Journal of King Saud University – Engineering Sciences (2011) **23**, 15–19

King Saud University

Journal of King Saud University – Engineering Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Comparative study of accuracy in distance measurement using: Optical and digital levels

Ismat M. Elhassan [a,*], **A.S. Ali** [b]

[a] *Department of Civil Engineering, KSU, Riyadh, Saudi Arabia*
[b] *Sudan Survey Department, Khartoum, Sudan*

Received 7 June 2009; accepted 25 October 2009
Available online 10 December 2010

KEYWORDS

Distance measurement;
Level;
Tacheometry;
Accuracy

Abstract In this research, three levels: the optical levels **NA2** and **N3** from Leica and the digital level **SDL30** from Sokkia were subjected to distance measurement accuracy test. A base line of length 100.000 m was first established and divided into 10 equal parts using geodetic means. This was then re-measured with each of the three test levels. The mean of the distance measured by each level was compared to the geodetically established length. The r.m.s.e. values for each distance measurement were computed as standard deviations from the mean. The results showed that the Leica **N3** and **NA2** optical levels were able to measure distances to an accuracy approaching 1/5000 and 1/4000, respectively, while the **SDL30** digital level achieved a distance accuracy figure of 1/10,000. The **SDL30**, therefore, gave accuracy values in distance measurement exceeding most known tacheometric methods. The results also indicate that in the absence of distance measuring instruments, levels can be used to measure distances of 100 m range to an accuracy within 1:4000.

1. Introduction

It is well known that leveling is a main branch in geomatic engineering. It can be defined as the process of measuring vertical distances between two or more ground points either directly or indirectly for the purpose of determining their elevations. The devices designed purposely to conduct leveling are called surveying levels. The classic spirit level has a line of sight that is set horizontal by a spirit level tube. Generally, surveying levels are classified into three main types according to the method of reading the leveling rod. These are optical levels, digital levels, and laser levels.

1.1. Optical levels

These are divided into many types in accordance with the technique of obtaining coincidence between the line of collimation and the horizontal plane through the instrument. Three main types of the optical level can be distinguished. These are: (a) dumpy level, where the sighting telescope is rigidly fixed to

* Corresponding author.
E-mail address: ismat@ksu.edu.sa (I.M. Elhassan).

Peer review under responsibility of King Saud University.
doi:10.1016/j.jksues.2010.10.001

Production and hosting by Elsevier

the standing axis of the instrument and can be rotated in just one direction that is about the standing axis. A system of three (ideally located) leveling screws and a spirit level are used to establish a vertical standing axis and, in consequence a horizontal line of sight to enable staff readings to be taken. (b) Tilting level, where the telescope is not rigidly fixed to the standing axis, but can be tilted a small amount in the vertical plane about a pivot situated below the eyepiece of the telescope. A circular (spot) level mounted on the tribrach is usually leveled independent of the main bubble. Many designs and models of titling levels exist. Some feature coincidence bubble readers in order to increase the accuracy of setting the main bubble. (c) Automatic level, where the horizontal line of sight is established by means of a combination of optical prisms and mirrors, supported by wires as in a pendulum, the arrangement being referred to as "compensator system" (Berry, 1977; Irvine, 1988). This reduces the need to set the instrument truly level, as with the previously mentioned levels.

1.2. Digital levels

The development of these levels became possible due to advances in microchip technology and image processing. The attributes of self-leveling instrumentation coupled with digital array photography and electronic image processing have generated a digital level that is very much close to being truly automatic. The instrument is operated in conjunction with a special bar-coded staff. This type of level has the same features as automatic levels, namely the eyepiece, the focusing knob, the compensator, the circular level bubble, tangent motion, the leveling screws and objective. This is in addition to the special features pertinent to it, i.e., a built-in solid-state "camera", a storage module, a microprocessor, a display register and a control panel.

Although the operation of digital levels varies in accordance with instrument type, model and make, the procedure is to set up and level the instrument and focus it on the bar-coded staff. The operator then processes the on-off switch on the control panel to receive instructions on the display screen.

The distance to the rod can also be determined and displayed by pressing the appropriate key on the control panel. When this "measurement without recording" mode is selected, the resulting readings could be recorded manually in a field book as in dumpy, tilting and automatic optical levels.

The other mode i.e. "measuring and recording" is, however, preferable in everyday survey practice. Herein, by appropriate manipulation of the keys of the control panel, the operator enters the number and elevation of the initial benchmark on which a back sight is to be taken. The software incorporated in the instrument will display, compute and store rod readings, heights of the instrument, elevations and distances to all or some of the turning points on the line of levels. The instrument is usually capable of taking several measurements on a rod held at a point, averaging the readings and computing standard deviation of rod height readings. For more refined work, enhanced or "extended" system accuracy can be chosen. At the end of the leveling job, the memory module can be removed and interfaced to a computer where the data are downloaded and processed to give hardcopy versions of the data and the least-squares-adjusted elevations of the points occupied by the rod.

1.3. Laser levels

These are devices that emit monochromatic, intense, coherent and directional radiation in the form of a rotating beam. Basically, a laser level consists of:

(a) A laser generating and leveling mechanism which projects a horizontal laser beam, and
(b) A photo-electric laser detector. This device can be moved up and down an ordinary leveling staff to give rod readings relative to the horizontal laser plane.

Since all height measurements are related to the rotating laser beam, it is mandatory to ensure that the plane created by this beam is horizontal. In practice, this is achieved by one of three methods: either by manually using tubular bubbles and instrument foot-screws as in dumpy and tilting levels, by utilizing optical compensator system as in automatic optical levels or by using some sort of an electronically-controlled self-leveling servomotors.

Most of the laser levels recently introduced in the surveying market have either optical compensators or servomotors to achieve a horizontal laser beam.

2. Distance measurement with stadia tacheometry using levels

Distance measurement with a level is possible using the theory and techniques of stadia tacheometry. This technique uses a theodolite or level and a leveling staff. An advantage of this method is that no specialized equipment is required. It involves the use of the two short lines marked on the diaphragm of the majority of theodolite and level telescopes. These lines are called the stadia hairs or stadia lines, and are marked as in Fig. 1. The distance between the stadia hairs is fixed and is called the "stadia interval".

If observations are made to a leveling staff, the diaphragm hairs, when viewed through the instrument telescope, will appear to cover a certain length (S) of the staff, the value of S depending on the horizontal distance (D) between the instrument and staff (see Fig. 1) and is called "staff intercept". The basic principle of stadia tacheometry is shown simplified in Fig. 2.

Fig. 2 shows a vertically held leveling staff observed with a telescope of which the line of sight is inclined to the horizontal. According to the theory of tacheometry, the distance D is given by the equation:

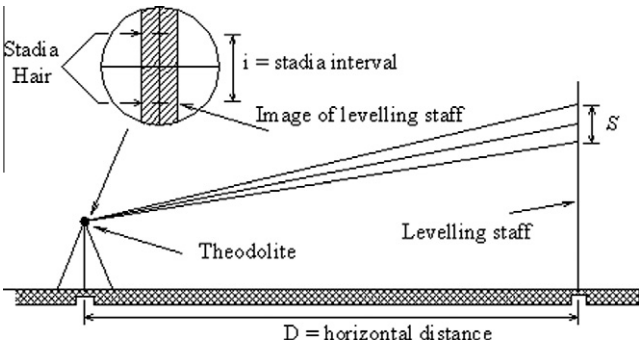

Figure 1 Stadia particulars.