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Research on design and establish of GNSS data receiver and transmission device used in the continuously monitoring displacement and deformation of works in real time

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ABSTRACT

This article presents a technical solution for monitoring for displacement and deformation in real-time based on GNSS CORS technology. The components and principles of operation of the monitoring system for displacement and deformation have been designed and establish. The continuously operation reference station (CORS) was used to correct position for monitoring station in the RTCM format. A device for receiving and transmitting data from the monitoring station to the server has been designed and and developed. NMEA messages have been decoded and filtered through three steps using home-made software that improves the accuracy of the monitoring results. The results show that the developed equipment system can monitor horizontally displacement to 3 mm and vertical displacement to 5 mm.

Keywords: Continuously monitoring; displacement; deformation; global navigation satellite system; continuously operating reference station; real Ttme.

I. Introduction

The industrialization and urbanization processes occur fastly during the last several decades which lead to industrial and civil construction projects are getting bigger and higher. However, the construction works on the ground are often displaced and deformed due to the impact of many different factors, therefore, monitoring displacement and deformation of construction works is an important task. The real time identification of the deformation and displacement of buildings can reduce the risk of accidents that can happen to people and avoid financial losses. Up to now in Vietnam most of the deformation and displacement monitoring works are mainly periodically carried out by traditional measuring devices such as hydrography, theodolite, electronic total or by GPS technology. Using those technology and equipments it is difficult to real time monitor continuously changing deformation and displacement.

The deformation and displacement surveying need to be automatically and continuously carried out in real time due to the rapid development of new technology. The deformation and displacement surveying of high-rise buildings has been effectively studied by GNSS technology [5, 7]. Deflection and horizontal displacement of brigdes can be determined by using GNSS technology [3]. The GNSS system currently allows the continuously reception of satellite signals using real time RTK dynamic measurement technology with high accuracy. The advantages of GNSS technology are to provide 3D data in real time, operate continuously with different weather conditions, position with high precision; therefore, this technology has been applied to survey effectively spherical displacement and deformation [6].

GNSS technology monitoring system has been widely and effectively applied in many countries over the world. However, these systems all have their own hardware, software and high cost. Therefore, the idea of developing a system for real time continuously monitoring deformation transformation based on GNSS/CORS technology has been proposed. Based on the working principle and data transmission mechanism of CORS station, this work has developed a device to receive and transmit the corrected data from the user (User) located at the monitoring position to master station (Server). All measurements from the used station are automatically and continuously sent to the master station. Here a software has been designed to handle the measured data that was sent from user at the monitoring point to produce the results of the immediately displacement and deformation of the construction works. To test the accuracy and stability of the system, a dedicated device has been designed and manufactured. The experiments data show that the monitoring system works properly, stably, continuously

24/7 and can monitor the deformation and displacement of the construction works from 3 mm upwards.

II. GENERAL PRINCIPLES OF DEFORMATION AND DISPLACEMENT MONITORING WORKS

The monitoring of deformation and displacement of construction works is essentially determination its position change in space over a period of time. The equation for calculating displacement and deformation of construction works is shown in the following formula [3].

$$dp = R'p - Rp = dp\,(Xp, Yp, Hp, t) \qquad (1)$$

where:

Rp - position of P point at time t = 0 (before deformation);

R'p - position of P point at time t > 0 (after deformation)

The deformation and displacement quantity in formula (1) is defined in 4-dimensional space, including 3 dimensions according to component coordinates X, Y, H and the fouth one is time t. The deformation along each coordinate axe is determined by the following formulas:

- Deformation along X: $Dx = X_i\,(t + 1) - X_i\,(t)$
- Deformation along Y: $Dy = Y_i\,(t + 1) - Y_i\,(t)$

-Fully deformation: $Dp = \sqrt{Dx^2 + Dy^2}$

-Vertical deformation (settlement): $\eta = H_i\,(t+1) - H_i\,(t)$

where: X_i (t), Y_i (t), H_i (t) are the coordinates of the i^{th} point at time t (before deformation).

X_i (t + 1), Y_i (t + 1), H_i (t + 1) are the coordinates of the i^{th} point at time (t + 1) (after the deformation).

Thus, the nature of the deformation and displacement determination is to determine the coordinates of the monitoring points attached to the building at different times. Real-time monitoring of deformation and displacement is to continuously and instantaneously determine the coordinates of the monitoring points. This process is performed by a technical solution based on GNSS/CORS technology.

III. THE COMPONENTS AND OPERATION PRINCIPLES OF SYSTEM FOR REAL TIME MONITORING DEFORMATION AND DISPLACEMENT CONSTRUCTION WORKS

A. Components of the monitoring system

Real time deformation monitoring system is developed based on GNSS/CORS technology. The whole system consists of two parts. The first part is the Continuously Operating Reference Station system (CORS) and the second part is the Continuously Monitoring Station System (CMSS) (Fig 1).

The set up CORS station system consist of two basic parts such as hardware and software. Hardware includes GNSS antenna (1), GNSS receiver (2), modem and internet connection (3), and host computer (4). Software for controling CORS station includes station management software (NRS-Station) and user management software (NRS-Server).

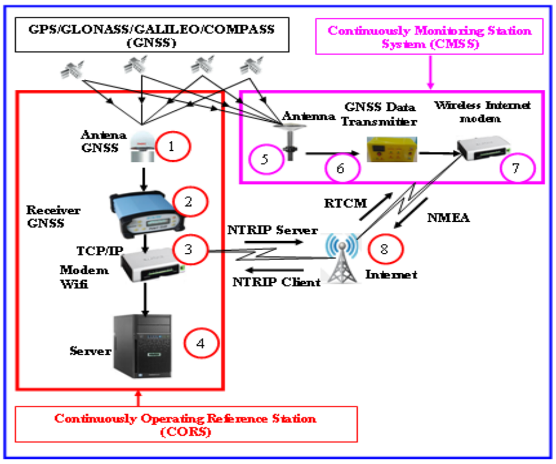

Fig.1. Diagram of real-time displacement and deformation monitoring system.

Continuously Monitoring Station System includes also hardware and software. The hardware includes a antenna that receives GNSS satellite signals (5), GNSS data acquisition and transmission equipment (6), modem (7) and wireless internet connection (8). The softwares include a software to receive and transmit GNSS data from the monitoring station to master station (Server GNSS CORS WDM) and a software for processing monitored data about deformation and displacement of construction works (GNSS CORS WDM).

B. Principle of operation of the monitoring system

The operating principle of the continuously monitoring station system the deformation and displacement of the construction works is based on the operation principle of GNSS/CORS system. The GNSS satellite signals are received by the antenna (1), transmitted to the GNSSNetS8 + receiver via a dedicated cable, where the satellite signals are decoded and passed through the modem (3) to the host computer (4). Through the host computer, which is connected to an internet connection with a static IP address, it is possible to decentralize management depending on each user with two accompanying softwars: NRS-Station (for calculation of data and allocation of static station data) and NRS-Server that provides false information for mobile measuring points, processes data of RTK dynamic network, and adjusts multivalued integers of the whole network, sets up the rectification model (including rectification of the troposphere error, the ionosphere, and the satellite orbit). Data in CORS station is continuously collected every 1 second, 15 seconds or 30 seconds depending on user requirements and is set up in NRS-Station software. The data is stored in a certain directory in the server according to the format of the RINEX file.

The deformation and displacement monitoring of construction works is implemented by the method of GNSS/CORS/RTK. User is a multi-frequency GNSS receiver with a telephone Sim slot located at the monitoring station, connected to the CORS station and it will sends the approximate coordinates to the master station through a series of measurement data with NMEA's standard data format (National Marine

Electronics Association) of the National Marine Electronics Association (USA) [8].

The measured data from rovers is sent to the master station according to the NMEA (National Marine Electronics Association) data format of the National Marine Electronics Association (USA) [8].

At the server NRS-Server software will calculate and determine the number of corrections for the user and exactly determine the coordinates for the user and transmit in RTCM data format [10, 11] and stored in the manual of the user.

IV. DESIGN AND DEVELOPMENT OF GNSS DATA ACQUISITION AND TRANSMISSION EQUIPMENT

IV.1. Designing hardware system

Receiving and transmitting data from monitoring station to CORS station is continuously carried out to real time provide the spatial position of the monitoring point. The GNSS data acquisition and transmission equipment includes the main modules as shown in Fig 2 is designed and developed.

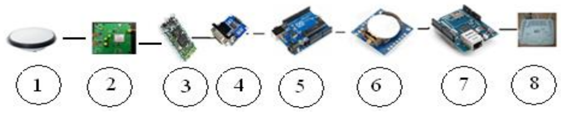

Fig.2. Some hardware devices for GNSS data acquisition and transmission

Names of main modules of GNSS data acquisition and transmission equipments are shown in Table 1.

Table 1. Modules for GNSS data acquisition and transmission system.

Nº	Device name
1	GNSS antenna
2	GNSS collection module
3	Module Bluetooth
4	Max232 signal acquisition module
5	Module for data processing Arduino UNOR3
6	Real-time module
7	Module Ethernet Shield W5100
8	Wireless Internet modem

IV.1.1 .Signal acquisition module Max232

Max232 signal acquisition module is device for transfering RS232 signal (Recommeded Standard 232) into TTL logic signal (Transistor-Transistor Logic) to be able to create communication between RS232 standard devices and TTL standard devices. Characteristics of module are high accuracy, reliability in data preservation, high processing speed, small power consumption, and signal delay.

IV1.2 Module for processing Arduino UNO R3 data

This is a central control module that controls the operation of other modules, codes are directly loaded on ATmega 328 microprocessor. In signal transmission protocols, the ATmega328 is responsible for receiving and computating data and returning them to other modules; from these the data form continuously connections and interdependent.

The module is designed with 7 analog pins, 13 digital pins, and 6/13 integrated digital pins. Board runs in direct DC voltage range from 7V to 20V, new type of ATmega 328 chip, AVR family, operates 8 bit platform, 5V voltage, 0.2 mA current, and all Boards have level power consumption of 2.5 W.

IV.1.3 Data storage and transmission to Ethernet W5100 server

This is a transmission system as well as a data storage system. Module integrated to Ethernet W5100 processor chip can give a LAN network transfer rate up to 100 Mbps. It is additionally integrated to Micro SD memory card mounting function up to 4Gb.
The module also integrates status indicating lights including LAN, Full, RX, TX ... to make error control more flexible.

IV.1.4 Real-time module

Real time module supplies the real time for Arduino to determine the time that data is transferred from Rover station to CORS station. The real time module is periodically calibrated to the satellite time to always ensures the accuracy required for all activities on the Rover system. Real-time module connects directly with Arduino using IC2s standard with analog 5 or analog 6 pin. The module is directly powered by 5V from Board Arduino. All the above modules are integrated together to create a GNSS data acquisition and transmission unit from the monitoring station to the CORS station management server. This device is called GNSS Data Transmitter (Fig 3).

a) b)
Fig.3. GNSS data receiver and transmission devicea
a) Front ; b) Behind

IV.1.5 Internet signal transmission system

This is a signal transmission tool from Rover to CORS station and reverse signal transmission. In the CORS modem, the modem is integrated and additional supported by output ports to create signal paths via wireless internet. This port is fixed with a static IP address provided by the network.

IV.2. Design and construction of system control software

After a GNSS data acquisition and transmission device has been designed and installed, controlling software has been designed and built. The software is written in NMEA's standard data format using the Arduino programming tool and the C # programming language.

When software source code has been written and checked for errors, it is loaded into the GNSS data transmitter via the USB connector to the computer by Arduino's programming tool. Software controlled GNSS data acquisition and transmission functions is implemented as follows:

The satellite signal collected from Rover in NMEA standard format is directly transmitted to Arduino via RS232 port;

The received Arduino signals is divided into two types $ GPGGA, $ GNGGA and other NMEA signals;

The $ GNGGA signals are transmitted to the Server according to NTRIP server protocol and other NMEA signals are simultaneously transmitted to Ethernet and stored in the SD memory card that is integrated in Ethernet in the text file format;

$ GNGGA signals are processed by specialized software and the results are sent to the software in the server to provide instant location;

These data are automatically processed by specialized software designed and deformation and displacement quantities are identified with the highest accuracy.

V. DECODE THE GNSS DATA STRUCTURE IN NMEA FORMAT

The data structure in the NMEA format is a technical standard that allows electronic devices to send information to computers and to another electronic device [9]. The standard was developed by the National Marine Electronics Association (NMEA). NMEA data structure has currently many versions but NMEA 0183 version is widely used and uses ASCII standard code.

The electrical standard used is EIA-232, most of the hardware allows format with the NMEA-0183 via EIA-232 port. In order to set up a program that controls satellite signal transmission and acquisition decive, it is necessary to have standard information about the format structure of this data standard. Table 2 displays the GNSS data structure according to NMEA 0183 format standard of some types of messages returned by Rover.

Each NMEA format code starts with a "$" character on a serial row and cannot consist of more than 80 characters. The data is displayed on a row with different types and separated by commas (,), after comma is space characters. Data streams are commonly GNGSA, GNRMC, GNVTG, GNGGA, GNGLL, GNGSV, GNZDA and then are information about time, coordinates, status, and altitude. In Table 2 presents some data codes according to NMEA format standard obtained from GNSS receivers.

Table 2. Some data codes according to NMEA 0183 format standard

$GNGGA,hhmmss.ss,llll.lll,a,yyyyy.yyy,a,x,uu,v.v,w.w,M,x.x,M,,zzzz*hh<CR><LF>
$GNGLL,llll.lll,a,yyyyy.yyy,b,hhmmss.sss,A,a*hh<CR><LF>
$GNGST,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,u.u,v.v,z.z*hh<CR><LF>
$GNGSA,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,u.u,v.v,z.z*hh<CR><LF>
$GNGSV,x,u,xx,uu,vv,zzz,ss,uu,vv,zzz,ss,...,uu,vv,zzz,ss*hh<CR><LF>
$GNRMC,hhmmss.sss,x,llll.lll,a,yyyyy.yyy,a,x.x,u.u,xxxxxx,,,v*hh<CR><LF>
$GNVTG,x.x,T,y.y,M,u.u,N,v.v,K,m*hh<CR><LF>
$GNZDA,hhmmss.sss,dd,mm,yyyy,xx,yy*hh<CR><LF>

All these data have been decoded to filter out the highest quality GNSS measurement information in which two types of $ GNGGA and $ GNGSV messages are specially paid attention. The GNGGA message line indicates which measurements meet the accuracy requirement (Fixed measurement value) and the GNGSV message line indicates the errors of Fixed measuring points. All measurements reached requirement accuracy are stored in daily files and these files have names associated with measured dates (eg data25082018.txt). These data files are processed by a software to give real-time results about deformation and displacement.

VI. BUILDING SOFTWARE TO RECEIVE AND PROCESS DEFORMATION AND DISPLACEMENT MONITORING DATA

Deformation and displacement monitoring data of construction works are continuously transmitted from the monitoring station to the host computer (Server) through the data transmission unit. There are two softwares designed to ensure that the monitoring station system can continuously works without being corrupted about the data. The first software has the function of receiving data from the rovers at the monitoring point and sending to the server. The second software has the function of analyzing and processing data sent from the first software to get the most accurate data file (Fig 4a) and to identify and display the deformation and displacement quantities. Software for analyzing and processing deformation and displacement monitoring data of construction works are written in VB.Net programming language by Visual Studio 2017 programming tool. The interface of the software is designed to be expressed as Fig 4b. The main modules of the software include:

- Module for processing real time GNSS data;
- Module for processing timeline data;
- Composite modules for determining vertical and horizontal displacements;
- Module for updating the names of monitoring works;
- Module for real-time control;
- Modules for warning of deformation and displacement of construction works that exceeds the allowed limit.

Fig. 4. Software interface processing deformation and displacement monitoring data

Hardware and software devices designed and built into a synchronous system that can continuously monitor the real-time deformation and displacement of the construction works.

VII. RESULTS AND DISCUSSION

VII.1 Design, build equipment system to real-time assess the accuracy of deformation and displacement monitoring of contruction works

The equipment system is designed and manufactured including a horizontal rail attached with a steel ruler to determine horizontal displacement. Monitoring landmark are attached to 4 wheels to be able to move on the rail. The monitoring landmark is attached to a vertical steel ruler to monitor vertical displacement. The monitoring device consists of a GNSS S82 receiver supplied by South Company (China), GNSS data acquisition and transmission equipment, wireless Internet modem, battery, solar battery. The GNSS receiver is fixed to the monitoring landmark, receiver is activated and monitoring device is connected to the receiver via Bluetooth. The system will automatically receive and transmit data to the server. The indication lights will show the operating status of the monitoring station system (Fig 5).

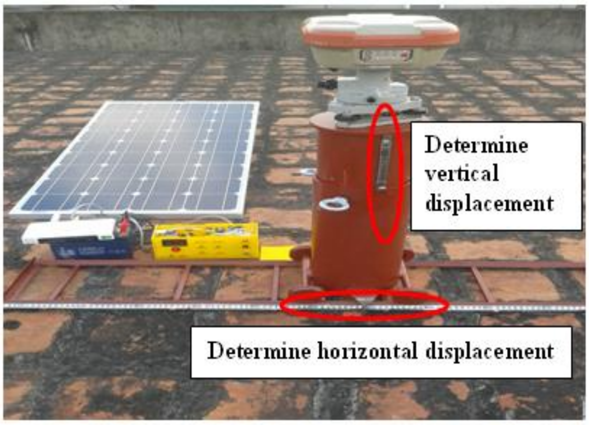

Fig. 5. The device system for evaluating the accuracy of real-time monitoring deformation and displacement of construction works

VII.2 Processing monitoring data

Experiments for real-time monitoring deformation and displacement construction works were perpormed in four different periods of time on 20, 22, 24, 26 of August 2018. With each monitoring point the signals are collected every hour when the monitoring point is moved to a certain distance. The deformation and displacement quantities of this monitoring point are determined based on the steel ruler attached to the monitoring milestone (this quantity is used for checking), then based on the monitoring data to determine the demormation and displacement quantities by CORS / RTK measuring technique.

Data collected at the NMEA 183 standard monitoring station is continuously sent from the monitoring station to server with a frequency of 1 message per second. Table 3 shows a segment of the data file according to NMEA standard collected at the monitoring station starting at 16h, 47 minutes, 13 seconds, on August 20, 2018.

Table 3. NMEA data collected at the monitoring station on 20 August 2018

$GNGGK,164713.00,082518,2104.3054650,N,10546.4090182,E,1,23, 1.7,EHT-1.331,M*72
$GNGGQ,164713.00,082518,2104.3054650,N,10546.4090182,E,1,23,1.000,-1.331,M*36
$GNGLL,2104.3054650,N,10546.4090182,E,164713.00,A,A*77
$GNGNS,164713.00,2104.3054650,N,10546.4090182,E,AANA,23,0.6,-1.331,,,*63
$GNGSA,A,3,03,10,14,16,22,26,29,31,,,,,1.1,0.6,0.9*2E
$GPGSV,3,1,10,03,12,320,41,10,28,166,44,14,57,029,49,16,37,203,46*75
$GPGSV,3,2,10,22,30,307,46,25,16,038,,26,69,200,51,29,14,084,41*7D
$GPGSV,3,3,10,31,50,356,51,32,51,077,50,,,,,,,,*7B
$GLGSV,1,1,04,70,68,348,45,71,17,333,43,73,49,267,50,80,45,003,45*66
$GAGSV,2,1,06,04,48,123,49,05,21,322,43,09,70,352,52,24,59,251,51*6F

Data file obtained according to NMEA standard of GPGGA and GPGST messages are processed to find the best measurements. The processing process is carried out in the following 3 steps:

Firstly, check the integrity of the messages in the NMEA data file.

After receiving messages in NMEA format from Rover, it is necessary to check the integrity of the messages in this data file, if the messages are missing information, do not use this message. The integrity check of data is done by analyzing all characters in the range from $ to of the NMEA message.

Secondly, filter the messages those coordinate information fixed.

In the GNGGA or GPGGA message sequence, if after the letter "E" is number 4, these measurements were used. If after the letter "E" is the number 0, 1, 2, 3 or 5, these measurements are not taken, (Table 4) shows a message segment that were filtered.

Thirdly, filter out messages those coordinates have been fixed but having the smallest position errors. Filtering out coordinates with small errors is done by analyzing the GPGST or GNGST message sequence.

Table 4. GNGGA data according to NMEA 0183 format

$GNGGA,070309.00,2104.29999960,N,10546.41406609,E,4, 22,0.7,23.698,M,-28.333,M,1.0,4095*4C
$GNGGA,070310.00,2104.30000020,N,10546.41406564,E,4, 22,0.7,23.699,M,-28.333,M,1.0,4095*41
$GNGGA,070311.00,2104.29999998,N,10546.41406593,E,4, 22,0.7,23.703,M,-28.333,M,1.0,4095*41
$GNGGA,070312.00,2104.29999893,N,10546.41406725,E,4, 22,0.7,23.700,M,-28.333,M,1.0,4095*44
$GNGGA,070313.00,2104.29999942,N,10546.41406699,E,4, 22,0.7,23.701,M,-28.333,M,1.0,4095*4F
$GNGGA,070314.00,2104.29999894,N,10546.41406737,E,4, 22,0.7,23.701,M,-28.333,M,1.0,4095*47
$GNGGA,070315.00,2104.30000032,N,10546.41406652,E,4, 22,0.7,23.689,M,-28.333,M,1.0,4095*40
$GNGGA,070316.00,2104.29999938,N,10546.41406966,E,4, 22,0.7,23.699,M,-28.333,M,1.0,4095*48
$GNGGA,070317.00,2104.29999921,N,10546.41406725,E,4, 22,0.7,23.698,M,-28.333,M,1.0,4095*49
$GNGGA,070318.00,2104.29999947,N,10546.41406839,E,4, 22,0.7,23.701,M,-28.333,M,1.0,4095*45
$GNGGA,070319.00,2104.29999955,N,10546.41406849,E,4, 22,0.7,23.696,M,-28.333,M,1.0,4095*4F
$GNGGA,070320.00,2104.29999779,N,10546.41406726,E,4, 22,0.7,23.699,M,-28.333,M,1.0,4095*4C
....

The average coordinate value is calculated from the coordinate values that have been filtered out over a monitoring period. Then the displacement of the buildings in the horizontal plane between the two monitoring points is determined through the coordinate of the ground (X, Y).

With monitoring data of 20/8/2018, horizontal displacement components can be identified:

- Displacement by OX axis:

$Q_x = X_{i+1} - X_i = 2330973.6773 - 2330973.6302 = 0.0471$ m

- Displacement by OY axis:

$Q_y = Y_{i+1} - Y_i = 580383.4861 - 580383.4816 = 0.0045$ m

-Complete translation:

$$Q = \sqrt{Q_X^2 + Q_Y^2} = \sqrt{0.0471^2 + 0.0045^2} = 0.0473 \text{ m} = 47.3\text{mm}$$

-Vertical displacement:

$$\eta = H_{i+1} - H_i = 23.651 - 23.690 = 39 \text{ mm}$$

Table 5 displays the horizontal and vertical displacement values determined by monitoring equipment and directly measured by a steel ruler mounted on the monitoring landmark, the maximum horizontal displacement is 2.3 mm and the minimum is 1.5 mm. The maximum displacement of vertical displacement is 4.2 mm and the minimum is 3.5 mm.

Table 5. Evaluation of accuracy of horizontal and vertical displacement monitoring results

Horizontal displacement (mm)			Vertical displacement (mm)		
Measured by steel ruler	Observed by CMSS equipment	Deviation	Measured by steel ruler	Observed by CMSS equipment	Deviation
45	47.3	2.3	35	39.0	4.0
50	51.5	1.5	45	49.2	4.2
55	53.2	1.8	55	58.5	3.5
60	57.8	2.2	65	68.7	3.7

VII.3 Experimental monitoring high-rise buildings

Using the equipment system that has been studied and developed, the monitoring experiments are conducted at the An Binh high-rise buildings in Hanoi, Vietnam. The building hass 24 storeys, 2 basements and 3 floors of commercial services. On the roof of the building, there are 04 corner observation stations with 4 Rover numbered Rover-01, Rover-02, Rover-03, and Rover-04 (Fig 6).

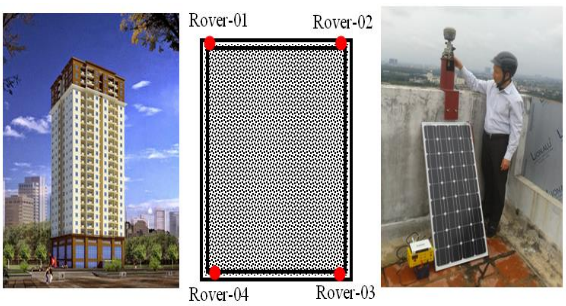

Fig. 6. Experimental monitoring of high-rise buildings

CORS station named CORS-N001 used for monitoring is built on the campus of Hanoi University of Mining and Geology and is about 2km from the An Binh building (Fig 7).

Fig.7. Installation of CORS N001 station system at Hanoi University of Mining and Geology

After installing monitoring stations on the roof of the building, monitoring is automatically performed. Data at the monitoring stations were continuously sent to the server in the NMEA standard format every second. The data is saved to the server by the default path and file name. The data of each day is saved to a file, the measurement message collected at the monitoring station and is sent to the NMEA-0183 standard format. Table 6 shows a piece of data collected at An Binh buiding monitoring station.

Table 6. A section of monitoring data of An Binh apartment building

$GPGGA,170000.000,2104.4617281,N,10545.8333509,E,4,13,0.8,10.451,M,-24.900,M,,0000*4C
$GPGLL,2104.4617281,N,10545.8333509,E,170000.000,A,R*46
$GPGSA,A,3,27,07,23,09,11,18,08,,,,,,1.8,0.8,1.6*3F
$GLGSA,A,3,78,77,88,87,81,68,,,,,,,1.8,0.8,1.6*2F
$GPGSV,4,1,14,08,79,009,55,41,54,229,50,23,51,222,51,09,50,267,52*75
$GPGSV,4,2,14,27,46,033,49,11,41,179,48,42,40,114,44,18,32,151,46*7F
$GPGSV,4,3,14,07,29,326,35,04,28,036,26,16,20,050,,01,16,174,26*79
$GPGSV,4,4,14,26,04,070,,28,03,267,*71
$GLGSV,3,1,09,88,66,146,45,87,47,044,47,77,40,039,38,78,27,338,42*62
$GLGSV,3,1,09,88,66,146,45,87,47,044,47,77,40,039,38,78,27,338,42*62
$GLGSV,3,2,09,81,24,190,42,67,17,229,30,68,17,284,40,76,10,097,23*6C
$GLGSV,3,3,09,79,01,310,*51
$GPRMC,170000.000,A,2104.4617281,N,10545.8333509,E,000.00,00 0.00,311018,,,R*7B
$GPVTG,000.00,T,,M,000.00,N,000.00,K,R*2E
$GPZDA,170000.000,31,10,2018,00,00*58
$GPGST,170000.000,0.005,0.003,0.002,86.5,0.002,0.003,0.004*5B
$PSTI,030,170000.000,A,2104.4617281,N,10545.8333509,E,10.451,-0.01,0.00,0.07,311018,R,1.0,10.0*2B
$PSTI,032,170000.000,311018,A,R,-996.703,288.763,-17.371,1037.836,286.16,,,,,*1E
$PSTI,033,170000.000,311018,1,R,0,G1,0,0,R1,0,0,G2,0,0,R2,0,0,,,,*6F
$PSTI,033,170000.000,311018,1,B,0,G1,0,0,R1,0,0,G2,0,0,R2,0,0,,,,*7F
$GPGGA,170001.000,2104.4617324,N,10545.8333456,E,4,13,0.8,10.420,M,-24.900,M,,0000*4E
$GPGGA,170001.000,2104.4617324,N,10545.8333456,E,4,13,0.8,10.420,M,-24.900,M,,0000*4E
$GPGLL,2104.4617324,N,10545.8333456,E,170001.000,A,R*42
$GPGST,170001.000,0.007,0.005,0.003,85.6,0.003,0.005,0.006*5A
……………………………………………………………………………

Monitoring is continuously carried out 24/7 within 3 months from 2nd August to 5th October 2018. Processing and analysing data, identification of deformation and displacement quantities and evaluation of stability of the observed building is carried out through the following steps:

1. Check the integrity of the measured messages and filter out messages whose coordinates have been adjusted (Fixed) in the GGA message format in the data file.

2. Filter out messages whose measurering values corrected position (Fixed)

3. Filter out the messages whose measurering values corrected position with the smallest errors.

4. Retrieve the coordinates of the monitoring station in the WGS84 coordinate system.

5. Transfer to VN2000 Vietnamese coordinate system

6. From the coordinates of the monitoring point in the VN2000 coordinate system, the measure average in every hour will give one position. Comparing coordinates between different time periods will determine the horizontal and vertical displacement of the buildings. Based on the displacement of the monitoring stations, the stability of the project will be assessed.

VIII. CONCLUSION

This work has focused on solving the problem of continuously monitoring of deformation and displacement using of GNSS/CORS technology. A diagram of continuously monitoring system has been set up including CORS station system and CMSS monitoring station. The message types of the GNSS data structure have been successfully studied and decoded including NMEA format messages sent from the host monitoring station to server of the CORS station.

A GNSS data transmission system has been designed to develop both hardware and software that can real time, continuously and automatically monitor of deformation and displacement of construction works. The developed system automaticaly works well, stably, ensure, and instantaneously transmission of data from the monitoring station to the host computer.

GNSS data processing software designed and developed allows to process data and immediately determine the deformation and displacement of construction works. The system of monitoring stations has been studied, developed, and tested by specialized equipment, showing that the monitoring system works well, stably, continuously and ensures the required accuracy to monitor deformation and displacement of the construction works up to 3 mm in plane and 5mm in height.

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