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Propagation of Refraction Error on Different Textures in Geometric Levelling

DS Munasinghe[1], PGRNI Pussella[2], VGAC Wickramasinghe[3]

[1, 2]Faculty of Geomatics, Sabaragamuwa University of Sri Lanka, Sri Lanka

[3]Foresight Surveyors (Pvt) Ltd, Raaneevilla, Machangolhi, Nikagas Magu, 20164 Male' City, Republic of Maldives

Abstract: ***Geometric levelling is a process in which the difference of elevation between points on the earth surface is determined. In establishing higher accurate Bench Marks in 1st order for surveying purposes, refraction error would act as a significant factor in maintaining the accuracy of the task. Generally, refraction causes to small height differences and it is usually considered as the largest systematic error in levelling with in mm/cm levels. Refraction is largely a function of atmospheric pressure and temperature gradients and it would change the light path of the line of sight. Generally, temperature gradients vary with the material of the surface of running such as grass, gravel, cement and asphalt. Present study models the refraction error occurred in determining the height difference for different textures such as asphalt, grass and gravel in order to identify the optimal surface material and time period for high accurate levelling tasks in geometric levelling. Level measurements were taken for a 1.5 km distance with an Auto Level at pre scheduled different time periods on three different days. This task was carried out for different textures and the gradients of temperature were determined. The temperature values were measured 02 minutes after setting up the instrument. The refraction correction was calculated by using relevant formula. The minimum refraction error, ranged from – 0.000,04 to 0.000,06 mm, was recorded for grass surfaces and the study identified the time slot from 0800h to 1000h as the best time duration for a levelling task. Further, the study concludes that the levelling task should be done on grass surfaces in establishing 01st order bench marks.***

Keywords: Refraction, Geometric levelling, Texture pattern

1. Introduction

The refractive properties of the atmosphere have placed some limits on the accuracy of conventional geometric levelling. Geometric levelling is a slow procedure which is confined by the horizontal line of sight. Along inclined terrains, refraction influences on the measurements systematically, because the horizontal line of sight passes obliquely through different isothermal layers of air [1],[2]. Geometric levelling is an old method in geodetic surveying which is used to measure elevation differences between two points on the Earth's surface. This is considered as a reliable and precise method to determine the vertical displacements.

There are three types of errors that associated with any geometric levelling procedure and named them as instrumental errors, personal errors and errors due to natural causes [3]. The natural errors can be occurred due to refraction, curvature of the earth, high winds and sun [3]. Current study is mainly focused on the effect of refraction in geometric levelling task. Generally, levelling instrument provides a horizontal line of sight and the ray gets bent towards the earth due to the refraction in the earth's atmosphere [3]. The effect of refraction is, therefore, opposite to that of curvature and the point would appear higher than what they really situated are. Hence, the correction of refraction should always be added to the staff reading[3] (see figure 01).

The refraction curve is irregular because of varying atmospheric conditions and surface texture pattern of the earth [3]. However, carrying out of levelling task is very difficult on different surface texture patterns and it is sensitive to regular or irregular error models. Mostly, geometric levelling applications have been conducted to establish first order bench marks which would be used as control points in second and third order levelling processes. Thus, in order to obtain accurate results, additional parameters such as pressure, temperature and working times at the field are considered[4],[5].

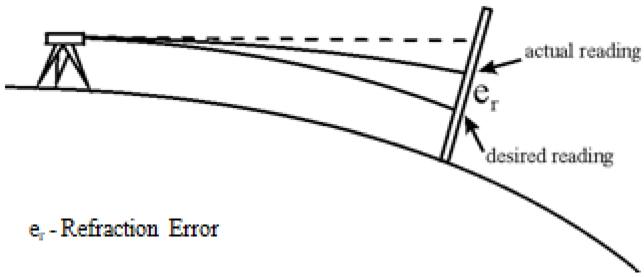
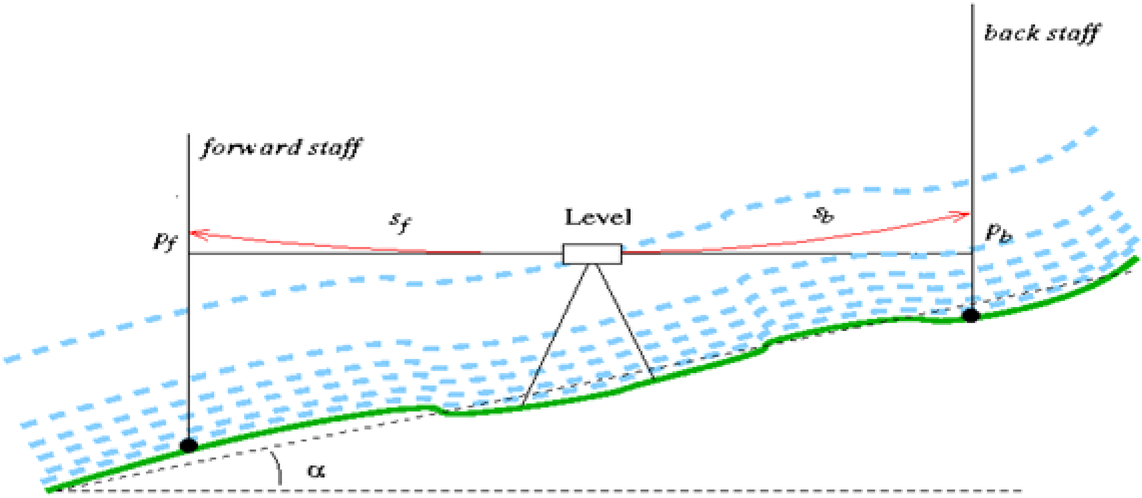


Figure 1: Refraction Error [6]

2. Research Problem

Refraction error is often regarded as one of the most serious problems in geometric levelling (figure 02). In most of levelling processes, the gradient of temperature, speed and direction of wind, barometric pressure and the temperature of the ground surface are measured to model the error pattern. However, temperature gradients of air would be utilized to compute, specially, the refraction error [7]. Temperature gradient varies for different surface materials such as grass, gravel, cement, and asphalt [7]. Therefore, it can be argued that, due to this variation of temperature of the surface material, the pattern for the refraction error can be changed. Hence, this study was focused to select the best materiel for geometric levelling processes to preserve the accuracy of the level readings.



Pf, Pb – Refraction Error
α- Slope
Figure 2: Refraction Error in Geometric Levelling

On sloping grounds (figure 02), the slanted distance between the back sight point and the instrument station and that to the fore sight station are different and, therefore, light rays undergo on different paths which are more or less curved, concave or convex, depending on the vertical temperature gradients being back and fore readings differentially affected [8]. Present study emphasizes the variation of refraction error on different surface materials especially in slope area.

3. Materials and Methods

A 1.5 km long survey line, as shown in figure 03, was chosen for this study. It is located in between 6˚42΄56΄N, 80˚ 47΄ 4″ E and 6˚42΄25΄N, 80˚ 47΄ 45″ E in Belibuloya, Rathnapura district, Sri Lanka (Figure 03). The elevation of this area varies from 591 m to 616 m. An automatic level with accuracy of 0.7 millimetres was used to determine the height differences and the Fly-Back method was used in the levelling process for different texture surfaces such as Asphalt, Grass, and Gravel. The observations were done during three days from 0800 h to 1000 h. To collect the data on temperature and atmospheric pressure, a thermometer with humidity meter and pressure meter were used. During the observation period, levelling staff was kept vertically using a level bubble and same instrument and the staff were used for the whole field process in order to minimize the instrumental errors. Fly-back level lines were run in between bench marks which were established temporarily. Temperature measurements were collected 02 minutes before setting the instrument to make sure that the system was sensing the temperature of the new environment. A 2 m height wooden rod was used to mount the humidity meter and pressure meter at different level such as 0.5 m and 1.5 m, because temperature varies highly above 2 m from the surface level. Figure 04 illustrates the overall procedure.

Figure 3: Experiment Area

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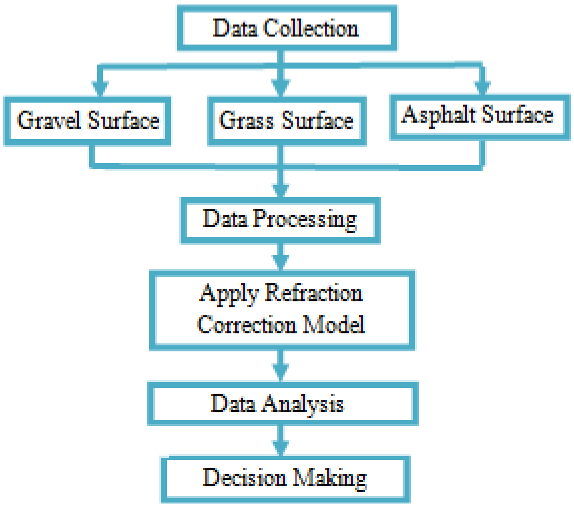

Figure 4: Refraction Error

In this current study, Kukkamaki's formulae were used to compute the refraction correction (Equation 01 and 02). According to this, refraction correction varies linearly with the height difference (Δh) and the measured temperature difference (Δt) and terrain slope is uniform in a single set-up of the instrument[7].

$$C_r = 10^{-5}.G.\left(\frac{s}{50}\right)^2.\ \Delta h.\ \Delta t \qquad \text{-- (Equation 01)}$$

In which,

$$G = \frac{5.94}{150^c - 50^c}\left[\frac{1}{c+1}(50^{c+1} - 150^{c+1}) + (150^c.100)\right] \text{(Equation 02)}$$

Where,

C_r - Refraction correction

S - Horizontal Distance between the instrument station and the levelling staff

Δh - Levelled height difference in scale division 0.5 mm

Δt - Measured temperature difference between 1.5m and 0.5 m above the ground surface

C - Exponent in Kukkamaki's model (In the study, it was used as - 0.1)

4. Results and Discussion

Figure 05 shows the effect of refraction in geometric levelling differences for different texture surfaces. It can be noticed that the refraction effect is highly correlated with the texture surface. Different distribution patterns of refraction correction indicate their uniqueness with the surface materials such as Gravel, Gravel and Asphalt. According to the figure, the minimum distribution of refraction correction (from 0.000,04 mm to 0.000,06 mm) has been recorded on grass surfaces. Further, gravel surfaces have been shown a remarkable variation on refraction correction and the error is well distributed along with Y-axis. When it is compared with gravel, asphalt surface has shown a better level of error with a limited variation along the Y-axis.

Figure 06 illustrates the refraction correction on different surface materials for different time periods. Accordingly, gravel surface has been shown a remarkable deviation from zero refraction value compared to other materials. The correction variation is considerable for different time intervals. This proves that, if a level line has going over a gravel surface, it has more refraction errors (-0.00004 to 0.00006 mm). Grass has shown a limited variation and it proves grass as the best surface for a levelling work compared to others and proves that the correction level is not depend on the time for grass.

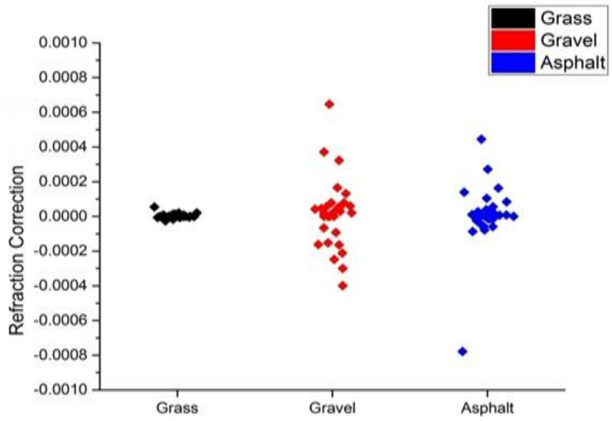

Figure 5: Variation of Refraction correction on different texture surfaces

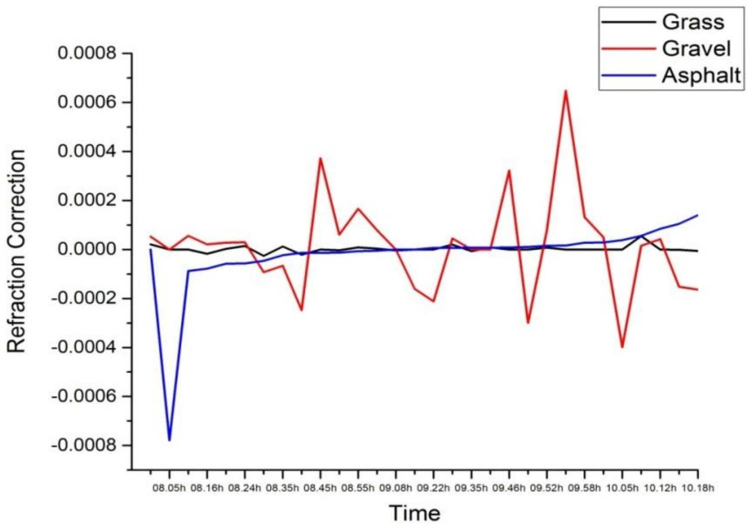

Figure 4: Variation of refraction correction for different time periods

5. Conclusion and Recommendation

From the results of the study, it can be concluded that refraction correction, though it is very small in size ranged from – 0.00004 mm to 0.00006 mm, should be taken into account importantly for level works where higher accuracies are required such as establishing bench marks. In order to minimize the refraction error, it should select lower heat emitted reflective surface texture materials. According to the results of this study, it can be noticed that temperature gradients vary with the surface materials. It can be affected due to the loss of static equilibrium of the atmosphere and the curvature of the path of light. And this would create changes in the temperature at different location depending on the height. This temperature variation factor on different surface materials is mainly influenced on the refraction. The results, further, shows that the refraction error can be minimized by running the level lines over grass surfaces. Therefore, it can be concluded that grass surfaces are better for precise works. In addition to that, the study identified the time duration from 0800 h to 1000h as the best time for running level lines of shorter distances over grass surfaces. Further, it can be recommended to expand this study by taking variation of pressure and humidity for long levelling traverses more than 100 km.

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