Application of Digital Image Correlation Technology in Geotechnical Structure Measurement

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Abstract: With the international trend towards digitization and intelligence, traditional geotechnical testing technology has gradually been replaced by digital image technology. This article focuses on the basic principle of digital image correlation method, discusses the applicability of this technology in strain measurement of geotechnical structures in civil engineering and bridge engineering, and discusses the development prospects of this technology.

1 INTRODUCTION

As an important part of civil engineering construction, the accuracy of geotechnical measurement results determines the overall quality of the project. However, existing testing techniques often require manual analysis and processing of data, resulting in low efficiency; The high cost of machinery and labor used is not conducive to the formation of scale. With the current international trend, the production system of digital maps and the intelligence and digitization of basic urban information are continuously promoted. At the same time, surveyors transmit the collected data in real-time to the network, achieving visual manipulation and efficient, convenient, and accurate data transmission. The new demand for measurement technology has accelerated the replacement of traditional manual drawing and mechanical measurement, and the application of digital image correlation technology in geotechnical structure measurement has emerged (Cao Lu, 2018).

Digital image related technology was proposed by scholars in the United States and Japan as early as the 1980s and has been invested in research and development. It is a modern optical measurement technology that integrates full field, three-dimensional, and non-contact measurements. Due to its strong adaptability to the external environment, low susceptibility to light interference, high degree of mechanical automation, and good operability, it has been widely applied in various fields such as bioscience, mechanical simulation, civil engineering, food safety, etc. In the field of civil engineering measurement, digital image related technology can be applied to measure the static displacement of objects during loading, such as torsion, bending, and tensile deformation. The accuracy of the results has been verified by scholars using finite element methods.

2 BASIC PRINCIPLES

Digital image correlation technology, also known as digital speckle correlation method, mainly consists of CCD or COMS cameras, lighting sources, image acquisition cards, and computers (Zhang Shunqing, 2017). It uses a CCD or COMS camera to store the captured image of the specimen on an image acquisition card, divides it into regions of interest at the pixel level through computer processing, and defines the specimen in each sub region of the region of interest as a rigid body. A search algorithm is used to calculate according to the pre-set correlation function, and the deformed rigid body specimen is compared with the region of interest to find the region with the highest correlation coefficient value, and locate the deformed rigid body specimen, and then calculate the deformation position of the rigid body specimen.

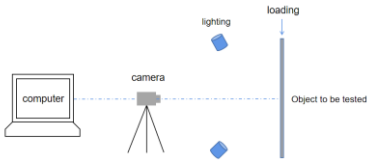

Figure 1. Schematic diagram of digital image related technology measurement system.

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2.1 Application of Digital Image Correlation Method in Bridge Crack Deformation Monitoring Monitoring

In bridge engineering, due to long-term external loads such as vehicle loads on the beam structure, cracks can easily occur over time, which can lead to insufficient bearing capacity of the bridge structure. Therefore, timely detection of cracks on the bridge structure can help workers prevent accidents and reduce the occurrence of dangerous accidents. According to the specifications of ACI and CBE, the allowable width of transverse cracks in bridge structures is 0.2mm, which is more stringent in areas with corrosion hazards. The allowable width defined as transverse cracks is 0.1mm; At the same time, longitudinal cracks are not allowed to appear in the beam structure of the bridge. For cracks and other deformations on the bridge beam structure, the electrical measurement method is usually used, which selects points for the bridge beam structure and measures the strain at representative points. However, this method is difficult to measure the strain at the mid span of the bridge, and when measuring deformations with minimal deformation, using a magnifying glass cannot meet the accuracy requirements. Therefore, non-contact digital image correlation technology was used in the measurement of cracks in bridge beam materials. In operational engineering, the field of view of the digital camera was adjusted to 102.64. * 82.09, and the calibration result was 0.0802 pixel at the pixel level. By intercepting the deformation area of 30 * 30 pixel in DIC software and comparing the displacement difference between the two areas, it was found that digital correlation technology has superiority and feasibility in measuring the deformation properties of bridge beam structures under dynamic and static loads (Bai Xiaohong, 2011).

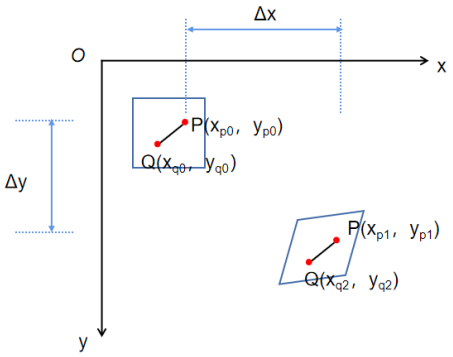

Figure 2. Measurement process of strain points in bridge structures (Wang Jing, 2003).

2.2 Application of Digital Image Correlation Method in Rock Microscopic Material Monitoring

In civil engineering, whether natural geotechnical materials or artificial materials, there is heterogeneity within them. This non-uniformity will lead to uneven strain in the structure under external loads, resulting in cracks in geotechnical structures constructed from geotechnical or synthetic materials (airport taxiways, large embankment supports, highway pavements), leading to a decrease in their mechanical performance. However, the detection of the aforementioned geotechnical structures faces challenges such as large monitoring areas and limited selection of detection methods. Usually, traditional sensors cannot solve problems such as cracks on highways, and laser, radar, ultrasound, and other technologies are used to solve them. However, if non-contact detection of the object being tested is required, digital image processing technology will emerge. It uses DIP technology to analyze the image situation and further detect the bedding structure of concrete materials in geotechnical structures, Further research will be conducted on the mechanical and physical properties of rock and soil materials such as concrete.

2.3 Application of Digital Image Correlation Method in Weld Strength of Materials Performance Detection

Similar to rock materials, weld material is also a non-uniform material, which is affected by different materials, temperatures, and construction processes, resulting in different mechanical properties; Therefore, it is very important to conduct quantitative research on weld material in different regions. With the growing use of DIC, many scholars have applied digital image correlation technology to the weld research of base metal. They take TC4 titanium alloy as the research object, place it in the uniaxial Tensile testing, and measure the strain field of weld material under different loads and areas. According to digital image correlation technology, the experimental results show that the strain in the base metal area is much greater than that in the weld seam area and the affected area, and the base metal area has good toughness. At the same time, the finite element model is used to verify the above results, indicating that using digital correlation technology can effectively detect the mechanical properties of the weld seam

material, with high accuracy and good measurement reliability (Hang Chao, 2013).

2.4 Applied to Damage Observation and Fatigue Assessment of Steel Components

Steel structural materials have the advantages of light weight, short construction period, strong seismic performance, and easy transportation, and are currently highly praised by domestic and foreign countries. With the vigorous promotion of steel structures and prefabricated installation methods, more and more building forms are constructed using steel structures, such as steel residential buildings, steel bridges, etc. It can be seen that the usage of steel structures is increasing day by day. Therefore, the damage and fatigue assessment of steel structural components will play a very important role in the operation of steel structural components, and have very good development prospects. Traditionally, the methods for damage and fatigue testing of steel structural components have low efficiency, are prone to blind spots in the detection process, and measurement instruments are relatively expensive. With the continuous fermentation of image recognition technology, operations based on digital image related technologies have emerged. Before the experimental operation, the specimens need to be divided into base metal and weld metal specimens. A fatigue testing machine is used to cyclically load the specimens, with a minimum loading setting of 10kN. Optical calibration equipment is used to calibrate the loaded specimens to form speckle. The fatigue performance of the base metal or weld material of the steel structure specimen is determined by comparing the three-dimensional displacement parameters and three-dimensional strain parameters of the speckle. The experimental results indicate that this method has a certain degree of predictability and can help technicians detect fatigue signals of steel structural materials in advance, providing effective support for the study of residual bearing capacity of steel structural components (Yang Yuntao, 2022).

3 CONCLUSION AND OUTLOOK

Digital image related technology is a widely used technology with good development prospects and advantages. It has good measurement stability in civil engineering materials and bridge engineering, and its future development trend will continue to develop towards intelligence, wide applicability, high precision, high efficiency, Technological convergence and other aspects, bringing more benefits to mass industrial production and life; At the same time, there are still urgent problems to be solved in digital image related technologies, including further overcoming challenges in low-quality image processing, multimodal image processing, privacy protection, and other aspects.

Of course, in addition to the above, there are also many material measurements using DIC technology, such as internal deformation of pipelines (Xiangjun Dai, 2023) and fatigue cracks. As well as rock cracks under high water pressure (Yun Tian, 2023), it can be seen that digital correlation technology (DIC) has applicability in various fields of engineering and is still worth further exploration.

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