with biophysical variables (LAI, FAPAR) and an in-situ spectral library to enhance the spectral discriminability of vegetation and spectrally similar surfaces. A Linear Spectral Mixture Model (LSMM) is applied to the PRISMA data to address the severe spectral mixing commonly encountered in coastal environments. Furthermore, CSK data are exploited to delineate urban settlements and aquaculture ponds. The classification results yielded an overall accuracy of 88% (Kappa = 0.83), demonstrating the efficacy of the multisensor approach in characterizing heterogeneous landscapes. This methodology exhibits significant potential for application in next-generation hyperspectral missions.