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HANOI UNIVERSITY OF MINING AND GEOLOGY

DIEM CONG TRANG

RESEARCH ON TECHNICAL SOLUTIONS TO IMPROVE THE EFFICIENCY OF GEODETIC WORK IN THE CONSTRUCTION OF SKYSCRAPER IN VIETNAM

MAJOR: SURVEYING AND MAPPING ENGINEERING

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DISSERTATION SUMMARY

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The dissertation will be defended before the University-level dissertation Evaluation Council at Hanoi University of Mining and Geology,
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PREAMBLE

1. Urgency of the subject

In the present time, there are a number of on-going skyscraper projects in our country. These are buildings with height (H> 100 m) or number of floors more than 40 floors. The construction characteristics of the skyscraper are as follows: building with very large height is built on a small area, thus the whole or a part of the building is oscillated with a relatively large amplitude and without rule due to the influence of external factors in construction process. In these cases, it is not possible to use traditional geodetic methods and equipment to ensure the verticality of the building during construction. Therefore, it is necessary to research technical solutions and modern geodetic equipment to ensure the construction according to the design in the condition that the building is always oscillated due to the influence of external factors.

2. Objective, object and scope of the research

Objectives of the dissertation: "Establish the scientific basis and methodology to build geodetic engineering solutions to improve the efficiency and accuracy of construction of skyscraper in Vietnam".

The object of research is the geodesy in construction of skyscraper in Vietnam.

The research scope of the dissertation includes: Research technical solutions to ensure construction accuracy of skyscraper in the construction process, research to improve the efficiency of geodetic work in the construction of skyscraper in Vietnam, research technology solutions and modern instrumentation available in Vietnam to meet the technical requirements necessary to ensure accuracy in the construction of skyscraper in Vietnam.

3. Research contents

- Survey the effects of the impact factors of the external environment (temperature, wind ...), and load of construction materials, causing oscillation of the skyscraper in space and over time during construction.
- Research to use GNSS - RTK technology in combination with electronic tachometer to determine instantaneous coordinates of main axis points on the working platforms used for skyscraper construction layout.
- Research on geodetic technical solutions to determine and arrange the work axis system on skyscraper working platforms under design requirements.

4. Research methods

Statistical methods, analytical methods, mathematical methods, comparison methods, experimental methods, informatics methods, expert methods.

5. Scientific and practical significance of the dissertation

- The dissertation's research results contribute to the development and completion of geodetic work in the construction of skyscraper and improve the qualifications and capabilities of the Vietnamese construction industry in the construction of large and typical projects with international stature.

- The research results can be applied to carry out geodetic work in the construction of skyscraper in Vietnam and in supervision consulting, inspection and acceptance of the works in the construction process and before putting into use high-rise buildings and skyscraper in Vietnam.

6. Theoretical perspectives

Theoretical perspective 1: Due to the influence of the external factors and workloads, the whole or part of the skyscraper will be oscillated relatively large without common rule. Therefore, it is necessary to study appropriate technical solutions to improve the efficiency and accuracy of geodetic work in the construction of skyscraper.

Theoretical perspective 2: Technical solutions using GNSS - RTK technology in combination with electronic tachometer proposed in the dissertation allow instantaneous positioning of points on the working platforms with accuracy under the skyscraper construction standards.

Theoretical perspective 3: Super HBD V1.0 computer program used for GNSS-RTK system and electronic tachometer allows geodetic data processing automation to improve the efficiency of skyscraper construction".

7. New perspectives of the dissertation topic

- Propose technical solutions using GNSS - RTK technology in combination with other geodetic devices to ensure that the work layout meets technical requirements in the construction of skyscraper in Vietnam.

- Research solutions to improve the accuracy and applicability of GNSS - RTK technology in combination with electronic tachometer to determine the instantaneous location of main axis points on the working platforms of skyscraper in construction process.

- Develop algorithm and set up specialized computer program Super HBDV 1.0 for construction, make inspection and acceptance of high-rise buildings and skyscraper. Super HBDV1.0 software allows signal coupling, automating the data processing on the working platforms to meet technical requirements and construction progress of skyscraper in Vietnam.

8. Structure of the dissertation

The dissertation structure consists of three parts: Preamble, 4 chapters of content and conclusion.

CHAPTER 1
OVERVIEW OF GEODETIC WORK IN CONSTRUCTION HIGH-RISE BUILDINGS AND SKYSCRAPER

1.1. Concept and development history of skyscraper

1.1.1. Skyscraper concept

1.1.2. Development history of skyscraper

1.1.2.1. In the world

1.1.2.2. In Vietnam

1.2. Geodetic work in construction of high-rise building and skyscraper

1.2.1. Geodesic work characteristics in construction of high-rise buildings

1.2.2. Geodetic work process in construction of high-rise buildings

1.2.3. Vertical conveying methods in high-rise building construction

1.2.3.1. Plumb line method

1.2.3.2. Method of usingplane of theodolite or electronic theodolite

1.2.3.3. Method of moving coordinates to high altitude by electronic tachometer

1.2.3.4. Method of using optical and laser vertical projectors

1.2.3.5. Construction axis movement with GNSS technology

1.2.4. Construction characteristics of skyscraper in Vietnam

1.2.4.1. Technology of concrete materials

1.2.4.2. Formwork work

1.2.4.3. Construction of reinforcement

1.2.5. Geodetic Tolerance limits in construction of high-rise buildings and skyscraper

1.3. Research on effects of external factors on the construction process of skyscraper

1.3.1. Effect of wind on the vertical position of the building

1.3.1.1. Concept, cause of formation, classification of wind

1.3.1.2. Nature and characteristics of wind

1.3.1.3. Impact of wind on the building

1.3.1.4. Wind load

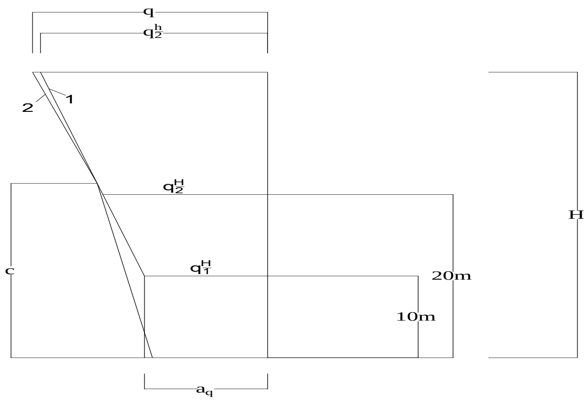

Figure 1.23. Diagram of wind pressure converted to equivalent trapezoidal shape

Wind load due to climate and weather impacts changes with time, altitude and location in the form of pressure on the wind or air intake surfaces of the house.

1.3.2. Research on effects of temperature on the vertical position of the building

Working characteristics of reinforced concrete structures of high-rise buildings and skyscraper in temperature change conditions in Vietnam: Regular deformation and elasticity of works under the impact of changing temperature. In high (hot) temperature conditions, the concrete expands, in low (cold) temperature conditions, it shrinks, and in humid air, it expands, in cold air, it shrinks. It can be considered as the normal deformation of the structure of high-rise buildings and skyscraper with reinforced concrete according to temperature or weather changes.

1.3.3. Effects of the work load on the vertical position of the building

1.3.3.1. Up load

1.3.3.2. Effects of the eccentricity of the vertical load

1.3.3.3. Other loads

1.3.4. Synthesis of the project's oscillation forms

1.3.4.1. Building motion

a. Long-term motion

b. Daily motion

c. Dynamic motion

1.3.4.2. Basic oscillating forms of skyscraper

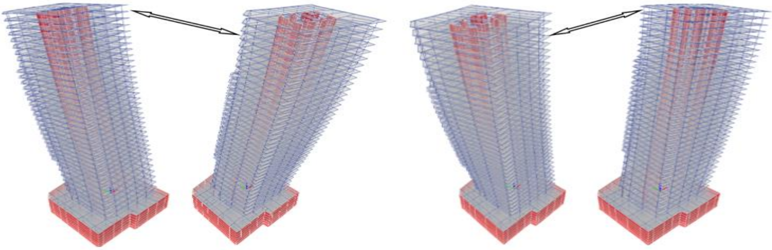

Figure 1.27. Oscillation form 1,2 of skyscraper

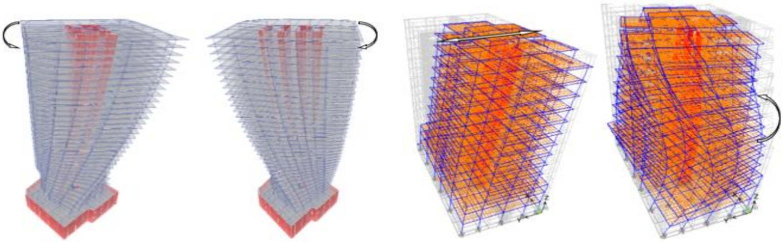

Figure 1.28. Oscillation form 3 of skyscraper

Thus, under the impact of many external factors such as wind, changes in temperature, load of the building itself, variable shrinkage of concrete, uneven settlement ... skyscraper is oscillated in the direction of the impact of foreign forces. Oscillation of the upper part of the building can be elastic and return to the initial position, may also be incomplete elastic and move to a new position. The movement trajectory, the oscillation speed of the building do not follow certain rules, it depends on the construction location, construction time and structure of construction materials.

1.4. Research works on geodetic work in the construction of high-rise building and skyscraper

1.4.1. Researches in foreign countries

In addition to some documents, textbooks, there are contents presenting geodesy in the construction of high-rise buildings and skyscraper such as: [49], [51], [52]…

1.4.1.1. Research on the influence of meteorological factors on the verticality of the buildings during construction: [53], [60], [61], [63], [64]…

1.4.1.2. Research on geodetic engineering solutions in the construction of skyscraper: [54]; [55], [60], [61], [63], [64]...

1.4.1.3. Research on applying Kalman filter in geodetic data processing: [56], [57], [62]...

1.4.2. Domestic researches.

In addition to some documents, textbooks, there are contents presenting geodesy in the construction of high-rise buildings and skyscraper such as: [5], [15]…

1.4.2.1. Research on geodetic engineering solutions in the construction of high-rise buildings: [2], [9], [12], [13] [11], [14], [16], [17], [30] [31]

1.4.2.2. Research on the influence of meteorological factors on the verticality of the buildings during construction: [24], [8]...

1.4.2.3. Research on geodetic engineering solutions in the construction of skyscraper: [8]...

1.4.2.4. Research on applying Kalman filter in geodetic data processing: [47], [10], [19], [33], [34], [35],…

1.4.3. Vietnamese Standards (TCVN)

Include the following documents: [37], [38], [39], [40], [41], [42], [43], [44]…

1.5. General assessment of research situation and research orientation of the dissertation

1.5.1. General assessment of research situation

In the world: Overseas technological processes have mentioned the oscillation of the building with great height, but did not present solutions, not yet mentioned methods of correcting the spiral value of the building due to the influence of external factors during construction. For a number of recently published documents, it has only been mentioned that the technology solution used to correct the layout of works under construction according to the design, but we have not grasped the content of the technology and the nature of the algorithm and the accuracy is not presented, so it is not suitable for the actual conditions in Vietnam (existing geodetic equipment, geological conditions, construction factors, construction level, economic conditions ...); There is no rule of skyscraper motion due to the influence of external factors and the workload of the building itself on the verticality of the building.

In Vietnam: Due to the limited production capacity of high precision measuring instrument, mainly imported modern technologies are used, it is not possible to manufacture specialized measuring equipment for geodetic work in construction of skyscraper.

In the skyscraper construction work in Vietnam, the geodetic work in the construction of skyscraper is mainly performed by foreign experts and companies.

1.5.2. Research orientation of the dissertation

1. Research on solutions to apply advanced and modern measurement technologies to replace traditional measuring equipment and methods with the

aim of automating the measurement process, improving accuracy and ensuring construction progress of skyscraper in accordance with construction technology characteristics applied in Vietnam.

2. Survey and evaluate the accuracy and applicability of GNSS - RTK technology in combination with electronic tachometer to determine the instantaneous location of the points to be arranged on the working platforms of skyscraper in construction process.

3. Research to develop algorithms and set up computer program for data processing to determine the instantaneous coordinates of the main axis points on the skyscraper working platforms.

4. Research on the method of arranging the project details in accordance with the design position to ensure technical requirements of skyscraper construction in Vietnam.

CHAPTER 2
RESEARCH ON TECHNICAL SOLUTIONS IN GEODETIC WORK IN THE CONSTRUCTION OF SKYSCRAPER IN VIETNAM

2.1. Research to select geodetic solutions to overcome effects of oscillation in the construction of skyscraper

2.1.1. Geodesic work characteristics in the construction of skyscraper in Vietnam

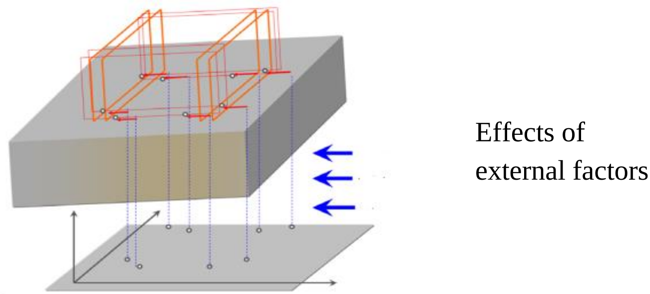

Figure 2.1. The skyscraper is oscillated due to the effects of external factors

2.1.2. Selection of technical solutions for geodetic work in the construction of skyscraper in Vietnam

2.1.2.1. Solution 1

2.1.2.2. Solution 2

2.1.2.3. Solution 3

Build work construction coordinate system (2D) with an unchanging and stable base point (BS), using GNSS - RTK technology to determine the total displacement of the skyscraper floor due to the influence of external factors and building loads compared to the initial BS, we can then:

- Determine the work's oscillation value.
- Move the construction axis to attitude.

2.2. Research on technical solutions for geodetic work in the construction of skyscraper in Vietnam

2.2.1. Principle of technical solution applying GNSS - RTK technology and electronic tachometer to locate the main axis points of skyscraper during construction

Supposed that at time t_1, building position is determined by points (A, B, C, D) with coordinates $(x, y)_1$ as shown in figure 2.3.

At time t_n, due to the influence of external factors, the points (A, B, C, D) move to the position (A1, B1, C1, D1) with instantaneous coordinates $(x, y)_n$.

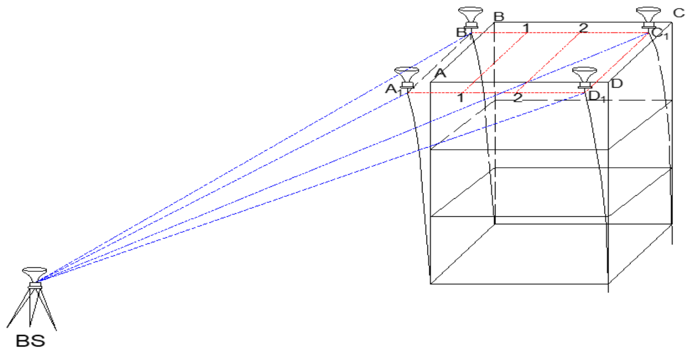

Figure 2.3. Solution of applying GNSS-RTK technology in construction of skyscraper

If using GNSS - RTK technology with Base station located at point BS and rover stations located at points (A1, B1, C1, D1), the instantaneous coordinate values of these points will be determined at the time t_n, ie values $(x, y)_n$.

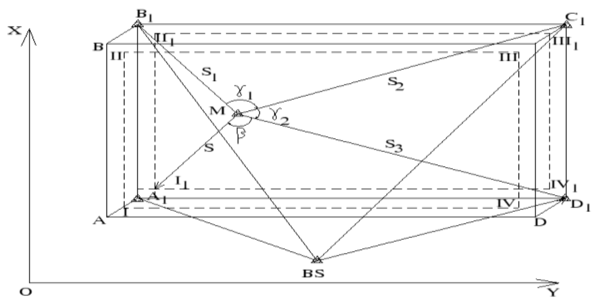

Figure 2.4. Principle of skyscraper construction axis layer by GNSS - RTK technology and electronic tachometer

The basic principle of this technical solution is shown in Figure 2.4

- First, it is necessary to build a construction coordinate system of the XOY in the form of 2D coordinate system. This coordinate system must coincide with the coordinate system used for the project design.

- The BS point is the point located near the work with the coordinates in the XOY system and fixed during the construction process. At the point BS, locate the base station when using GNSS - RTK technology.

2.2.1.1. At the first floor surface (foundation surface of the building)

- Supposed that at times t_1, the position of the first floor of building is determined by points (A, B, C, D) with the coordinates of $(x, y)_1$ as shown in figure 2.4

- Points (I, II, III, IV) are the intersection points of the main axes or the basic axis on the work with coordinates of $(x, y)_{1\ T}$

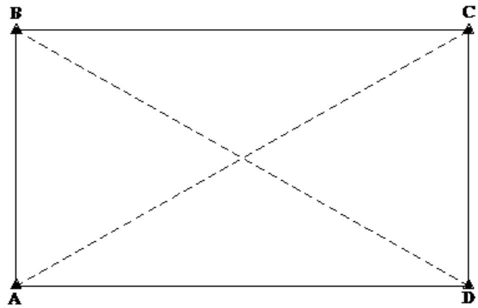

Figure 2.5. Layout of rover stations on sliding formwork floor

- At points A, B, C, D, rover measuring stations are arranged fixed to the sliding formwork floor of each floor or the elevator system of the building.

- Locations of rover stations form a geodetic quadrilateral as shown in Figure 2.5. The distance between the locations of the rover stations is measured with high accuracy right from the foundation ground. The values of these distances are used to evaluate GNSS - RTK signal strength on the working platforms in the future.

- The coordinates of points A, B, C, D are accurately determined by static GNSS technology in the VN - 2000 system and ground measurements in the XOY system. These coordinate values are used as the basis for:

+ Determination of total displacement due to the influence of external factors on the nth construction floor at time t_n compared with the point BS in the XOY coordinate system

+ Determination of the work's twist on the nth construction floor at time t_n.

2.2.1.2. At the nth construction floor

- At time t_n on the "nth" floor due to the influence of external factors and the work's load, points (A, B, C, D) move to the position (A_1, B_1, C_1, D_1) with instantaneous coordinates $(x, y)_2$, points (I, II, III, IV) move to position (I_1, II_1, III_1, IV_1) with coordinate $(x, y)_{2\,T}$ as shown in figure 2.4.

- On the nth floor using GNSS technology - RTK, it can determine that the instantaneous coordinates of the RTK measuring points (A_n, B_n, C_n, D_n) in the XOY system at time t_n is $(x, y)_n$. Then, it is possible to determine the total displacement of the points (A_n, B_n, C_n, D_n) on the nth floor relative to points (A, B, C, D) on the 1st floor. That is also the displacement of the points (I_n, II_n, III_n, IV_n) at time t_n relative to the original coordinates of these points at time t_1

- If on the construction floor of the nth floor, place an electronic tachometer in an arbitrary position (point M) and use the inverse-angular intersection to points (A_n, B_n, C_n, D_n), measure the angle γ_i and edges S_i (Figure 2.4), we will determine the coordinates of point M at time t_{2n} (in XOY generation) from there, we can determine the layout factors of points I_n, II_n, III_n and IV_n to the position indicated by the design by polar coordinate method from point M through layout angle β and polar edge S (Figure 2.4)

2.2.1.3. Functions of the GNSS - RTK system and the electronic tachometer in the proposed technical solution

- Determine the total displacement and oscillation due to the influence of external factors of the nth construction floor compared to the 1st and (n - 1)th floors.

- Determine displacement and oscillation trajectory of working platforms in real time. The results of continuous GNSS - RTK measurements form a database that is used to determine the average displacement of the regression line and represent the average total displacement of the work.

- Continuous GNSS - RTK measurement results are used in conjunction with continuous, real-time measurements of the building's inclination along the vertical direction used to determine correction numbers as X components and Y to precisely adjust the building’s verticality [54].

2.2.2. Required accuracy of geodetic work in construction of skyscraper

The symbol f is the permissible tolerance limit. According to [67] Permissible tolerance limit in arranging vertical axis for works with height H ≥ 150 m, f ≤ ± 30 mm.

If this permissible tolerance limit is considered as limit error, the median error m is determined by the formula [4]:

$$m = \frac{f}{t} \tag{2.5}$$

The m-value includes the effects of the following error sources:

$$m^2 = m_{tđ}^2 + m_{tc}^2 \tag{2.6}$$

In which: m_{td} is the error caused by the geodetic work

mt_c is the construction and installation error

If these two error sources are considered as independent and equally influential:

$$m_{tđ} = \frac{m}{\sqrt{2}} = \pm 10,6 \text{ mm} \quad (2.7)$$

On the other hand, geodetic work error includes control net error (m_{kc}), measurement error GNSS - RTK (m_{rtk}) and error of determine the workstation coordinates M (m_{TM}), layout error (m_{bt}), it mean:

$$m_{tđ}^2 = m_{kc}^2 + m_{rtk}^2 + m_{TM}^2 + m_{bt}^2 \quad (2.8)$$

Using the principle of co-effects and insignificant effects, and after some changes, we have:

$$m_0 = \frac{m_{td} k}{\sqrt{1+3k^2}} \quad (2.11)$$

Replace k = 2 and m_{td} = ± 10,6 mm into (2.11) we get m_0 = ± 5,9 mm. From there, according to (2.10), we have m_{kc} = ± 2,9 mm

Thus, the mean error of the position of the control network (base station location) must not exceed the quantity ± 2.9 mm.

m_{TM} is the error for determining the coordinates of the workstation M, the source of this error includes the error of the angular-edge intersection (m_{GH}) to determine the coordinates of the installation point of the workstation M and the error due to the working platform's oscillation (m_{dd}).

$$m_{TM}^2 = m_{dđ}^2 + m_{gh}^2 \quad (2.12)$$

Use the principle of negligible influence and changes, we have

$$m_{gh} = \frac{m_{TM} k}{\sqrt{1+k^2}} \quad (2.14)$$

Replace the value m_{TM} = ± 5,9 mm into equation (2.13) and (2.14) ,we have m_{gh} = ± 5,3 mm; $m_{dđ}$ = ± 2,6 mm

For the displacement quantities (d_i) due to the building's oscillation, it should be determined using the GNSS-RTK technology with accuracy $m_{dd} \leq$ ± 2,6 mm.

Construction axis points on the working platforms are arranged with the following accuracy: m_{td} = ± 10.6 mm

These are the calculated results corresponding to the values f = 30 mm and H ≥ 150 m.

2.2.3. Evaluation of the applicability of technical solutions using GNSS - RTK technology combined with electronic tachometer in construction ofskyscraper

- Do not leave floor vents between floors like when using a vertical projector to pass the main axis vertically.

- The measuring accuracy of GNSS - RTK almost does not depend on the height of the building, so it is possible to pass the coordinates, from there, moving the axes from the foundation plan to the nth floor at any height. This avoids the error accumulation commonly encountered when using traditional fractional projection methods.

2.3. Research on solutions to improve the accuracy when using the combination of GNSS-RTK technology and electronic tachometer in the construction of skyscraper in Vietnam

2.3.1. Research on solutions to improve positioning accuracy by GNSS - RTK technology in the construction of skyscraper in Vietnam

2.3.1.1. Overview of GNSS - RTK technology

2.3.1.2. Research on solutions to improve the accuracy of GNSS - RTK measurement results in the construction of fixed assets in Vietnam

Figure 2.7. Accuracy testing equipment of GNSS - RTK technology

Solutions to improve the GNNS-RTK accuracy for rovers include:

- Increase the signal reception time:
- Ensure the stability of the rover's receiver antennas

Thus, when the measured value increases n times then the mean error will decrease $\sqrt{n}$ times.

Thus, we can conclude that to increase the accuracy of the GNSS - RTK measurement, it is necessary to increase the signal reception time at rover stations with the reception time from about 60s at each GNSS - RTK measuring position.

2.3.1.3. Survey of the accuracy of detecting displacement due to oscillation of the skyscraper by GNSS - RTK technology

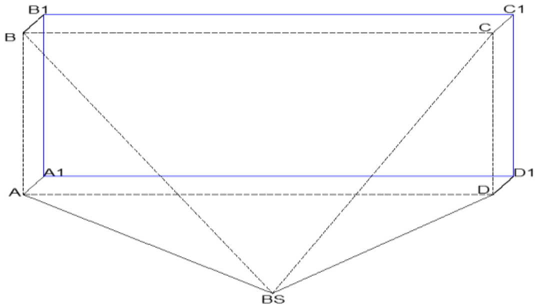

Figure 2.8. Experimental grid diagram to detect skyscraper oscillation's displacement.

Displacement detection measurement accuracy d_i of the skyscraper by the GNSS-RTK technology reaches accuracy from $m_{go} = \pm 1.7$ mm to ± 2.1 mm

Compare with technical specifications on skyscraper oscillation measurement as mentioned in section 2.2.2, we see that the GNSS-RTK technology meets the necessary technical requirements when determining oscillation displacement of skyscraper between two times t_1 and t_2 in the construction process.

2.3.2. Application of Kalman filter to process the GNSS - RTK data

2.3.2.1. The basic principle and formula of Kalman filtration

State Model: $$X_k = F_{k-1}X_{k-1} + B_k U_k + W_k \quad (2.19)$$

Measuring value model: $$L_k = D_k X_k + V_k \quad (2.20)$$

Kalman filtration is an iterative estimation, the calculation cycle can be divided into two main steps:

Step 1: Predict or update status:

$$X_k^- = F_{k-1,k} X_{k-1} + B_k U_k \quad (2.21)$$

$$P_k^- = F_{k-1,k} P_{k-1} F_{k-1,k}^T + Q_k \quad (2.22)$$

Step 2: Update measured values:

$$K_k = P_k^- D_k^T \left[D_k P_k^- D_k^T + R_k \right]^{-1} \quad (2.23)$$

$$\hat{X}_k := X_k^- + K_k (L_k - D X_k^-) \quad (2.24)$$

$$P_k = P_k^- - K_k D_k P_k^- \quad (2.25)$$

2.3.2.2. Kalman filter application in processing GNSS - RTK measurement data

2.3.3. Survey the influence of the slope of the working platform of skyscraper

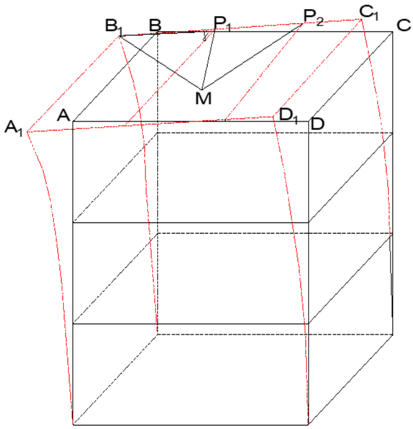

Figure 2.9. Tilt angle γ of the working platform at the time t_i

Therefore: When arranging the details on the working platforms in the construction works, if the inclination angle γ of the working platform does not exceed 14', it is not necessary to calculate this correction in the side length when arranging the works.

2.3.4. Calculate and convert the GNSS - RTK coordinates to the construction coordinate system

When using GNSS - RTK technology in combination with electronic tachometer to arrange on the working platforms of skyscraper, it is necessary to carry out the calculation of converting the results of GNSS - RTK measurements at the times of arranging the design and construction coordinate system of the work. This solution will ensure the uniformity of the construction design and construction coordinate system, reduce the deformation of the length of the side measured by GNSS technology in the construction coordinate system, which helps to improve the accuracy of the GNSS - RTK measuring points used as the basis for detailed layout on skyscraper working platforms.

2.3.5. Check and evaluate the stability of the base station setpoint

Technical solutions using GNSS-RTK technology in construction arrangement Skyscraper are based on the principles: use a construction coordinate system on the ground with a fixed point outside the construction area whose coordinates do not change during construction (used as the base station location). The coordinates of the rover stations arranged on the project are determined by the coordinate increments compared to the base station point. Therefore, the selected point is the base station point that needs to be stable and needs regular measurement, inspection and data processing to assess the stability of this fixed point.

2.4. Research on development the procedures of using GNSS - RTK technology in combination with electronic tachometer in the construction of skyscraper in Vietnam

2.4.1. Establish a control net outside the building

2.4.2. Geodetic work in the construction of the foundation

2.4.3. Use GNSS-RTK technology to measure and check the construction axis system arranged on the foundation surface

2.4.4. Move control points (work axis) to the attitude

Sequence of building axes using GNSS - RTK technology combined with electronic tachometer in construction Skyscraper in Vietnam as follows:

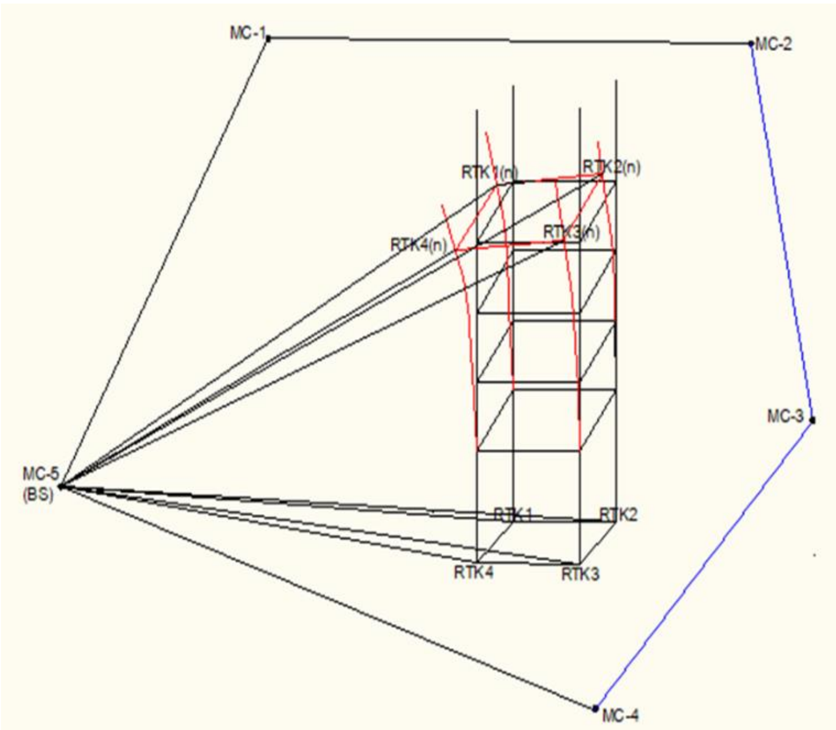

Figure 2.11. Layout plan of rover and base station to move axes upwards during construction of skyscraper

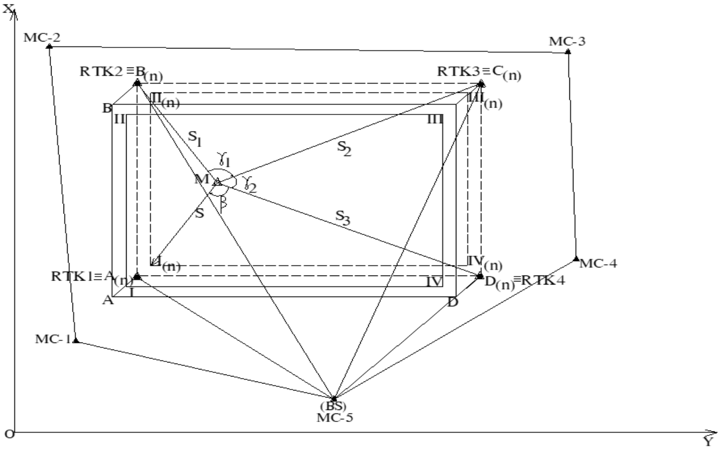

Figure 2.12. Diagram of the process of moving axes upwards in construction of Skyscraper

2.4.5. Detailed layout on the construction sites

2.4.6. As-built drawing measurement

2.4.7. Geodetic work in the project completion stage

2.4.8. Observation of work deformation displacement

2.5. Research to expand the applicability of GNSS - RTK technology in combination with electronic tachometer in some types of geodetic work

2.5.1. Research and apply technology of RTK - RTK in combination with electric power plants in the construction of high-rise buildings

2.5.2. Application of GNSS-RTK technology in combination with electronic tachometer in consulting, monitoring, checking and acceptance of high-rise buildings

2.6. Comments

From the research results between theory and experimental calculation in Chapter 2, we draw some of the following comments:

- The solution using GNSS - RTK technology combined with electronic tachometer allows to determine all the layout points at any time "t" with accuracy under the requirements in construction of high-rise buildings and skyscraper.

- This solution overcomes the disadvantages of traditional solutions such as high-rise building, so there is no need for floor vents; in construction of skyscraper, it is completely possible to arrange the building in the fluctuating condition caused by the external factors and regardless of the building height.

In order to apply this technical solution effectively, it is necessary to pay attention to the problem: processing GNSS-RTK measurement data, calculating the conversion of coordinates of GNSS-RTK measuring points to the construction coordinate system and the stability of the base station site in GNSS-RTK technology.

CHAPTER 3
RESEARCH ON DEVELOPING ALGORITHMS AND COMPUTER PROGRAMS FOR GEODETIC WORK IN THE CONSTRUCTION OF SKYSCRAPER IN VIETNAM

3.1. Necessity of development of specialized computer programs

3.2. Development of block diagrams and algorithm

3.2.1. Development of block diagrams

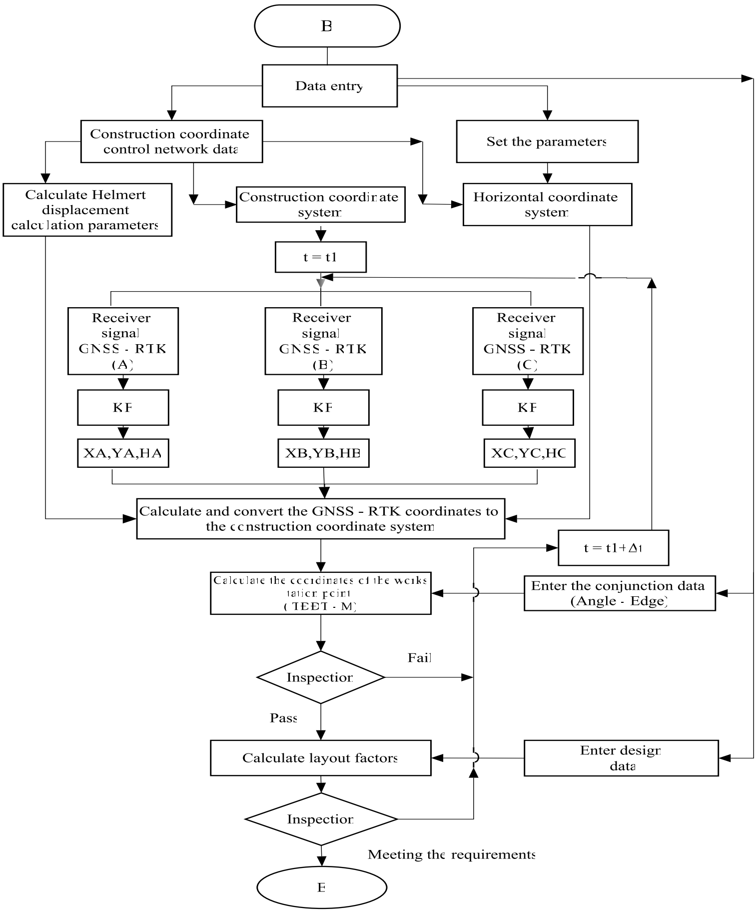

Figure 3.1. Diagram of computer program for geodetic work in the construction of skyscraper

3.2.2. Development of algorithm

3.2.2.1. Kalman filtering algorithm

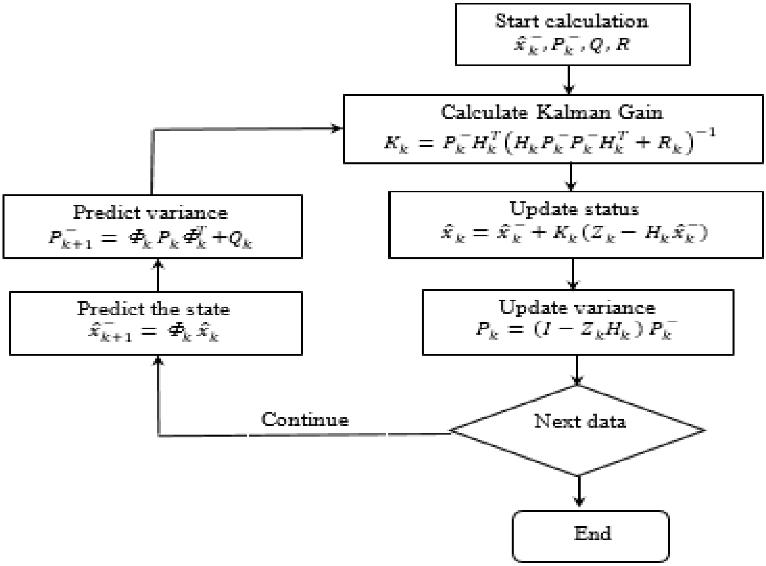

Figure 3.2. Block diagram of computational steps in Kalman filter

3.2.2.2. Algorithm for converting the coordinates of the GNSS - RTK measuring points to the construction coordinate system

3.2.2.3. Algorithm for calculating layout factors

3.3. Development of Modules of the program

3.3.1. Introduction on Super HBDV 1.0

3.3.1.1. Main interface

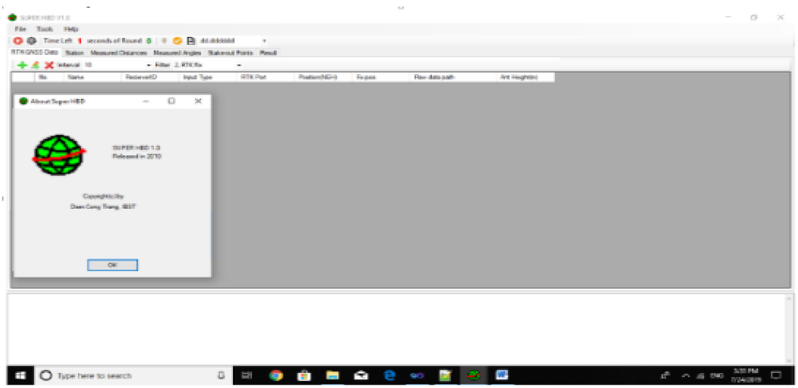

Figure 3.5. Main interface

3.3.1.2. Set parameters in Tool/ Setting
3.3.1.3. Operation for module to install GNSS - RTK points
3.3.1.4. Operation for module to enter electronic tachometer station point
3.3.1.5. Operation for module to enter measuring edges
3.3.1.6. Operation for module to enter the measuring angles
3.3.1.7. Operation for module to enter the layout points
3.3.1.8. Software running and receiving GNSS - RTK data
3.3.1.9. Calculation results and point layout

3.3.2. Comments

The software was developed running on Windows platform, with a simple and convenient interface for users with fast and instant calculations.

CHAPTER 4
SOME EXPERIMENTAL CALCULATION AND MEASUREMENT RESULTS

4.1. Survey on the accuracy of the point location using GNSS - RTK technology with signal reception time increased to 1 minute and 5 minutes (Experiment 1)

4.1.1. Experimental purpose

4.1.2. Experimental content

4.1.3. Experimental results

Evaluate the positioning accuracy by GNSS - RTK technology according to the formula (4.7), we get that positioning accuracy by GNSS - RTK technology reaches accuracy $m_S = \pm 0.41$ mm

From measurement results and experimental calculations, it shows that: positioning accuracy by GNSS - RTK technology compared to the requirements presented in Section 2.2.2 meets the required technical requirements.

4.2. Survey on the accuracy of detecting displacement due to oscillation of skyscraper by GNSS - RTK technology (Experiment 2)

4.2.1. Experimental purpose

4.2.2. Experimental content

4.2.3. Experimental results

With n as the number of GNSS - RTK measurements. Use the formula (4.8) and the calculated data in Table 4.2 to calculate:

$m_{d1} = \pm 2.0$ mm; $m_{d2} = \pm 1.7$ mm; $m_{d3} = \pm 2.1$ mm

Comparing with the technical indicators of measuring oscillation of the skyscraper stated in Section 2.2.2, we see that GNSS - RTK technology meets the necessary technical requirements when the enemy moves due to oscillation of the buildings between two times t_1 and t_2 in the construction process.

4.3. Experiment to evaluate the reliability and accuracy of the RTK-RTK system in combination with the electromechanical machine processed by Super HBDV 1.0 software on the model (Experiment 3)

4.3.1. Experimental purpose

4.3.2. Experimental content and results

4.3.2.1. Equipment in use

Figure 4.9. GNSS-RTK machine - mounted 360^o mirror and 3G broadcasting system

4.3.2.2. Experimental content

a. Determine the parameters for calculating the coordinates

b. Measuring organization

❖ *Option 1:*

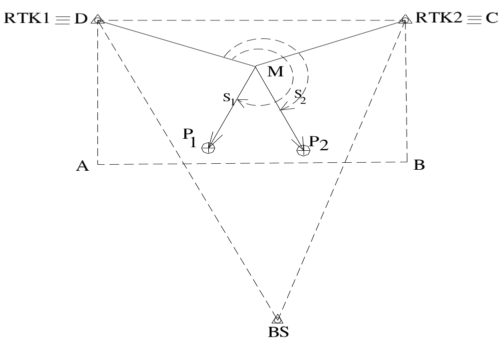

Figure 4.9. Experimental grid diagram - option 1

❖ *Option 2:*

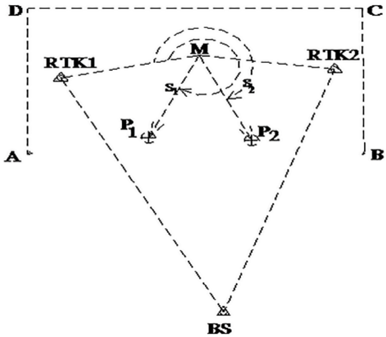

Figure 4.10. Experimental grid diagram - option 2

** Evaluate the point layout accuracy according to the design elements:*

m_p = 2.72mm

** Evaluate the accuracy of layout points according to the layout coordinates*:

m_p = 2.24mm

❖ *Option 3:*

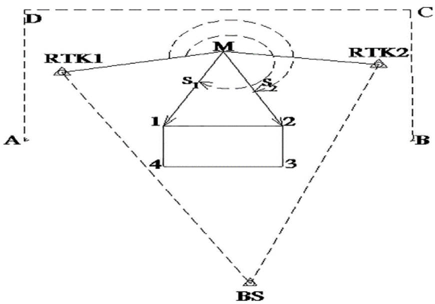

Figure 4.12. Experimental grid diagram - option 3

** Evaluate the mutual accuracy of layout points according to distance measurement error*

The mean square error determines the length of the side or the reciprocal square error between two layout points: m_S = 2.19 mm

4.3.3. Comments

From the experimental measurement results on the model shows:

- Effectiveness of GNSS - RTK technology solutions: With 1 base station located at the base point of the construction coordinate system and the rover stations located at any position, it is possible to determine the coordinates of the points to be arranged with accuracy within permissible limits and this accuracy, ensuring the construction of skyscraper.

- The achieved accuracy of the proposed solution meets the geodetic requirements in the construction of skyscraper and allows the identification of dedicated control grid points or any points to be located on the workstation process in real time.

- The established reliability of the established computer program and the reasonableness of algorithms built in the program has been proven.

4.4. Experimental application of GNSS - RTK technology in combination with electronic tachometer and Super HBDV 1.0 software at V3 tower - project on Terra 50-floor Apartment building - An Hung (Ha Dong - Hanoi City) (Experiment 4)

4.4.1. Project Description

4.4.2. Experimental purpose

4.4.3. Diagram of control grid system serving construction of projects

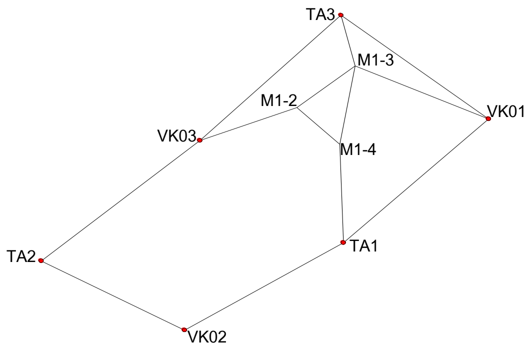

Figure 4.14. Premise control grid diagram at the Terra - An Hung project

4.4.4. Experimental content

The point layout error is calculated according to the layout factors: m_p = 3.5mm

4.4.5. Comments

From experimental measurement results on V3 tower - Terra project - An Hung, it shows that:

- Using GNSS - RTK technology in combination with Super HBD V 1.0 software allows the layout of main axis points on the working platforms with the precision under the necessary technical requirements in construction of high-rise buildings and skyscraper in our country.

- When using this technology for construction layout on high-rise buildings and skyscraper, some shortcomings of the traditional point projection method have been overcome (there is no need to leave floor clearance, avoid the accumulation of errors, reduce the influence of the optical extractor on the measurement results ...)

- This technological solution is favorable for the construction arrangement in the fluctuating conditions of the work due to the influence of external factors.

4.5. Application experiment of SUPER.HBD V1.0 software at Golden Park Tower project

4.5.1. Project Description

4.5.2. Experimental purpose

4.5.3. Experimental content and results

4.5.3.1. Basic control landmark system

4.5.3.2. Layout diagram of experimental grid of Golden Part Tower

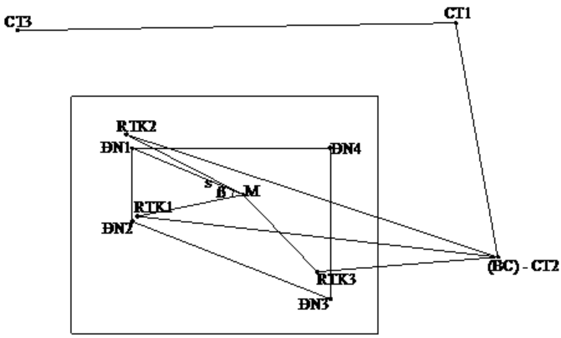

Figure 4.19. Experimental grid diagram of Golden Part Tower - SuperHBD.V1

4.5.4. Experimental results

The point layout error is calculated according to the layout factors: m_p = 3.02 (mm)

4.5.5. Comments

From the experimental measurement results on the Golden Park Tower, it shows that:

Using GNSS - RTK technology in conjunction with Super HBDV 1.0 software allows to locate points to be arranged in detail on the working platform with the accuracy under the necessary technical requirements in construction of high-rise buildings and skyscraper in our country.

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

From the research results of theory and measurement of experimental calculation, the following conclusions can be drawn:

1.1. The skyscraper is a high-rise building, built on a narrow area, thus, during the construction process, a part or the whole work is always oscillated due to the influence of external factors with relatively large amplitude without general rule. Therefore, it is necessary to apply appropriate technical solutions to improve the efficiency and accuracy of geodetic work in construction of the skyscraper.

1.2. Technical solutions using GNSS - RTK technology combined with electronic tachometer have been studied theoretically with experimental measurement results, allowing the layout of all the points on the building in real time. This allows the detailed layout of buildings on the working platforms in case the building is always oscillated due to the influence of external factors. This is also the effectiveness of the proposed technical solutions in the construction of skyscraper in Vietnam.

1.3. When using GNSS - RTK technology in combination with electronic tachometer in construction of skyscraper, some solutions proposed in the dissertation should be applied in order to improve the accuracy of geodetic work. The results of theoretical research and experimental measurements show the effectiveness of the above technological solutions.

1.4. Super HBDV 1.0 Specialized computer program used for high-rise buildings and skyscraper construction has solved the signal coupling, automating the process of geodetic data processing on the working platforms. The experimental measurement results show that Super HBDV 1.0 software has fast data processing speed with high reliability, meeting technical requirements and construction progress of skyscraper in Vietnam.

1.5. The research results in the dissertation can be applied to conduct the geodetic work for construction, consulting and supervision, inspection and acceptance of the quality of the high-rise buildings and the skyscraper, as well as other modern works. The results of this research contribute to improving the professional qualifications and practical applications of our country's geodetic specialization in the construction of large international typical works.

2. RECOMMENDATIONS

2.1. It is necessary to continue to study and complete the process of measuring, calculating and processing data for modern technology application solutions to improve the efficiency of surveying in the construction of skyscraper in Vietnam.

2.2. In the current Vietnam Standard system, the standards for geodetic work in the construction of skyscraper are not promptly updated and new technologies are added, which affects the construction progress and the quality of skyscraper in our country when constructed with modern technology. Therefore, we recommend that the competent authorities soon issue Vietnam Standards and legal documents in accordance with the actual construction of skyscraper in Vietnam today.

LIST OF PUBLISHED AUTHOR'S SCIENTIFIC WORKS RELATED TO THE CONTENT OF THE DISSERTATION

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2. Diem Cong Trang, Nguyen Quang Thang (2018), "Solution for checking the verticality of works in the construction of skyscraper". *Collection of ACI international conference reports, Institute of Construction Science and Technology, p. 347 - 362.*
3. Tran Ngoc Dong, Diem Cong Trang, (2017), "Methods to improve the efficiency of moving coordinates and elevation to high-rise building working platforms in Vietnam". *International Workshop on Intelligent Management of Infrastructure, ICSMI, Hanoi University of Transport and Communications, p. 317 - 328.*
4. Nguyen Quang Thang, Vu Thai Ha, Diem Cong Trang (2017), "Solution for reduction of effects of some factors on accuracy of staking out axis to working platforms in construction of skyscraper". *The International Conference on Geo-Spatial Technologies and Earth Resources in Hanoi, Vietnam, October 2017, pg.67 - 73.*
5. Nguyen Quang Thang, Vu Thai Ha, Diem Cong Trang (2019), "Solution of moving elevation to the working platforms with GNSS technology in the construction of skyscraper". *Journal of Construction Science and Technology, (3), p.59 - 64.*
6. Tran Viet Tuan, Diem Cong Trang (2018), "Surveying the accuracy of GNSS - RTK technology in some geodetic work types". *Journal of Geodesy and Cartography Science, (37), p. 46 - 49.*
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8. Diem Cong Trang, Tran Viet Tuan (2019), "Research on application of GNSS - RTK technology in inspection, acceptance and evaluation of the verticality of skyscraper before being put into use". *The XV Young Staff Science Conference - Institute of Construction Science and Technology.*
9. Tran Viet Tuan, Diem Cong Trang (2019), "Research on GNSS-RTK technology solutions in the construction of skyscraper in Vietnam". *Journal of Geodesy and Cartography Science, p.39 - 43.*
10. Tran Viet Tuan, Duong Thanh Trung, Diem Cong Trang (2020), "Research on improving the efficiency of measurement and processing of geodetic data in the construction of skyscraper in Vietnam". *Journal of Geodesy and Cartography Science, (44), pp.11-15.*