The Applicability Of Iphone 4s Compass In Measuring Discontinuities Azimuth

Mohd Faqrul Azwan Bin Mat Rapi [1], Rini Asnida Abdullah[1,a*]

[1]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

[a*]asnida@utm.my

Keywords: Benchmarking, building classification, safety performance.

Abstract. This study presents the applicability of iPhone 4s smartphone compass as an alternative device in measuring discontinuities azimuth. A build-in compass applications that easy to access and user friendly will make the process in obtaining data for discontinuities easier and practical. To evaluate and validate the precision and accuracy of the iPhone 4s clinometer compass, an existing conventional method for measuring the geometrical orientations which is Clar's compass were used in this study. This study took place in UTM Geotechnical Laboratory on a rock mass model under controlled environment in order to eliminate errors that may mislead the output of the data. The average difference between values measured using iPhone 4s clinometer compass and the Clar's compass in the laboratory test was 0.8° for dip and 2.8° for dip direction. The kinematic analysis was carried out using DIPS 6.0 software and the results showed that about 0.53% of wedge failure and 13.16% of oblique toppling that is encountered for the rock slope on the rock mass model. The results from kinematic analysis show a good agreement with the rock mass model observation. iPhone 4s clinometer compass offers geoscientist a fast, reliable, and convenient tool for geological investigation.

Introduction

Rock slope stability is dependent on the accurate survey of unstable areas. To accurately forecast the stability of a rock mass, the orientations and properties of discontinuities need to be evaluated in the field.Traditional surveying methods such as the detail line and window mapping methods require precise measurements using geological compasses and surveying equipment. To identify the characterization of rock slope stability using the traditional methods, it is often a very hazardous and time consuming work besides will lead to uncertainties errors by human. The investigation the rock slope stability that has potential of rock fall or sliding will put the surveyor in danger. Latest technology improvements have created a more advanced tools and methods that can resolve some of these problems.

Previous study

The rapid uptake of smartphones has led to a variety of smartphone applications and mobile technologies. Smartphones offer increased mobility and connectivity in comparison with desktop or laptop devices. These advantages enable the development of a wide range of software to assist users, which can utilize data from built-in sensors including cameras, microphones, and accelerometers. Built-in accelerometers and magnetometers are useful for measuring gravity and geomagnetic fields quickly, techniques which are useful for field investigations that require a large number of measurements.

Geological site investigation requires integrated processes from data acquisition to analysis. Rapid data acquisition is often required for immediate decision making in applications such as underground mining and tunnel construction. Conventional geological site investigation includes measurement using compass-clinometers, transfer of the measured data to a device such as a desktop or a laptop computer, and analysis of the data using specific software. This process requires exclusive devices for each step. Furthermore, the precision and accuracy of data depend on the skill level of the operator. Some time-consuming steps and processes that introduce inaccuracies can be improved by devices such as digital compass-clinometers. However, these devices are expensive and consequently are rarely used [7].

Several studies have examined geological applications for smartphones. One of the most recent examples discusses the GeoTools software [8]. GeoTools is an android-based smartphone application employing several of the capabilities of smartphones for supporting measurements of geological structures, photography, and note-taking. Other studies have recommended similar smartphone-based applications for field investigations, but these studies focused on measurement and recording utilities, and did not consider visualization or analysis of measured data [9][10].

Methodology

In order to achieve objective of the study, physical model of a rock mass were develop for this project [Figure 1]. The motivation behind this physical model is to have a joint surface that is not influenced by the weathering such as the joint planes situated at site. Other than that, joint physical model was manufactured to have a deliberate joint system that is difficult to establish at field. The subsequent joint model has a surface rock in even, vertical and slanted to be more like genuine rock incline. 24 points are representing difference surface of each blocks were recorded using the Clar's Compass and iPhone 4s Compass.

Figure 1: The Rock Mass Model

Dip and Dip Direction MeasurementThe Clar compass was used for the measurements of the dip and dip direction of the rock discontinuities orientation. Figure 2 shows the Clar compass that has been used.

Holding the compass at waist-height, the user looks down into the mirror and lines up the target, needle, and guide line that is on the mirror. Once all three are lined up and the compass is level, the reading for that azimuth can be made [1].

Figure 2: Measure dip angle and dip direction using Clar's Compass

For iPhone 4s clinometer compass, upon running the clinometer compass application iPhone 4s compass will appears notification if detects any interference that usually caused by magnetic field or an electronic device like a cell phone or stereo. To calibrate the iPhone compass, users just need to tilt the screen for the red ball roll around the circle as shown in figure 3. It is advice to tilt the phone after 3 to 4 readings were taken just to avoid magnetic field interruption that can cause errors in data collection. For the clinometer calibration, the device needs to be put on the levelled surface. Tapping onto the screen to calibrate the readings until it shows zero degree.

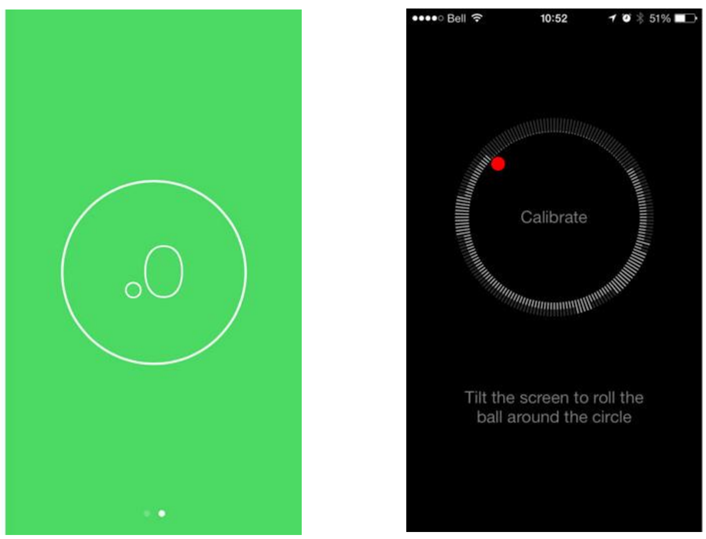


Figure 3: Calibrating iPhone 4s clinometer compass

ProcedureProcedure of measuring the dip direction and the dip angle of a plane using iPhone 4s Compass:

1) The phone is placed on the surface of the desired plane.
2) The position of iPhone 4s were held upside down as shown in figure 4
3) In order to ensure the compass are levelled, the cross marks on the iPhone 4s compass must lies in the origin line. The dip direction was recorded.
4) Slide the iPhone 4s compass to the next page that shows the clinometer application.

5) The reading of the clinometer was recorded as the dip angle.

Figure 4: Measure dip direction using iPhone 4s clinometer compass

To support the result obtain for this study, a data from the previous research by [4] Mohamad Safuan (2015), which carried out on the same model was utilised, he used the close range photogrammetry were included in comparing the precision on different devices.

Data analysis

Joint Plane Orientation Readings

Joint orientation measurements were carried out on the physical model. A total of 26 points were observed by using Clar's Compass and iPhone 4S compass to perceive out the dip and dip direction of the slope from the physical model. On the other hand, Mohamad Safuan investigated the joint orientation based on dip and strike using close-range photogrammetry which involved taking images as much as possible so that it covered the whole physical model surfaces. Introducing the control point for the purpose of obtaining the reference coordinate was also required for this process.

Since the experiment perceive the dip and dip direction taking at different occasion, it is important to compare the data obtained from the iPhone 4s Compass readings with Clar's Compass and from PhotoModeler readings with Clar's Compass. In addition, characteristics such as accuracy of data, its practicality and viability in the field, and ease of processing and analysis of data must also be considered in verifying this alternative method.

In order to compare the accuracy of the data taken from both Clar's Compass and iPhone 4s Clinometer Compass, the data must be sort by comparing the both values obtained. For this study, the conventional method which is the Clar's Compass is assumed to be more reliable method and is taken as the base for the comparison. From the differences listed on the last two columns of Table 3 and Table 4, it shows that the iPhone 4s Clinometer Compass and PhotoModeler possess some deviation when used to measure the orientation of joints when compared with Clar's Compass. The conventional method is taken as reference for comparison and small variations were identified.

Table 1: Data from Clar's Compass

SECTION	DIP ANGLE	DIP
J1S1	NA	3^{o}
J1S2	348^{o}	88^{o}
J2S1	352^{o}	8^{o}
J3S1	NA	1^{o}
J3S2	349^{o}	90^{o}
J4S1	349^{o}	36^{o}
J5S1	NA	6^{o}
J5S2	339^{o}	88^{o}
J5S3	253^{o}	89^{o}
J6S1	NA	2^{o}
J6S2	358^{o}	90^{o}
J7S1	11^{o}	104^{o}
J7S2	358^{o}	14^{o}
J7S3	102^{o}	86^{o}
J9S1	315^{o}	38^{o}
J10S1	306^{o}	22^{o}
J11S1	46^{o}	96^{o}
J11S2	354^{o}	108^{o}
J12S1	358^{o}	76^{o}
J12S2	56^{o}	80^{o}
J13S1	337^{o}	90^{o}
J14S1	315^{o}	26^{o}
J15S1	284^{o}	26^{o}
J16S1	343^{o}	90^{o}

Table 2: Data from iPhone 4s Compass

SECTION	DIP ANGLE	DIP
J1S1	NA	3^{o}
J1S2	346^{o}	88^{o}
J2S1	353^{o}	8^{o}
J3S1	NA	2^{o}
J3S2	349^{o}	89^{o}
J4S1	354^{o}	36^{o}
J5S1	NA	5^{o}
J5S2	344^{o}	90^{o}
J5S3	255^{o}	88^{o}
J6S1	NA	3^{o}
J6S2	359^{o}	88^{o}
J7S1	18^{o}	102^{o}
J7S2	0^{o}	13^{o}
J7S3	108^{o}	85^{o}
J9S1	316^{o}	38^{o}
J10S1	307^{o}	22^{o}
J11S1	49^{o}	96^{o}
J11S2	358^{o}	106^{o}
J12S1	352^{o}	77^{o}
J12S2	59^{o}	80^{o}
J13S1	337^{o}	88^{o}
J14S1	314^{o}	26^{o}
J15S1	289^{o}	26^{o}
J16S1	344^{o}	89^{o}

Table 3: Comparison of the measured readings for joint rock mass physical model using Clar's Compass and iPhone 4s Clinometer Compass

	Clar's Compass		**iPhone 4s Clinometer Compass**		**Different**	
Section	**Dip Direction**	**Dip Angle**	**Dip Direction**	**Dip Angle**	**Dip Direction**	**Dip Angle**
J1S1	NA	3 ^{o}	NA	3 ^{o}	NA	0 ^{o}
J1S2	348 ^{o}	88 ^{o}	346 ^{o}	88 ^{o}	2 ^{o}	0 ^{o}
J2S1	352 ^{o}	8 ^{o}	353 ^{o}	8 ^{o}	1 ^{o}	0 ^{o}
J3S1	NA	1 ^{o}	NA	2 ^{o}	NA	1 ^{o}
J3S2	349 ^{o}	90 ^{o}	349 ^{o}	89 ^{o}	0 ^{o}	1 ^{o}
J4S1	349 ^{o}	36 ^{o}	354 ^{o}	36 ^{o}	5 ^{o}	0 ^{o}
J5S1	NA	6 ^{o}	NA	5 ^{o}	NA	1 ^{o}
J5S2	339 ^{o}	88 ^{o}	344 ^{o}	90 ^{o}	5 ^{o}	2 ^{o}
J5S3	253 ^{o}	89 ^{o}	255 ^{o}	88 ^{o}	2 ^{o}	1 ^{o}
J6S1	NA	2 ^{o}	NA	3 ^{o}	NA	1 ^{o}
J6S2	358 ^{o}	90 ^{o}	359 ^{o}	88 ^{o}	1 ^{o}	2 ^{o}
J7S1	11 ^{o}	104 ^{o}	18 ^{o}	102 ^{o}	7 ^{o}	2 ^{o}
J7S2	358 ^{o}	14 ^{o}	0 ^{o}	13 ^{o}	2 ^{o}	1 ^{o}
J7S3	102 ^{o}	86 ^{o}	108 ^{o}	85 ^{o}	6 ^{o}	1 ^{o}
J9S1	315 ^{o}	38 ^{o}	316 ^{o}	38 ^{o}	1 ^{o}	0 ^{o}
J10S1	306 ^{o}	22 ^{o}	307 ^{o}	22 ^{o}	1 ^{o}	0 ^{o}
J11S1	46 ^{o}	96 ^{o}	49 ^{o}	96 ^{o}	3 ^{o}	0 ^{o}
J11S2	354 ^{o}	108 ^{o}	358 ^{o}	106 ^{o}	4 ^{o}	2 ^{o}
J12S1	358 ^{o}	76 ^{o}	352 ^{o}	77 ^{o}	6 ^{o}	1 ^{o}
J12S2	56 ^{o}	80 ^{o}	59 ^{o}	80 ^{o}	3 ^{o}	0 ^{o}
J13S1	337 ^{o}	90 ^{o}	337 ^{o}	88 ^{o}	0 ^{o}	2 ^{o}
J14S1	315 ^{o}	26 ^{o}	314 ^{o}	26 ^{o}	1 ^{o}	0 ^{o}
J15S1	284 ^{o}	26 ^{o}	289 ^{o}	26 ^{o}	5 ^{o}	0 ^{o}
J16S1	343 ^{o}	90 ^{o}	344 ^{o}	89 ^{o}	1 ^{o}	1 ^{o}

Table 4: Comparison of the measured readings for joint rock mass physical model using Clar's Compass and Closed-Range Photogrammetry

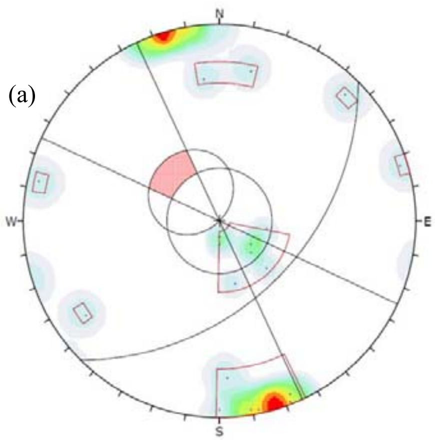
	Clar's Compass		Close-Range Photogrammetry		Different	
SECTION	**STRIKE**	**DIP**	**STRIKE**	**DIP**	**STRIKE**	**DIP**
J1S1	N30°W	5°	N31°W	3°	1°	2°
J1S2	N29°W	88°	N29°W	86°	0°	2°
J2S1	N25°W	10°	N28°W	5°	3°	5°
J3S1	N33°E	3°	N28°E	8°	4°	5°
J3S2	N30°W	90°	N29°W	86°	0°	4°
J4S1	N40°E	40°	N31°E	37°	5°	3°
J4S2	N70°W	72°	N65°W	77°	5°	5°
J5S1	N20°W	5°	N26°W	1°	6°	4°
J5S2	N25°W	89°	N26°W	84°	2°	5°
J5S3	N70°W	80°	N65°W	86°	6°	6°
J6S1	N31°W	89°	N28°W	84°	2°	5°
J6S2	N23°W	2°	N22°W	17°	1°	5°
J7S1	N13°E	78°	N13°E	82°	1°	4°
J7S2	N10°E	12°	N6°E	6°	4°	6°
J7S3	S70°E	86°	S64°E	85°	6°	1°
J8S1	N20°E	73°	N16°E	69°	4°	4°
J9S1	N30°W	40°	N28°W	35°	2°	5°
J10S1	N35°W	22°	N30°W	21°	5°	1°
J11S1	N26°E	82°	N20°E	81°	5°	1°
J11S2	N30°W	76°	N29°W	80°	0°	4°
J12S1	N27°W	79°	N27°W	74°	1°	5°
J12S2	N27°E	76°	N28°E	71°	1°	5°
J13S1	N40°W	90°	N34°W	87°	6°	3°
J14S1	N38°W	25°	N34°W	23°	4°	2°
J15S1	N30°W	22°	N29°W	17°	1°	5°
J16S1	N14°W	2°	N20°W	8°	6°	-6°

The average deviation of iPhone 4s clinometer compass compare to Clar's compass for dip direction is 2.8o and dip angle is 0.8o. In other hand, the average deviations for photo modular method with Clar's compass is 3.0o for dip direction and 4.0o for dip angle. Both of the results showing non-significant different which said to be accepted as the standard deviation for general orientation of fractures is the difference reading should be in the range of + or – 10 as described by [3].

Kinematic Analysis (DIPS 6.0)

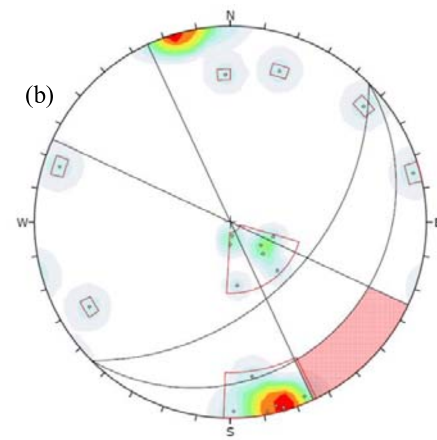
Additional meaning to the joint measurement, Kinematic analysis will be performed to investigate the probability of failure. Since the results obtained by comparing the reading taken from Clar's Compass and iPhone 4s Clinometer Compass were slightly difference 0.8 o for dip angle and 2.8 o for dip direction, this will not shows a significant difference mode of failure. An iPhone 4s clinometer compass data were chosen to be analysed for kinematic analysis. Kinematic analysis has been performed in DIPS 6.0 software. By incorporating the slope and discontinuities data as in Table 2. Figure 5(a – d) shows the kinematic analyses for planar, wedge, direct toppling and flexural toppling respectively.

(a)



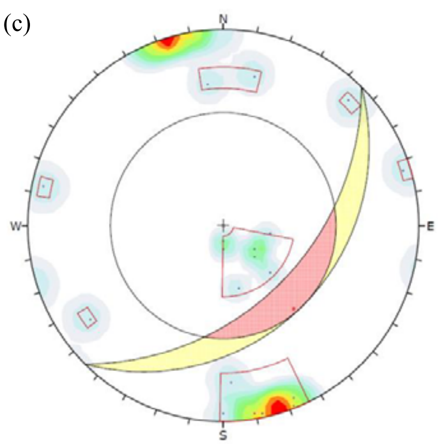
Kinematic Analysis	Planar Sliding		
Slope Dip	45		
Slope Dip Direction	135		
Friction Angle	30°		
Lateral Limits	20°		
	Critical	Total	%
Planar Sliding (All)	0	20	0.00%

(b)



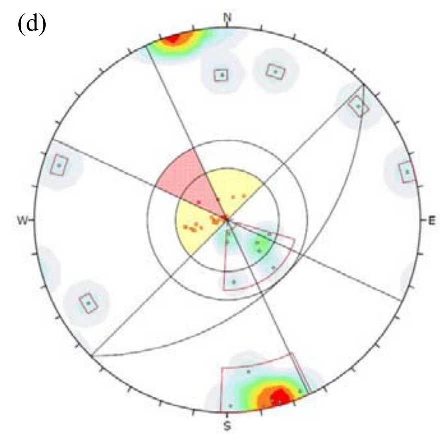
Kinematic Analysis	Flexural Toppling		
Slope Dip	45		
Slope Dip Direction	135		
Friction Angle	30°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	0	20	0.00%

(c)



Kinematic Analysis	Wedge Sliding		
Slope Dip	45		
Slope Dip Direction	135		
Friction Angle	30°		
	Critical	Total	%
Wedge Sliding	1	190	0.53%

(d)



Kinematic Analysis	Direct Toppling		
Slope Dip	45		
Slope Dip Direction	135		
Friction Angle	30°		
Lateral Limits	20°		
	Critical	Total	%
Direct Toppling (Intersection)	4	190	2.11%
Oblique Toppling (Intersection)	25	190	13.16%
Base Plane (All)	0	20	0.00%

Figure 5:Kinematic analyses results for (a) planar, (b) wedge, (c) flexural toppling and (d) direct toppling

Table 5 summarises the kinematic analysis results, it was found that there is no possibility for planar and flexural toppling failure to occur. The highest risks are due to direct toppling failure, with 15.27%. It indicates that 29 critical intersection out of total 190 mean set plane intersection.

Table 5: Summary of kinematic analysis results

Analysis	Percentage (%)	Critical of Joint Set
Planar	0	0
Wedge	0.53	1
Flexural Toppling	0	0
Direct Toppling	15.27	29

Conclusion

Based on the objectives of the research, the following conclusions can be made accordingly:

1. In comparing the method used for this study, iPhone 4s clinometer compass might be a handy device as a measuring tool in geological field as they are build-in sensors with advanced accelerometers and magnetometers technologies and also works with GPS. However, iPhone 4s clinometer compass are simply exposed to errors because of it sensitivity to surrounding environment. The device needs to be calibrate regularly in order for the errors to be wipe out. Compare to conventional device which is Clar's compass, the common errors that produced during data collection are usually due to the person who took the reading and record data.
2. The kinematic analysis was carried out using DIPS 6.0 software and the results showed that about 0.53% of wedge failure and 13.16% of oblique toppling that is encountered for the rock slope on the rock mass model. The results from kinematic analysis show a good agreement with the rock mass model observation.
3. Since the difference of the data recorded from two different methods are less than 10^{o}, iPhone 4s clinometer compass prove to be reliable and offers geoscientist an alternative method which are fast and convenient tool for geological investigation.

References

[22] Babaie, Hassan A., (2001). The Brunton® Compass and Geological Objects. Georgia Geological Society Guidebooks, 21:1, 55-60.

[23] Giani, G., & Giani, G. (1992). Problem Definition. In Rock slope stability analysis (p. 29). Rotterdam: A.A. Balkema Wyllie, D. C. (1999). Foundation on Rock, 2nd Edition. UK: Taylor and Francis.

[24] Hoek, E., & Bray, J. D. (1981). Rock slope engineering. CRC Press.

[25] Farny, N. J. (2012). Field methods of measuring discontinuities for rock slope stability analysis on price mountian, VA (Order No. 1529639). . (1220893420). Retrieved from https://vpn.utm.my/docview/1220893420?accountid=41678

[26] Breithaupt "COCLA" Stratum Compass(2016). [Online]. [Accessed 19 February 2016]. Available from world wide web : from http://westerntechnical.com/acatalog/Breithaupt_Kassel_COCLA_Compass.html

[27] DipAnalyst 2.0. (n.d.). Retrieved Feb 10, 2016, from http://www.dipanalyst.com/Kinematic Analysis/Kinematic Analysis.html

[28] Lee, S., Suh, J., & Park, H. D. (2013). Smart compass-clinometer: a smartphone application for easy and rapid geological site investigation. Computers & Geosciences, 61, 32-42.