DIMENSIONAL SURVEY USING TERRESTRIAL LASER SCANNING FOR INDUSTRIAL CONSTRUCTION IN MALAYSIA

MUHAMMAD AFIQ BIN AZIZ

UNIVERSITI TEKNOLOGI MALAYSIA

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MUHAMMAD AFIQ BIN AZIZ

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DEDICATION

Specially dedicated for my beloved:

Father, Aziz bin Amat Temin

Mother, Junainah Binti Jono

Thanks for the loves, prayer and support

for my success

My siblings

Muhammad Arif and Nur Afiqah

My wife

Nur Amalina binti Aminuddin

Thanks for always being supportive

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ABSTRACT

Measuring and generating a three-dimensional (3D) model using laser scanning techniques is increasingly common in various fields because laser scanners can produce a large number of observation points in a short time. This study focuses on data acquisition using Leica C10 laser scanner and 3D modeling using Autodesk Revit software for construction industry and that which is in accordance to QLASSIC standards. Leica C10 is known as a long distance laser scanner that is suitable for collecting data of large objects while Autodesk Revit is a software for generating 3D models using laser scanner data for construction industry. Two building structures namely precast concrete and cast-in-situ concrete were used in this study. The crucial procedure before data collection was to ensure that the station of laser scanner allowed at least three black/white targets to be viewed for registration purposes. For the analysis, the distance measured between design model and measuring tape, and distance measured between design model and 3D model from the laser scanner were compared. To support QLASSIC, the difference should not exceed ± 10mm. The results of the study for the precast concrete show that the value of RMSE between the design model and the 3D model from the laser scanner is 2.972mm while for the design model and the measuring tape is 14mm. For cast-in-situ concrete, the Root Mean Square Error (RMSE) value between the design model and the 3D model from the laser scanner is 3.346mm while the RMSE value between the design model and the measuring tape is 14.823mm. The results of the analysis indicate that the measured distance between the design model and the 3D model from the laser scanner is in accordance with the permissible accuracy in QLASSIC standard. The flatness percentage analysis was also performed for cast-in-situ concrete. While the QLASSIC standard for flatness percentage analysis is set at 70%, the flatness percentage analysis for cast-in-situ concrete between design model and the 3D model from the laser scanner is 79.5%. In conclusion, Leica C10 is suitable for industrial construction and supports QLASSIC standards.

ABSTRAK

Pengukuran dan penjanaan model tiga dimensi (3D) menggunakan teknik pemgimbasan laser semakin kerap digunakan dalam pelbagai bidang kerana ia mampu menghasilkan bilangan titik cerapan yang banyak dalam masa yang singkat. Kajian ini memberi tumpuan kepada pengimbasan data menggunakan pengimbas laser Leica C10 dan pemodelan 3D menggunakan perisian Autodesk Revit dalam industri pembinaan sejajar dengan piawaian *QLASSIC.* Leica C10 dikenali sebagai pengimbas laser jarak jauh yang sesuai digunakan untuk proses pengumpulan data bagi objek bersaiz besar manakala Autodesk Revit adalah perisian untuk menjana model 3D menggunakan data pengimbasan laser untuk aplikasi industri pembinaan. Dua objek struktur binaan industri iaitu konkrit pratuang dan konkrit tuang di situ digunakan dalam kajian ini. Prosedur penting sebelum pengumpulan data adalah memastikan kedudukan stesen pengimbas laser dapat melihat sekurang-kurangnya tiga sasaran hitam/putih untuk tujuan pendaftaran. Bagi tujuan analisis, jarak diukur antara model rekabentuk dengan pita ukur dan jarak diukur antara model rekabentuk dengan model 3D dari pengimbas laser dibandingkan. Bagi menyokong *QLASSIC*, perbezaan ini tidak boleh melebihi ± 10mm. Hasil kajian bagi konkrit pratuang menunjukkan bahawa nilai Min Selisih Punca Kuasa Dua (RMSE) antara model rekabentuk dengan model 3D dari pengimbas laser ialah 2.972mm manakala bagi model rekabentuk dengan pita ukur adalah 14mm. Bagi konkrit tuang di situ, nilai RMSE antara model rekabentuk dengan model 3D dari pengimbas laser adalah 3.346mm manakala nilai RMSE antara model rekabentuk dengan pita ukur adalah 14.823mm. Hasil analisis menunjukkan bahawa pengukuran jarak antara model rekabentuk dengan model 3D dari pengimbas laser adalah menepati ketepatan yang dibenarkan dalam piawaian *QLASSIC*. Analisis peratusan kerataan turut dilakukan untuk objek konkrit tuang di situ. Walaupun piawaian *QLASSIC* bagi peratusan kerataan ditetapkan pada 70%, analisis bagi objek konkrit tuang di situ untuk model rekabentuk dan model 3D dari pengimbas laser ialah 79.5%. Kesimpulannya, Leica C10 sesuai digunakan dalam industri pembinaan dan ia menyokong piawaian *QLASSIC*.

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LIST OF ABBREVIATIONS

$\mu 1$	-	Mean of observation from dataset 1
$\mu 2$	-	Mean of observation from dataset 2
μd	-	Difference of Mean Sample
AZRB	-	Ahmad Zaki Resources Berhad
CAD	-	Computer-Aided Design
CIDB	-	Construction Industry Development Board Malaysia
CIS	-	Construction Industry Standard
CONQUAS	-	Construction Quality Assessment System
GPS	-	Global Positioning System
H_o	-	Null hypothesis
H_a	-	Alternative hypothesis
ID	-	Identification
LiDAR	-	Light Detection and Ranging
n	-	Number of samples
PNB	-	Permodalan Nasional Berhad
QA	-	Quality Assurance
QC	-	Quality Control
QLASSIC	-	Quality Assessment System In Construction
RMSE	-	Root Mean Square Error
S	-	Standard Deviation
S^2	-	Variance Of Sample
TOF	-	Time of Flight
$\bar{x}$	-	Mean of Sample
x	-	Element of the sample
x, y, z	-	Coordinates value
Z_0	-	Z score
3D	-	Three Dimensional
2D	-	Two Dimensional

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Three dimensional (3D) data acquisition increases the accuracy and speed of infrastructure by using terrestrial laser scanning. The use of terrestrial laser scanning is a new trend in acquiring building information (Bosche *et al*., 2015). The survey yields a digital data set, which isessentially a dense “point cloud”, where each point is represented by a coordinate in 3D space. The advantage of this method is that the high point density can achieve 5 to 10mm resolution. The terrestrial laser scanning records thousands of points per second and each point has intelligence, location coordinates and elevation information (Sepasgozar *et al*., 2014). All these points are placed into the same local coordinate system to make up a point cloud which represents the area, building, or object being scanned in a 3D space. Most modern terrestrial laser scanning are rated to have their best accuracy at distances up to 100-130m (Son *et al*., 2015). Terrestrial laser scanning provides higher efficiency in data collection, and is especially useful in an unreachable place as it gives complex and detailed 3D point cloud data in a matter of minutes. The benefits of the terrestrial laser scanning technology are immediately apparent in the survey industry.

The users of terrestrial laser scanning are very impressed with the speed of captured information, the ability to conceptualize survey projects in 3D, its ability to scan objects and areas at a distance (Tang *et al*., 2010). Total station or GPS is a conventional surveying technique involved in collecting important points and features. This process has become slow since an individual point has to be collected one at a time. More than 1,000 points per second information could be collected by using terrestrial laser scanning. According to Kim *et al*., (2014), the terrestrial laser scanning technique has also been applied to full-scale precast concrete panels for dimensional quality assessment with complex geometries. Atasoy *et al*., (2009) used two types of terrestrial laser scanning for construction quality control elements in the building. Terrestrial laser scanning is still a new method applied in data capturing of complex 3D scene data. Therefore, many Geomatic engineers have less knowledge on the way of operating the instrument and data processing. Application and study of 3D modelling by one of the latest technologies; terrestrial laser scanning are essential for Geomatic engineers to grow along with current market (Hori *et al*., 2007).

Construction is one of the steps in creating and building an infrastructure or a facility (Merriam-Webster, 2015). A construction needs plan, design, and funds to complete a project. Each construction industry has their own guideline to make sure the procedure is according to the approved standards (Olanrewaju and Abdul-Aziz, 2015). The Construction Industry Development Board (CIDB) is responsible for the construction industry standard in Malaysia. Quality Assessment System in Construction (QLASSIC) is a system to measure and evaluate the quality of a workmanship in building construction based on Construction Industry Standard (CIS 7:2006). CIS 7 was developed in November 2006 by CIDB's Technical Committee (TC). It is comprised of *Jabatan Kerja Raya* (JKR), *Jabatan Perumahan Negara* (JPN), Real Estate and Housing Developers Association (REHDA), *Pertubuhan Akitek Malaysia* (PAM), Master Builders Association Malaysia (MBAM), National House Buyers Association (HBA) and other relevant organizations. The standard specifies the requirements on quality of workmanship and assessment procedures for construction work building **(**Construction Industry Standard, CIS 7:2006). QLASSIC assessment instrument uses steel measuring tape and L-square to measure the dimension of the infrastructure, while the steel wedge and spirit level are used to determine flatness of the surface. These methods can only make a single measurement with less accuracy and precision.

Previous research Tang *et al*., (2011) has shown that TLS can provide and support more complete measurement. It can also reliably control the surface flatness in construction. TLS measures 3D coordinates of point clouds of an object in a short time of period with mm-level accuracy. The different viewpoints of the station need to be merged together before it can completely reconstruct the object (Gruen and Akca, 2005). It enables surveyors to create detailed 3D models for virtual inspection, hence is a promising alternative for dimensional measurement and flatness geometric data collection. Data collection using TLS for measurement is very good because it has a promising technique and potential to be accepted as a new measurement technology (Schulz, 2007). Furthermore, it also provides accurate position and measurement of an infrastructure.

1.2 Problem Statement

Contact measurement method continues to be the conventional method for dimensional data acquisition in the construction industry. It is suitable for non-complex surfaces and geometry. However, for complex surfaces and geometry, the contact method gives unsatisfactory results (Tang *et al*., 2010).

The instruments such as steel measuring tape and L-square are used to measure the dimension of an infrastructure while steel wedge and spirit level are used to measure the flatness of a surface. These instruments require a longer period to complete the measurement task in a construction site. Besides that, these measurement techniques are also prone to human errors such as incorrect reading while taking a measurement. Consequently, this error causes result inaccuracy.

The most advanced non-contact measurement method used in the construction industry is distometer and total station. By using this instrument, the measurement of wall vertically using total stations is conducted by measuring only a few points at different heights along horizontal spaced vertical lines. The risk with such partial measurements is that location presenting discrepancies larger than specified can remain undetected, leading surveyors to incorrect conclusions with potentially detrimental consequences (Tang *et al*., 2011). Furthermore, it can be argued that the significant involvement of humans in the process adds the risk of manual errors (Bosche *et al*.,2009). There is thus a need for approaches that enable more complete and reliable dimensional measurement, without requiring disproportionate amounts of human interaction and time.

TLS is a modern technology that is revolutionizing surveying works. As highlighted in numerous previous research works such as Tang *et al*. (2011), Bosche *et al*. (2009), and Romsek (2008), TLS can provide surveyors with the means to conduct far more complete measurements in relatively short times, which would in turn lead to more reliable dimensional results.

To conclude, terrestrial laser scanning point cloud data was used to develop a 3D model of engineering structures, which are the outcome complete with the dimensional measurement and 3D point cloud data to support the construction industry. TLS enables more efficient 3D data acquisition in the field of civil infrastructure compared with conventional techniques (Son *et al*., 2015).

1.3 Objectives of Study

The objectives of the study are:

i. To compare the weakness of using conventional measuring tool in QLASSIC assessment on infrastructures for the construction industry.

ii. To evaluate the point cloud data from terrestrial laser scanning for support of QLASSIC assessment.

1.4 Scope of Study

Throughout the research, the scope of the study, which covers the 3D model and the flatness of the construction industry in the study area using point cloud data obtained from terrestrial laser scanning, are as follows:

i. Simulation test site for dimensional measurement.

The simulation test site has been established for preliminary results. By using the precast concrete, the dimensional measurement can be defined using terrestrial laser scanning. The test was carried out at Sejati Concrete, Senai.

ii. Identification of TLS, station, target used for dimensional measurement.

Pulse based TLS is used for the acquisition of data in the form of point cloud data. This is because of its accuracy and the wavelength can go further to collect the data. The model of the equipment is Leica C10 which is available at the lab. The equipment, Leica C10, is equipped with CYCLONE software. The data processing, which involves filtering and registration, are performed using the CYCLONE software. The stations used in this study include 4 stations for simulation test at Sejati Concrete, Senai and 16 stations for PNB building at Jalan Sultan Ismail, Kuala Lumpur. Each station must see the structure that is to be scanned to overlap with other stations. 4 Black/ White targets were used for the simulation test while 20 Black/ White targets were used in real site for the control point of the point cloud data. The target was used to overlap with the other stations during registration.

iii. 3D modelling and flatness analysis of the structure.

The point cloud data from the TLS processed using Autodesk Revit for the 3D Modelling of the structure. The modelling was generated by knowing the edge to the edge of the structure. Then, the value of dimension between the edge of the structure is obtained. The values are then compared with the design model and measurement tape (conventional method). In addition, the flatness analysis was done using 3DReshaper software. To obtain the flatness analysis result, point cloud data from TLS must do mesh model. Mesh model is a collection of vertices and polygons that define the shape of an object in 3D. Then, from the mesh model, there is need to overlap with the design model to get the flatness percentage analysis between the two models.

1.5 Significance of Study

The importance and substantial contribution expected after the results of this study:

i. To introduce TLS as the main source in the field of construction industry in Malaysia.

The technology used in this study can provide the professional surveyor with instruments that can be cost-effective to survey large complex sites without compromising the contractors' ongoing building activities. This new technology can also provide true, accurate data and save time in the field.

ii. To improve safety in construction industry.

Lately, a large number of cases of negligence and safety issues occurred in the construction site. This has increased awareness of safety issues in the workplace. TLS can be used to avoid having to capture data directly from dangerous sites such as a high risk building for surveyors, heavy traffic roads and railroad tracks. TLS can be observed from an allowed distance because it applies the concept of contact free measurements device.

iii. To have enough evidence for the placement of structures

Point cloud data would be invaluable in the future to resolve ownership disputes, residents, engineers and contractors with valid evidence regarding the placement of structures. For field surveyors, they can complement the survey work quickly and economically.

1.6 Organization of Thesis

From this study, five chapters are designed to explain the concept, process and results as follows:

Chapter 1: Introduction

This chapter explained the background, objectives, scope, problem statement and significance of the study regarding the Dimensional Survey Using Terrestrial Laser Scanning For Industrial Construction In Malaysia.

Chapter 2: Literature Review

The literature review focuses on several topics such as construction industry, QLASSIC, terrestrial laser scanning, flatness, and measurement.

Chapter 3: Methodology

This chapter shows the methodology that is used in this study in order to process the data which involved these procedures:

I. Data Acquisition

   a) Project Planning
   b) Data Collection

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