International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 4 (May 2014) http://ijirae.com

Tower verticality for Tall Building using DGPS

Milind N Phatak[1]
Civil and Environmental Engineering Department
Veermata Jijabai Technological Institute,
mphatak89@yahoo.com

Dr Sumedh Y Mhaske[2]
Civil and Environmental Engineering Department
Veermata Jijabai Technological Institute,
symhaske@vjti.org.in

ABSTRACT-- With growing demands of urban infrastructure, tall buildings are resorted to as an ideal solution for the space in our already overcrowded cities like Mumbai. First and for most challenges in construction of tall is ensuring verticality. The present day planer must plan must consider factors like wind loads, crane loads, construction sequence, and other factors while planning. In constructing of a high rise building there are usually a lot of movement at upper levels, these are factors affect verticality which tends to sway. Presently there are methods such as Plumb bob, Construction laser, Total Station etc. However there are glaring common disadvantages in all this which lack of accuracy. Application of GPS has accounted obviated certain, however development of Differential Geographic Positioning System (DGPS) as it offers solution to mitigate most of problem. This paper shows application of DGPS on one of the site in Mumbai for tower verticality.

Keywords— Tall buildings, DGPS, GPS, tower verticality, surveying technique.

I INTRODUCTION

There has been considerable interest in the construction of super high-rise and iconic buildings recently. From a surveying perspective, these towers present many challenges. In addition to being very tall, high-rise buildings are often quite slender and during construction there is usually a lot of movement of the building at upper levels due to wind loads, crane loads, construction sequence, and other factors. It is essential that a straight "element" be constructed that, theoretically, moves around its design centre point due to varying loads and, if all conditions were neutral, would stand exactly vertical. This ideal situation is rarely achieved due to differential raft settlement, differential concrete shortening, and construction tolerances. Structural movement creates several problems for correct set-out of control at a particular instant in time the surveyor needs to know exactly how much the building is offset from its design position and at the same time he must know the precise position at the instrument location. Construction vibrations in the building and building movement further complicate this situation, making it very difficult, if not impossible, to keep an instrument levelled up. While constructing vertical member between slabs they are in plumb the verticality is an issue when the slab is been casted at that time we cannot locate the centre point hence there is a need to find survey method to overcome this.

II. INTEGRATION OF ENGINEERING GEODESY PROCESSES INTO CONSTRUCTION PROCESSES

In buildings erection a potential increase in quality of construction can be achieved through an optimized interface and better integration of the engineering geodesy processes. Particularly different tolerance specifications and accuracy requirements within the interdisciplinary interface between mechanical engineering and construction can lead to considerable time and cost problems e.g. this could be the case, if the elevator shaft machinery has to be changed and adopted to match the shaft geometry resulting from concrete works. To prevent such inadequacy engineering geodesy is normally involved in the whole process of building construction. The interaction between geodetic and construction processes takes place at different stages of construction works in recurring manner.

A Global Positioning System

GPS receiver is able to determine how far it is away from the satellite, and thus to position itself somewhere on a sphere with a known centre and radius when a second satellite is detected another sphere is calculated, and the locus of possible positions for the receiver becomes the circle of intersection between the two spheres. A third satellite provides another sphere, which will intersect this circle at just two points. One of these will typically lie many thousands of kilometres away from the surface of the earth; discarding this will give one possible position for the receiver. At this point, the principal error in the calculation is caused by the clock in the receiver (the satellites have atomic clocks, which are highly accurate). Because light travels at 300Mm/s, an error of just 1µs in the receiver's clock will cause an error of 300m in the calculated radii of all the spheres, and thus a large error in the calculated position. For this reason, a fourth satellite must be detected and a fourth sphere calculated the radii of all four spheres are then adjusted by an equal amount, such that they all touch at one single point. This point is taken as the position of the receiver, and the required adjustment in the radii (divided by the speed of light) is taken to be the receiver clock error.

One of the disadvantages in using GPS is the number of GPS instruments required to be employed simultaneously and the amount of time required to measure the readings at various positions. In this scenario, DGPS comes in very handy where with a limited number of DGPS employed, relevant readings can be comparatively taken in much lesser time and with better degree of accuracy. The factors which most affect the accuracy of a single high-quality GPS receiver are errors in the positions of the satellites, errors in the satellite clocks and the effects of the earth's atmosphere on the speed at which the satellite signals travel. If two such receivers are within, say, 10 km of each other, the effects of these factors will be virtually identical and the difference vector in their positions will be correct to within a decimetre or two. If the distance between the receivers is greater than this, the accuracy of a simple difference calculation is degraded by the fact that the two receivers will be observing the same satellites, but from somewhat different angles so that the positional and clock errors of the satellites will have slightly different effects on the calculated positions of the two receivers. [1]

B Differential Global Positional System

The difficulties mentioned above are overcome, however, by a more sophisticated form of post-processing which requires one of the receivers to be at a known position, and then effectively corrects the positions of the satellites using the data recorded by that receiver. Ultimately, the accuracy of DGPS is limited by the fact that signals to the two receivers are passing through different parts of the earth's atmosphere and will suffer different propagation effects. This constrains the overall accuracy of DGPS to about 2 mm for every kilometre of separation between the two receivers (i.e. 2 parts per million), up to the point where the two receivers can no longer see the same satellites. The measurement by using DGPS is done as shown in Fig 1. DGPS allows accurate positioning by considering such error components as satellite orbit error, satellite clock error, ionosphere and troposphere time delay as common errors, and eliminating them.

The final precision of DGPS is achieved by measuring the phase of the carrier wave onto which the P-code is modulated. The chipping rate of the P-code is 10.23 MHz, which means the bits in the signal are about 30 m apart. By contrast, the L1 carrier wave has a frequency of 1,575.42 MHz, and thus a wavelength of about 19 cm. Interpolation of the phase of the carrier signal will yield a differential positional accuracy of a few millimetres, provided it has been possible to use the P-code to obtain a result to within 19cm beforehand. If not, the carrier phase cannot be used because of the uncertain number of whole wavelengths between the satellite and the receiver. The attempt to determine the number of whole carrier wavelengths is called 'ambiguity resolution'. It is usually possible to resolve ambiguities when the receivers are up to 20 km apart, given a good GDOP and enough observation time and it is usually unwise to attempt it if the receivers are more than 30 km apart, because of the unknown differences in atmospheric delays along the two paths. Note, therefore, that the term 'DGPS' can imply a wide range of relative positioning accuracy, from about 2 mm up to 2dm or so. A final factor which is important at the top level of precision is 'multipath', i.e. the reception of signals which have not come directly from the satellite but which have bounced off (for instance) a nearby building; this can cause errors of up to half a metre in the calculated position of the receiver. For this reason, differential GPS stations should always be sited well away from buildings and large metal objects. In particular, differential GPS cannot be relied upon to produce accurate results in the middle of a construction site; it is much better practice to use DGPS to fix control stations around the edge of the site, and then to use the more conventional surveying methods within the site. [1]

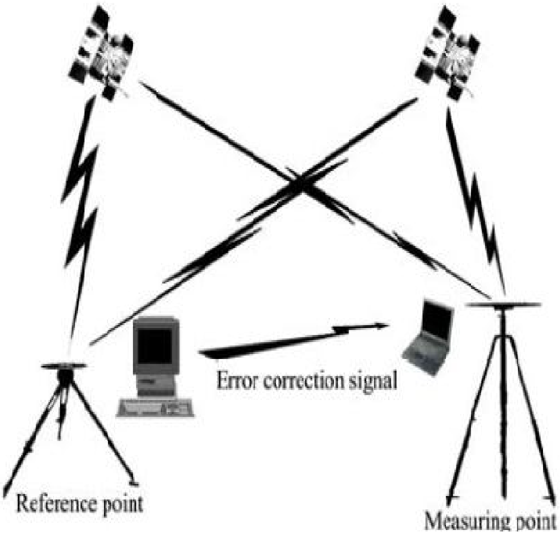

Fig. 1 Measurement by DGPS [4]

Testing for accuracy of readings using DGPS can be done as fallows In developing a lateral displacement monitoring system of high-rise buildings using GPS, we first identified the error range by the baseline distance between a base station and rover stations of DGPS. Also, we investigated the feasibility of the displacement measurement using DGPS by artificially generating displacements on the test model and comparing the GPS measured displacements against actual laser measurements. In general the impact of ionosphere and the signal delay through the atmospheric layer within 20 km range are considered as common error components. Here, for the sake of accurate observation we varied the baseline distance to 1km, 2.5 km, and 4 km and measured errors for 40 minutes at 1 Hz each as shown in Fig 2

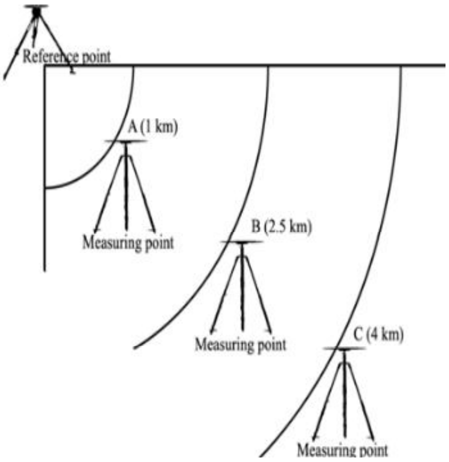

FIG. 2 TEST FOR ACCURACY [4]

III DATA COLLECTION

For performing practical on tall building a under construction building in Mumbai was selected. Three experimental points as rover are selected on floors at height above150meter and for base station site was selected as VJTI college on the terrace of civil Engg departmental Matunga, Mumbai. The Trimble Geo XT^{TM} handheld from the Geo Explorer 2008 series is used for collection ref Fig 3. First instrument is kept on base station and data is started to be collected and after that readings from rover are collected, per point 30mis readings were collected for practical.

Fig 3. Positioning equipment

A Analysis

For analysis pathfinder office software was used. These files will be saved as .ssf file format. Now differential correction process for cancelling out man-made and natural errors in the GPS signal. This requires the use of another GPS receiver set up on a position with known location. The receiver on the known location computes its location with the GPS satellite data and compares this position with the known value for its actual, known, position. This difference (hence differential) is the error in the transmitted GPS signal.

The differential value is then used for correcting, either in real-time or during post processing, the positions collected by other GPS receivers during the same time period, observing the same satellites. after that the corrected file in .cor format will be saved. Exporting that file into lat long coordinates so a Microsoft access MDB is a generic database format used by Microsoft access and other spreadsheet and database application. Spatial data is not a standard part of the MDB format coordinates are saved in the database file as attributes of each record. MDB files are in binary format.

1 Conversion of Lat and Long in to local cordinate system

The coordinates of GPS measurements is wgs-84 Cartesian coordinate system. Thus, in order to see the real directions of the displacements, all wgs-84 Cartesian coordinates have been transformed to a local top centric coordinate system because obtained directions in this system are incompatible with directions on the physical ground. As of the latest revision, the wags 84 datum surface is a pole-flattened spheroid. With major (transverse) radius a = 6378137m at the equator, and minor (conjugate) radius c = 6356752.314245m at the poles (a flattening of 21384685755km or?????=0.335% in relative terms).

Following formula was adopted for this conversion.

$A=6378137$
$C=6356752.3142$
$RN= a/ [1-(\sin^2 ø) (a^2-c^2)/a^2]^{1/2}$
$X= (RN+h) \cos ø \cos \lambda$
$Y= (RN+h) \cos ø \sin \lambda$
$Z= (RNc^2/a^2+h) \sin ø$
Where X, Y, Zis local coordinates
Ø, λ, h are longitude, latitude and height
RN is constant derived from longitude
A and c are constants

Table 1 Displacements in X, Y direction.

Reading No	Displacements in mm		PDOP value	HDOP value	Variation in Height mm	Accuracy
	X direction	Y direction				
49	840.122	204.19	3.68658805	3.342223883	6.612	Poor
109	6.74585855	6.74585855	3.41457963	3.056974888	6.532	Best
214	1323.603399	-192.2279702	4.7202158	4.508751869	-5.816	V. Poor

Similarly data from each floor can be calculated for three different point an can help in finalizing the bench mark at each level. The real advantage is that the surveyor is able to continue to set control even when the building has moved “off centre” confident that he will construct a straight concrete structure. The analysis isolates factors such as wind load, crane loads, and raft slab deformation and also relates movement to the construction sequence. Another advantage is that the surveyor is able to get precise positions at the top of the formwork without the need of sighting external control marks of building, which becomes increasingly difficult to observe as the building rises. The control surveys are completed in a shorter time, improving productivity, which is an important consideration when the building is moving or there are vibrations.

B Final result

Table 2 Day wise and point wise compilation of X and Y coordinates (in Meter)

	P1		P2		P3	
Coordinate	X	Y	X	Y	X	Y
Day1	1785365.23	615045.960	1785346.20	615034.543	1785319.53	615035.913
Day 2	1785364.27	615045.562	1785346.88	615033.560	1785321.64	615035.130
Day 3	1785369.58	615046.522	1785350.96	615035.242	1785323.69	615036.391

From the above table, it can be inferred that there is a variation in the longitudinal direction. It can be attributed to sway of the building owing to its height or other atmospheric factors like pull of sun etc. However, the readings of the latitude do not depict much variation as compared to the longitude.

IV CONCLUSIONS

GPS was firstly used for only navigational purpose, but with the advancement in technique, now it is possible to use it for tower verticality. This paper promotes the use of DGPS as tool for marking bench mark at each level of a high rise building so that we can ensure tower verticality. Verticality is always concern of planning engineers. The initial marking at each level is the key after that with that reference all other points are marked. While maintaining the progress of building construction this paper sees the potentials of DGPS as tool for marking in improving the quality of construction. However, the cost associated to this survey technique is more but in spite of this it can be used on site as it is time saving and better quality can be achieved. Accuracy depends on instrument used for marking as it is the main limitation. In future DGPS can be used from start of project so that good amount of data can be collected for validating.

REFERENCES

[1] Aylmer Johnson (2004)"Plane and geodetic surveying: the management of control networks" pg no 53-67.
[2] Chien-Ho Ko, Wei-Chieh Wang, and Jiun-De Kuo (2007) "Improving Formwork Engineering Using the Toyota Way" Journal of Engineering Project, and Production management, EPPM 13-27.
[3] Douglas HAYES, Ian R SPARKS, Joël VAN CRANENBROECK (2006) "Core Wall Survey Control System for High Rise Buildings" Shaping the Change Congress Munich, Germany.
[4] Hyo Seno Park ,Hong GyooShon, Soo Kim, Jae Hwan Park (2004) "Monitoring of structural behaviour of High rise building using GPS" CTBUH Conference 2004.
[5] Juergen Schweitzer, VitaliKochkine, Volker Schwieger and Fritz Berner.(2012) "Quality assurance in building construction, based on engineering geodesy processes" Construction Economics and Management II , Italy.
[6] Kijewski Correa, Kochly M and Stowell J (2004) "On the Emerging Role of GPS in Structural Health Monitoring" Conference proceeding of CTBUH seoul.
[7] Liu Xiaoyong, , Hu Yiming, Chen Daoyang, Wang Lili. (2012) " Safety control of hydraulic self-climbing formwork in south tower construction of Taizhou Bridge" 2012 International Symposium on Safety Science and Technology page no 248.
[8] SatheeshGopi, R.Sathikumar, N.Madhu (2006)"Advanced Surveying: Total Station, GIS and Remote Sensing" Pearson education publication.