Steel Reinforcement construction monitoring method based on 3D Laser Scanning and BIM technology

Dongyan Xue[1,a*], Lusheng Mo[1,b], Yao Li[1,c]

dyxue2008@163.com[a*], xzasapross@126.com[b], Lily15610181927@163.com[c]

School of Civil Engineering and Architecture, Jiangsu University of Science and Technology, Zhenjiang212100, China[1]

Abstract: This paper proposes a Steel Reinforcements construction monitoring method based on 3D Laser Scanning and BIM technology: Using the family Library function of BIM software, the building information model of concrete and reinforcement of the structure is established；By dividing the reinforcement construction into several scanning steps, the three-dimensional laser scanner is used to scan the reinforcement in the construction in steps, and the point cloud data model of each step is obtained; The point cloud data model of Steel Reinforcement and the building information model of Steel Reinforcement are compared by post-processing software, and the error analysis is carried out to check whether the accuracy of Steel Reinforcement construction meets the requirements of the specification. If it does not meet the requirements, it will be adjusted. The case study results show that the proposed method based on BIM and 3 D Laser Scanning can effectively improve the construction accuracy of Steel Reinforcements.

Keywords: 3D Laser Scanning; BIM Technology; Steel Reinforcement Construction Technology; Point Cloud Data

1 INTRODUCTION

In the current construction environment, the traditional Steel Reinforcement construction accuracy is poor, affecting the quality of the project. As an important part of reinforced concrete structure， Steel Reinforcement is difficult to mend or inspect， once the project is completed. In the past, the use of optical monitoring methods in the case of outdoor open air, weather, and wind direction is particularly easy to interfere with the measurement factors. 3D Laser Scanning technology can go deep into any complex field surroundings for any scanning undertaking. Its range is spacious and the maximum upright field of the horizontal field of view can reach from300degrees to 360degrees. It has the feature of being quick, accurate and having strong freedom fighters to environmental interference factors. From another point of view, the use of commercial software to model is a common means. For example, according to the design drawings, based on the original CAD design drawings and data, using AutoCAD, 3Dmax, BIM software, etc. With the continuous enhancement and development of BIM technology software, BIM technology is being used in engineering.

Some scholars have indicated that 3D Laser Scanning technology uses 3D Laser Scanning instruments to monitor various engineering buildings and has significant advantages over traditional monitoring methods. Francioni M first put a 3D Laser Scanning instrument into the

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landslide interface, realized that deformation monitoring of the landslide, and solved the landslide without safety problem. Min-Koo Kima, Jack C.P. Cheng Automatic detection and analysis of geometric quality of precast concrete members based on 3D Laser Scanning the automatic detection algorithm for Steel Reinforcement side based on 3D Laser Scanning is proposed. Clarenz U proposed an algorithm to reduce noise in complex point cloud data by defining an anisotropic data point diffusion mathematical model. Wang et al. used a 3D Laser Scanning tool to answer the difficulty of cloud model location. In the observation of ancient buildings in Istanbul, Cumhur Sahinfirst combined CAD, 3Ds Max and 3D Laser Scanning technology. Scanning technology and BIM technology to enhance the exactness contrast has become usual methods. The application of construction progress detection, Liu Shasha proposed a method of BIM combined with the integration of point cloud data, and realized that the semi-automatic construction progress detection of the main building project through practical engineering. Wang Tao conducted a fusion experiment of 3D Laser Scanning technology and BIM technology to study the construction error. Wang Daibing conducted construction guidance through BIM reverse design, which improved the accuracy of construction and saved construction costs.

At present, although 3D Laser Scanning technology has shone in the field of building construction monitoring, there is no feasible process plan for the construction monitoring of Steel Reinforcements. The purpose of this paper is to supply a feasible check method for the precise building of Steel Reinforcements in view of the above difficulty. By establishing the BIM model of Steel Reinforcements，it is divided into several construction steps. The two models are compared to analyze the construction accuracy of Steel Reinforcements, and then the Steel Reinforcements that do not meet the requirements of accuracy specifications are adjusted in time to ensure the accuracy and reliability of Steel Reinforcement construction as much as possible.

2 BIM MODELING OF STEEL REINFORCEMENT

In the actual project, the role of BIM is often to restore the model according to the drawings or to design the drawings first, and then turn the model, which only plays the role of BIM technology reverse engineering. This is a waste of BIM technology resources, many construction units to misunderstand BIM technology. The construction business is in the procedure of digitalization and intellectualization, but the process of intellectualization is unhurried. And the forward design of bridge reinforcement based on BIM relies on the parametric driving function, which can directly use the parametric results to generate an association between the reinforcement and the bridge model. The first model can be automatically modified by adapt the limits with a plan alteration happens.

This paper presents a forward design process of Steel Reinforcements in bridge engineering based on BIM technology. All parametric design here is based on the object that can be loaded into the Library, that is, in many Revit Library template files. We can build a new Library template file with specific parameters such as material, length and other related parameters through the template file, and can put it into the project as a loaded object or embed it into other related group template files to form a new project file. In this way, compared with the traditional model turning process, it has been significantly optimized from the perspective of time and economy. With the increase of the project, the Library template file also increases, and the design process will become more and more convenient. The specific manifestations are as follows: Autudesk Revit software will be used to follow the following steps: (1) After drawing the concrete model line, you can mark the size in the Library category and add some basic parameters. Then, adjust the geometry of the cross-section T-beam Library is adjusted through the three-dimensional view to test whether it meets the needs. (2) Draw the Steel Reinforcement model line, and also use the corresponding dimension to set the parameters, check and adjust it. Finally, the two-part model is cut to verify the correctness of the model. (3) The Library of the T beam is placed in the model. Using the Steel Reinforcement function of Revit software, various Steel Reinforcements can be effectively arranged on the section. The BIM model of the concrete and Steel Reinforcements of the structure is established, and the Revit Library is formed. Part of the Library is indicated in Figure 1:

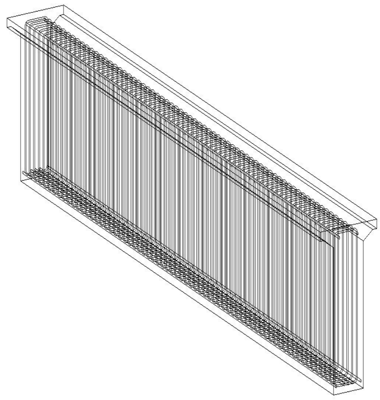

Figure 1: T Beam Steel Reinforcement Library

3 3D LASER SCANNING POINT CLOUD DATA ACQUISITION

3.1 Outdoor processing

According to the design requirements of the specialist committee of the Ministry of Communications of main road bridge design, uncomplicated T beam arrangement requirements of widespread pictures (March 2008 first edition) as the research object, through Steel Reinforcement size reduction processing, in the laboratory for binding. In the specific scanning work, this scanning adopts a Z + F5010x ground 3D Laser Scanning instrument for non-contact scanning. And for the first time, the Steel Reinforcement building was scanned according to the step division, particularly: The first step is compulsory longitudinal Steel Reinforcement at the bottom of the T-beam web, the stirrup of the web and the corresponding erecting Steel Reinforcement; The second step is the binding of longitudinal reinforcement on both sides of the T-beam web; Thethird step is the binding of reinforcement stirrups of the T-beam flange plate; The fourth step is the binding of the Steel Reinforcement at the bottom of the flange plate of the T-beam; The fifth step is the reinforcement binding of the top surface of the T-beam flange plate.

This scanning station will adopt the method based on target splicing: during the scanning operation, a special target ball that can match the Z + F software is used as the feature point of the same name to ensure that the adjacent scanning station can scan more than three public targets. Then the stitching parameters are automatically calculated by software to realize the stitching of point cloud data. Note that the useful facts on the target should not be unknown, and the mark should be planned in the scanning region.

3.2 Indoor processing

Due to the skeleton shape characteristics of the Steel Reinforcement, the formed point cloud must be very dense. So, the amount of point cloud data of Steel Reinforcements is very large. The previous ground 3D Laser Scanning instrument splicing standard only requires that the point cloud coverage of each station reaches 30% to be spliced, while this splicing standard requires that the point cloud coverage of each station must be above 80% before splicing. In the past, the target ball splicing is used as long as the target ball can be identified, regardless of its quality or data damage. This splicing standard will only select high-quality target balls for splicing. This can effectively improve the quality of the model in the process of splicing.

In addition, the splicing method is based on the target ball splicing method of the same name: It is a multi-point cloud splicing method in which two adjacent stations scan more than three common targets and register point clouds through homonymous target points. Its essence is that Z + F Laser control uses the least squares algorithm to overlap the two site clouds with a certain degree of overlap. The coordinates of the same name feature points in the overlapping area are p1 = (x1, y1, z1) and p2 = (x2, y2, z2), respectively the coordinate transformation relationship between the point cloud coordinate systems is:

$$\begin{Bmatrix} X_1 \\ Y_1 \\ Z_1 \end{Bmatrix} = \begin{bmatrix} 1 & \lambda & -\omega \\ -\lambda & 1 & \phi \\ \omega & -\phi & 1 \end{bmatrix} \begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} \tag{1}$$

If the selected targets meet the requirements, the point cloud model will be reconstructed after successful splicing. At the same time, the software will also give the corresponding splicing report. If the splicing report produced by all the stations in this scanning operation is summarized, the accuracy of the point cloud data model of the model can be further analysed, as indicated in Table 1:

Table 1: Point cloud data model error report.

Registration group	MAX error/mm	MINI error/mm	AVG error/mm	STD error/mm
1	1.4	-0.1	0.5	0.5
2	1.5	-0.1	0.4	0.5
3	0.9	0.0	0.3	0.4
4	0.7	-0.1	0.3	0.4
5	1.5	0.0	0.2	0.4
6	1.3	-0.1	0.6	0.7

The mathematical standard statistics of the above table error data are deliberate, and the stem mean town square error is 0.49mm. While minimum error is 0mm, the average error is 0.38mm, and the arithmetical error is 1.7mm. Combined with the table data and the scanning point cloud of each station, when the number of homonymous points in the overlapping area of adjacent stations is greater than 80% of the total number, the point cloud stitching accuracy can be controlled at 0.5mm. In the error statistics, the stem mean town square error and the amount of dispersion of the data are usually shown by the average error. Therefore, it can be considered that the accuracy and reliability of point cloud registration in this case are high, which can effectively reflect the point cloud data model of Steel Reinforcements. The point cloud model after joining is indicated in Figure 2：

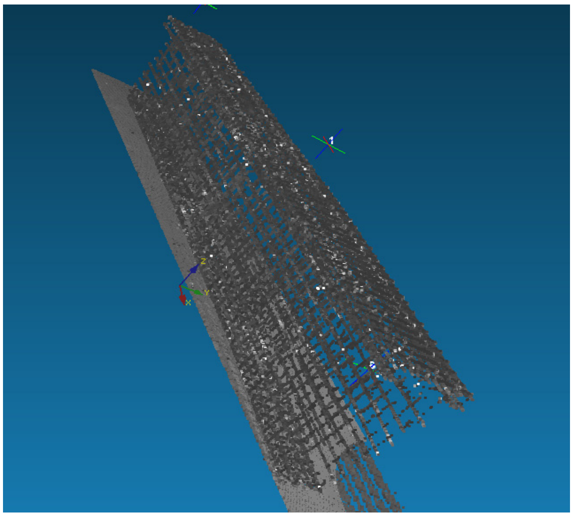

Figure 2: T Beam Steel Reinforcement point cloud

4 STEEL REINFORCEMENT CONSTRUCTION PRECISION CONTROL

In this paper, the Z + F5010x scanner supporting post-processing software Geomagic qualify will be used as a data processing and analysis platform, and the overall accuracy of the Steel Reinforcement model will be used as the analysis object. In Geomagic qualify, the model is cut, encapsulated and fitted with surface fitting. N-point pair and the feature-based pair are adopted, that is, the majority of degrees of freedom of the model can be accurately and quickly constrained by the matching of feature pairs based on the N-point pair. The model is initially aligned, and then the left-over degrees of independence are constrained by the best appropriate alignment, and eventually the model is aligned. The specific steps are as follows: taking the BIM model of the first step as the reference data, taking the point cloud data model of the second step as the contrast data. Then the two models are compared to find the difference between them, giving the contrast diagram different colors according to the difference magnitude. The model contrast consequence is indicated in Figure 3. Expected to the chance of the point cloud piece of the ground and the point cloud at the bottom of the Steel Reinforcement and the totally eliminating the discrete point cloud, the dark situation at Figure 3 is caused：

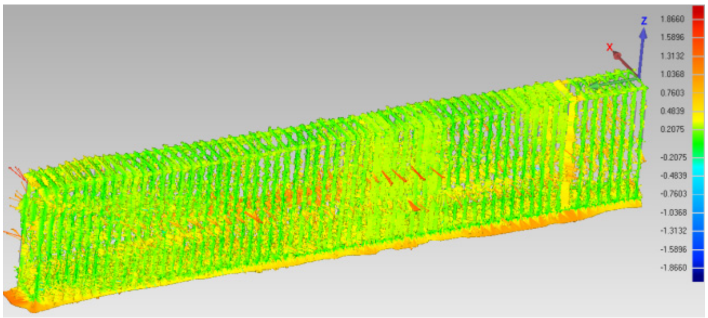

Figure 3: The first step deviation contrast diagram

According to Figure 3, the overall model contrast data in the first step are as follows: maximum deviation (+/-): 1.8660/-0.8866mm; average deviation (+/-): 0.2119/-0.0364mm; the standard deviation is 0.1969mm. The RMS deviation is 0.2861mm. It can be seen that there is a certain deviation in the accuracy of the overall model, so we will manually adjust the stirrups marked as yellow in the above figure manually, and adjust them to the next step of scanning after eliminating the deviation. Then, according to the contrast of the appropriate consequence, the mistake analysis is carried out. If the requirements of the specification are met, next step scanning is carried out. Adjust the position of the Steel Reinforcement whose error exceeds the specification requirements. The point cloud model data of the Steel Reinforcement in the next step is compared with its corresponding BIM model to detect the construction accuracy. The construction step of 2-5 is repeated until all the Steel Reinforcements are bound. The second to fifth deviation contrast diagrams are shown in Figs. 4-7.

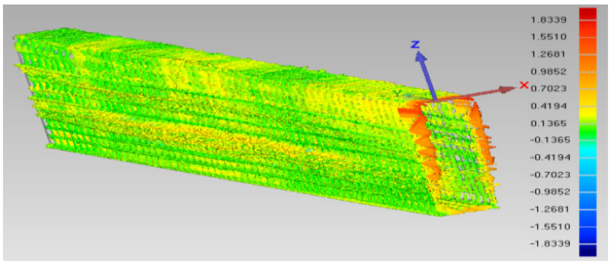

Figure 4: The second step deviation contrast diagram

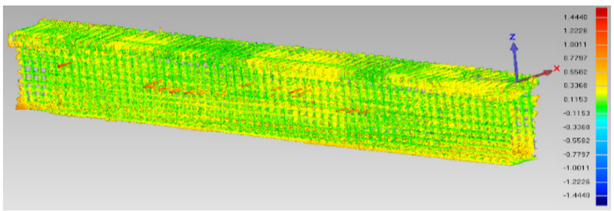

Figure 5: The third step deviation contrast diagram

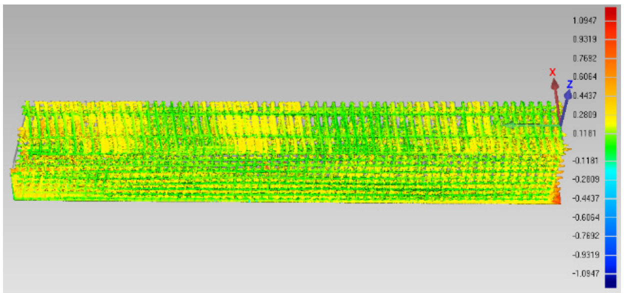

Figure 6: The fourth step deviation contrast diagram

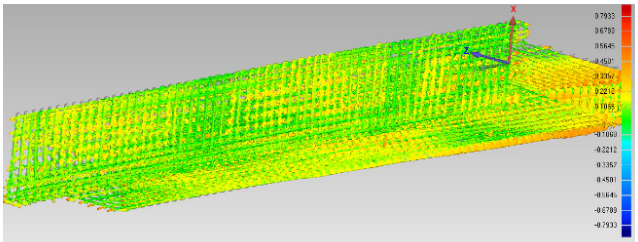

Figure 7: The fifth step deviation contrast diagram

The analysis of all the monitored deviation results is imported into the EXCEL table in the form of creating a report for output. The results are indicated in Table 2.

Table 2: Model contrast analysis report.

Model contrast phase	MAX error（+/—）/mm	MINI error（+/—）/mm	STD deviation/mm	RMS error/mm
1	1.866/-0.886	0.211/-0.886	0.196	0.286
2	1.524/-0.446	0.144/-0.017	0.096	0.170
3	1.109/-0.674	0.123/-0.012	0.096	0.152
4	1.449/-0.429	0.121/-0.012	0.085	0.143
5	0.793/-0.530	0.112/-0.011	0.083	0.135

According to the analysis and contrast results, it can be seen that before each step is carried out, the overall deviation of the model can be effectively reduced by comparing the error analysis of the model and then manually adjusting the Steel Reinforcement.

5 CONCLUSION

Based on BIM and 3D Laser Scanning technology, construction quality detection and control are systematically analyzed in different construction steps of Steel Reinforcement. The field scanning mode, data processing method, two model comparison methods and establishment of the BIM model of Steel Reinforcement are analyzed. The principle of bridge Steel Reinforcement construction monitoring is systematically analyzed. The 3D Laser Scanning technology and BIM technology are applied to the quality monitoring of Steel Reinforcement construction, and a set of systematic 3D Laser Scanning Steel Reinforcement construction monitoring method is formed. The specific steps are as follows: Steel Reinforcement construction is divided into several scanning steps, and the 3D Laser Scanning instrument is used to scan the Steel Reinforcement in the construction in steps to obtain the point cloud data of each step. Import the point cloud is imported into professional processing software for processing, and a point cloud data model is established;for the layout of Steel Reinforcements, the BIM model of concrete and Steel Reinforcements is established by using the Library function of BIM software. The point cloud data model of Steel Reinforcement and the BIM model of Steel Reinforcement are compared and the error analysis is carried out. Through the error analysis report to test the accuracy of steel construction to meet regulatory requirements. If the requirements of the specification you do not meet, manual adjustment is immediately carried out, and then the next step of construction carry out, so repeated until the end of the whole project. In this paper, the precision control of Steel Reinforcement construction is realized by applying 3D Laser Scanning and BIM technology to Steel Reinforcement construction monitoring. The identification process is simple, easy to operate and practical, which can effectively reduce the construction error and ensure the construction quality of the Steel Reinforcement.

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