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A DEVICE FOR MEASURING DRILL ROD AND DRILL HOLE ORIENTATIONS

by

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ABSTRACT

Accuracy in drilling holes for explosives can be of considerable importance in the excavation of hard rock. It is particularly important in presplit blasting where final results cannot be better than the drilling allows. Traditional methods, using angled templates and spirit level, have largely been replaced by bubble and pendulum inclinometers; transducer or optical alignment gauges are also becoming common. Most however have shortcomings when precise alignment or a measurement of orientation, rather than just a setting or measure of dip, is required. The report describes a new drill orientation device which does not have these shortcomings and is simple and versatile, having an accuracy adequate for most surface excavations where precision drilling is required and a repeatability well within the requirements for presplitting.

1. INTRODUCTION

1.1 Importance of drilling accuracy

Correct positioning of the explosive charge in a rock mass is essential for success when using controlled blasting techniques. Accuracy is particularly important in presplit blasting[1] to ensure that charges are correctly positioned at predetermined spacings on the design plane. This accuracy can be related to face lift, the higher the lift the greater the accuracy required. Since high lifts are generally preferable to multiple benching, tight tolerances are normally specified in contracts using presplitting. In mineral exploration, quarrying and site investigation drill holes should accurately follow the alignment intended. In underground rock excavation drill deviations of only a few degrees in relatively short holes can significantly reduce the speed of advance.

Inaccurate placement of charges usually leads to increased overbreak or underbreak. Where concrete structures are designed to abut against the final face increased concrete take or a requirement for secondary blasting can be expected to accompany inaccuracy. A poor appreciation of the symptoms of inaccurate drilling can lead to the decision to increase explosive charge weights to compensate for unsatisfactory results. This usually results in increased disturbance and instability in the design face and a corresponding increase in overbreak. All add to final costs.

In excavation techniques relying on precise placement of charges drilling accuracy is thus of vital importance; final results cannot be better than the drilling allows[2]. In surface rock excavation drilling for blasting is generally shallow, individual holes seldom exceeding 15m. Deviations in drill holes caused by adverse rock conditions over such relatively short lengths is seldom significant when using appropriate equipment in experienced hands. Final accuracy is thus primarily a function of precision in setting up. Emphasis must therefore be placed in ensuring an adequate level of accuracy in setting up.

The Drill Orientation Device (DOD) has been designed to allow simple and quick measurement of drill rod and drill hole orientation at a level of accuracy consistent with field requirements.

1.2 Existing technqiues

Traditional methods of aligning a drill rod relied on 'care and a good eye'[3]. Later methods used an angled template and a spirit level. Experienced drillers can achieve a surprising accuracy with these methods, particularly with vertical holes. With angled holes such subjective judgement cannot be relied upon and instrumental help is required.

Bubble or pendulum inclinometers, either hand held or rig mounted, have been used in an attempt to increase accuracy. The results of measurements of accuracy of presplit drill holes aligned using traditional techniques augmented by the occasional use of a small hand held bubble inclinometer are given in Table 1. The accuracy measurements were made on half-barrels exposed on a final presplit face. Some slight deviation due to near-face blast disturbance can therefore be expected.

TABLE 1

Accuracy of presplit drill holes aligned using traditional methods

(a) Dip

Locality	Rock	Max. Height of face	No. of measurements	Dip of drill holes (degrees)			
				Mean	S.D.	Range	Design
Cut 1 A9 Calvine	Banded gneiss	10 m	221	70.5	2.8	62–86	71.6 (3 in 1)
Cut 2 "	"	12 m	1242	71.2	3.1	60–90	"
Cut 3 "	"	12 m	51	73.5	4.6	64–82	"

(b) Azimuth

Locality	Rock	Max. height of face	No. of measurements	Azimuth of drill holes (degrees North)			
				Mean	S.D.	Range	Design
Cut 1 A9 Calvine	Banded gneiss	10 m	151	217	13.5	181–300	235
Cut 2 "	"	12 m	584	217	15.5	175–255	211–222 (curving face)
Cut 3 "	"	12 m	51	227	17.6	200–282	202

Transducer and optical alignment gauges have also been developed; these are usually rig mounted. All however have serious shortcomings whenever precise alignment or a measurement of orientation, rather than just an accurate setting of dip, is required.

1.3 Basic requirements

Drill rods and drill holes are essentially linear elements whose orientation can be defined by a dip (the vertical angle between the element and the horizontal) and an azimuth or dip direction (the clockwise angle between the vertical projection of the element on the horizontal plane and a reference direction). (Fig. 1). Instruments for measuring orientation of either drill rods or drill holes must therefore be capable of measuring both. Because of the close proximity of rig and drill steel directional measurements relying on magnetic compass readings cannot be used. Gyroscopic methods are inappropriate because of their high costs. Relative sighting methods must therefore be used to measure azimuth.

The accuracy must be adequate for the type of drilling being carried out. In presplit blasting this is related to final face height and a maximum tolerance is usually defined in terms of deviations from the theoretical design position[1]. In-plane and from-plane tolerances of 300 mm and 200 mm are normally specified. Accuracy requirements of dip and azimuth for differing face heights and the above tolerances are given in Table 2. For a face height of 20 m a dip accuracy of 0.57 degrees and an azimuth accuracy of 2.7 degrees are thus required. This level of accuracy is regarded as adequate for most near-surface drilling for excavation purposes.

TABLE 2

Accuracy requirements in presplit drilling

Lift Height (m)	Accuracy required *1	
	Dip (± °) *2	Azimuth (± °)*3
2	5.74	28.4
4	2.87	13.7
6	1.91	9.1
8	1.43	6.8
10	1.15	5.5
12	0.95	4.5
14	0.82	3.9
16	0.72	3.4
18	0.64	3.0
20	0.57	2.7
22	0.52	2.5
24	0.48	2.3
26	0.44	2.1
28	0.41	1.9
30	0.38	1.8

*1 In-plane and from-plane tolerances of 300 mm and 200 mm resp. specified.

*2 Assumes zero azimuth error

*3 Assumes zero dip error on drill hole.
Dipping at 71.6 degrees (3 in 1).

2. DESIGN

A Drill Orientation Device (DOD) designed for research purposes, manufactured in aluminium, and having a sighting alidade is shown in Plate 1. A simplified model designed for on-site use and having a prism viewer is shown in Plate 2. The DOD consists of a central body, containing two positioning 'V' blocks and a graduated template on which an alignment arm can rotate.

The standard 60-90-60 degree graduated dip scale is adequate for most surface drilling but can be extended to any lower angle if necessary. On the arm a two-direction bubble level and a right angled prism, with sighting lines, mounted parallel to the arm provide a simple and accurate means of alignment. The graduations on the template allow direct setting and measurement of dip from a position over or under the drill rod. A clamping cable, tightened by a simple screw and nut mechanism, allows the device to be held as required, loosely or firmly, on a drill rod. For the direct measurement of azimuth in a non-ferrous environment a compass can be attached to the mounting plate provided on the arm.

Several design variations have proved useful. For measuring the orientation of half-barrels a length of rigid tubing consistent with the accuracy of measurement required and the hole diameter can be attached to the 'V' blocks. In instances where a surveyed reference line is not provided, a sighting alidade instead of a prism can be used to give a relative measure of azimuth. Alternatively, the prism can be mounted at right angles to the arm for viewing along the drilling line.

3. ACCURACY

Estimates of repeatability* under field conditions were made by a single operator carrying out a number of measurements of dip and azimuth on a 3.8 cm diameter drill rod using the research model DOD. The sighting alidade was used for measuring relative azimuth. Results are given in Table 3.

TABLE 3

Repeatability of Dip and Azimuth readings using the research model DOD

(a) Dip

No. of measurements	Dip (degrees)			
	Mean	S.D.	Range	Repeatability (r)
201	75.52	0.13	75.0–75.9	0.37

(b) Azimuth

No. of measurements	Azimuth (degrees)			
	Mean	S.D.	Range	Repeatability (r)
201	85.6	0.29	84.5–87.0	0.82

Estimates of accuracy were also obtained under laboratory conditions. A number of measurements of orientation were made on a length of 5.0 cm diameter metal tubing using both research and simplified models of the DOD. The prism viewers were used for measuring relative azimuth. True dip and azimuth were calculated using trigonometric techniques. Results are given in Table 4.

The average deviation and repeatability of both dip and azimuth measurements indicate that the DOD has the capability of meeting the requirements of presplit drilling.

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* The statistical terminology follows the recommendations of BS 5497 Pt 1 1979 Precision of test methods.

TABLE 4

Estimates of accuracy of DOD measurements *

(a) Dip

DOD model	No. of measurements	Dip (degrees)		
		Average deviation	S.D.	Repeatability (r)
1. Research	9	+0.22	0.09	0.26
2. Simplified (1)	14	–0.01	0.08	0.23
3. Simplified (2)	15	+0.06	0.08	0.23

(b) Azimuth

DOD model	No. of measurements	Azimuth (degrees relative)		
		Average deviation	S.D.	Repeatability (r)
1. Research	9	–0.51	0.22	0.62
2. Simplified(1)	14	–0.02	0.34	0.96
3. Simplified(2)	15	–0.09	0.21	0.59

* Laboratory estimates derived from trigonometric calculations

4. APPLICATION

The DOD has applications wherever and whenever accurate near-surface drilling is required. It is a satisfactory, simple and cheap alternative to not only the traditional techniques of setting drill alignment but also to the more sophisticated and expensive transducer and optical systems presently available.

The results of measuring the accuracy of presplit drill holes aligned using the DOD only are given in Table 5. The accuracy measurements were performed using precision surveying techniques on drill hole traces exposed on the final face. A marked improvement over traditional methods is apparent. The inaccuracies still present are attributed mainly to errors other than alignment such as drill deviation with depth and near-face disturbance during blasting and mucking-out.

Not only is the DOD effective at setting initial drill alignment it can also be used for checking continuing alignment and for measuring drill rod and drill hole orientations. With minor adaption it can be used to measure the orientation of half-barrels on a presplit face.

Detailed instructions for use are given in the Appendix. Methods of setting azimuth in presplit drilling by surveying-in sighting points on reference lines located in front of, or behind, the design slope are shown in Fig. 2. Similar techniques can be used for the measurement of relative azimuth.

TABLE 5

Accuracy of presplit drill holes aligned using the DOD

(a) Dip

Locality	Rock	Max. height of face	No. of measurements	Dip of drill holes (degrees)			
				Mean	S.D.	Range	Design
A1 Penmanshiel	Interbedded Greywacke-shale	15 m	66	69.9	1.04	67.5 to 72.3	70.0

(b) Azimuth

Locality	Rock	Max. height of face	No. of measurements	Azimuth of drill holes (degrees relative)*			
				Mean	S.D.	Range	Design
A1 Penmanshiel	Interbedded Greywacke-shale	15 m	66	−8.68	2.5	−2.5 to −13.5	0

* Azimuth has been measured relative to a design face azimuth of zero degrees.

5. CONCLUSIONS

In contrast to current methods, including sophisticated transducer and optical systems made specifically for drill rig alignment, the DOD allows drill azimuth to be set and measured. The design makes it largely independent of the rig type and drill rod diameter and the basic model can be used on all normal diameter drill rods without modification. The accuracy is adequate for most surface excavations where precision drilling is required and the repeatability is considerably better than traditional techniques.

Mounting on the rig is not required and out of alignment errors between rig and rod are thus avoided – DOD measurements are made directly on the drill rod. The easy portability and absence of the need for permanent mounting enables the DOD to be removed from the harsh drilling environment between measurements thus preserving good condition and accuracy. Alignment can be easily checked at any time during drilling. A single DOD can thus quite easily serve a number of drilling rigs. In its simplicity, versatility and ability to measure azimuth the DOD is considered superior to existing drill rig alignment gauges and can be made for a fraction of the cost.

6. ACKNOWLEDGEMENTS

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The work for the report was carried out in the Scottish Branch of TRRL.

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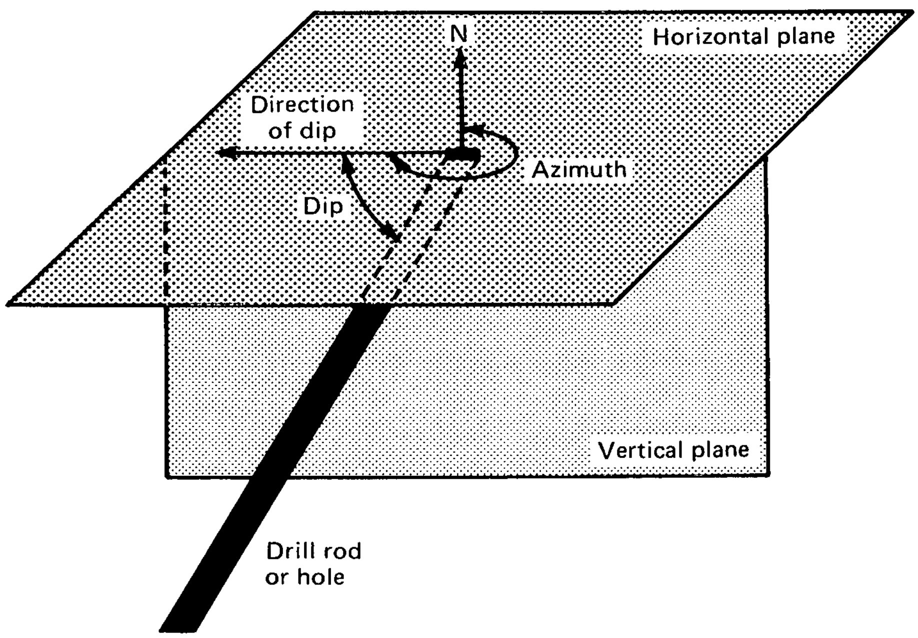
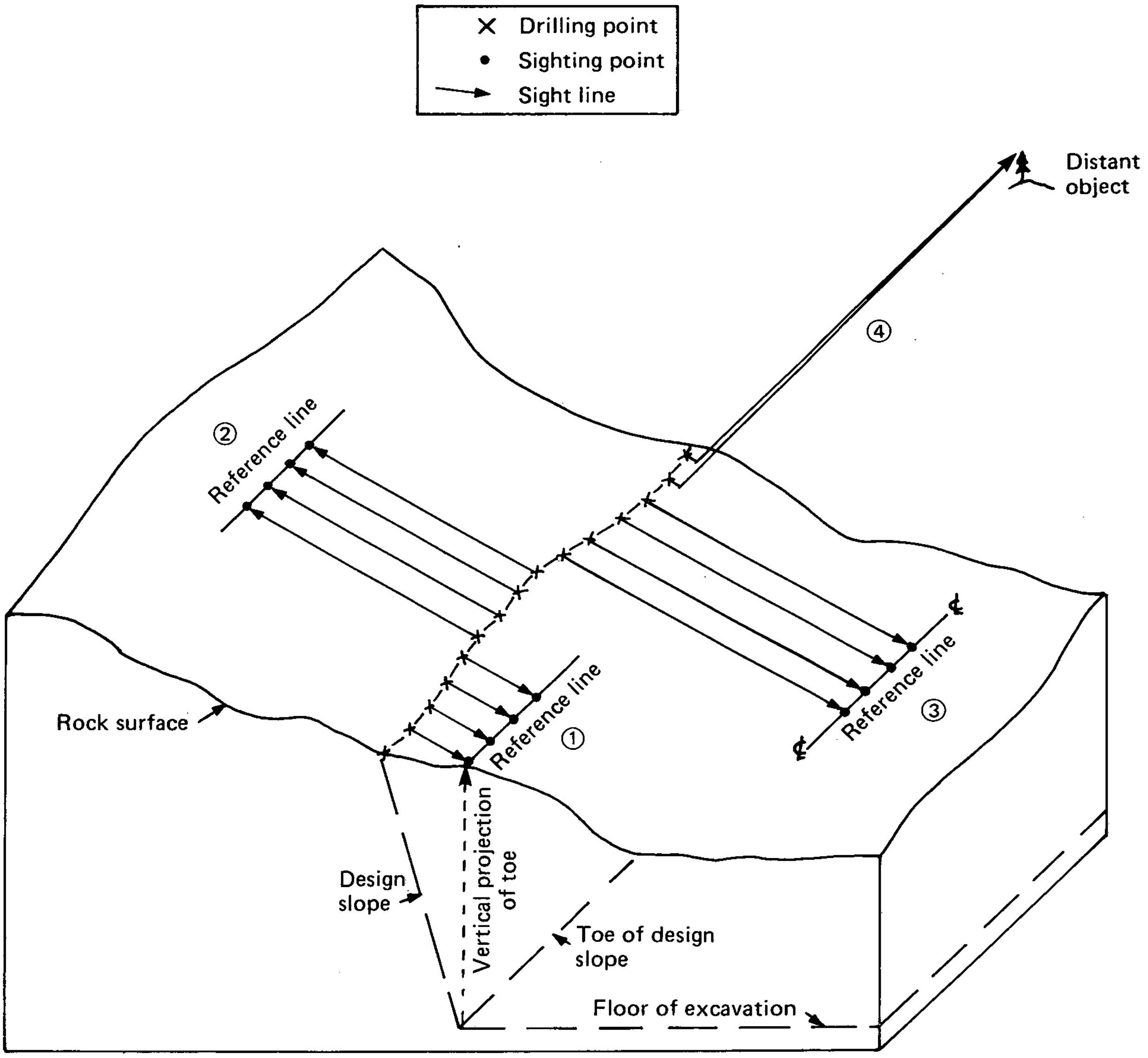


Fig. 1 Measurement of drill rod or drill hole orientation



METHODS

Using prism viewer parallel to arm
- ① Sighting points on surveyed-in reference line near the drilling line
- ② Sighting points on surveyed-in reference line at a distance behind the design slope
- ③ Sighting points on surveyed-in reference line at a distance in front of the design slope

Using sighting alidade or prism perpendicular to arm
- ④ Single distant sighting point

Fig. 2 Methods of setting azimuth using the D.O.D.

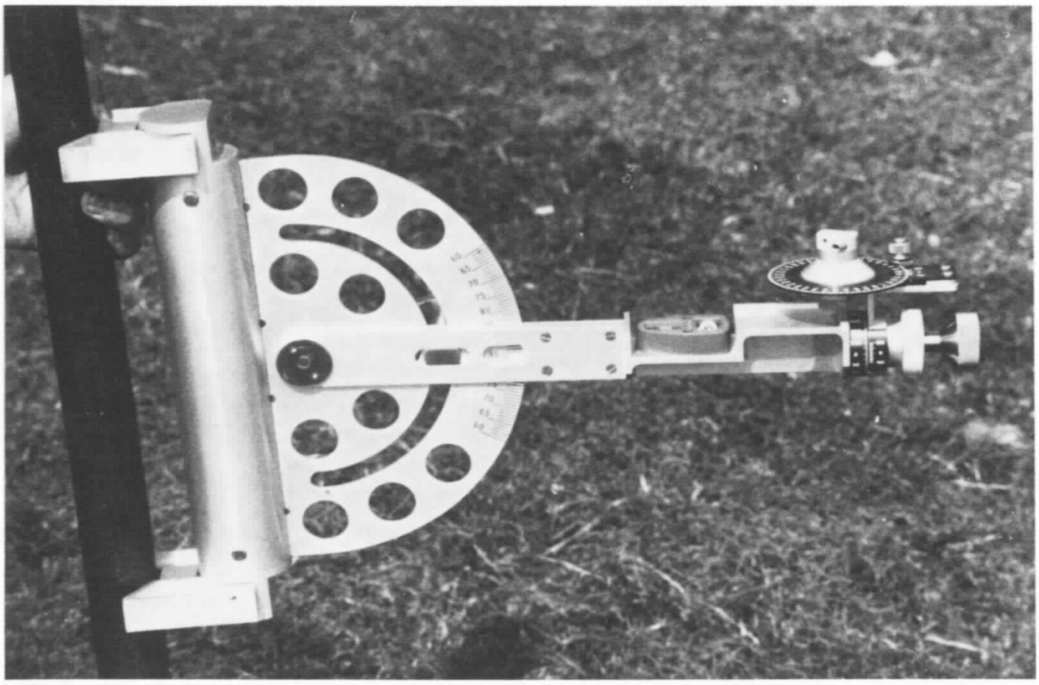


Plate 1 Research model DOD with sighting alidade

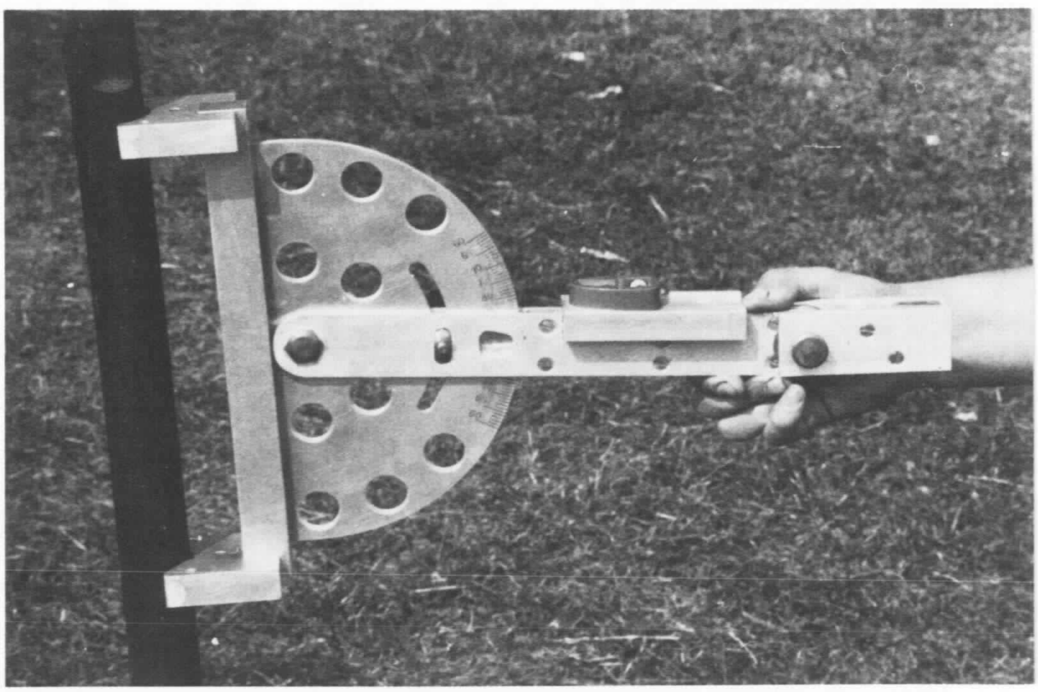


Plate 2 Simplified DOD with sighting prism

8. APPENDIX

THE DOD – INSTRUCTIONS FOR USE

8.1 Setting drill rod orientation

8.1.1 Requirements

1. Drill rod orientation device (DOD) with securing cable.
2. Position of each drill hole surveyed in and marked on rock surface.
3. A surveyed-in reference line parallel to the design slope and located either in front of or behind the drilling line. Sighting points for each of the boreholes are positioned where the directionof dip intersects this line.

8.1.2 Actions

1. Set DOD to the required dip, choosing upper or lower scales as required.
2. Lock the arm in position using the clamping screw.
3. Clean the drill rod where the DOD is to be positioned.
4. Attach the DOD to the drill rod in a position convenient for using the prism viewer.
5. Ensure that the V blocks are in contact with the drill steel. If the DOD is mounted on the head section of a down-the-hole hammer make sure that the V blocks are not positioned on a weld or joint.
6. Tighten the cable clamp so that slippage of the DOD under its own weight is prevented yet manual adjustment is still possible.
7. Align the drill rod by moving the rig head until each bubble level is zeroed and the prism sighting marks line up with the appropriate sighting point for the hole about to be drilled. With standard rig designs this procedure is likely to be an iterative one.
8. The drill is now correctly orientated. Slacken the securing cable and remove DOD before commencing drilling.

8.2 Orientation check during drilling

8.2.1 Requirements

1. Drill Orientation Device (DOD).
2. Surveyed in reference line with sighting points.

8.2.2 Actions

1. Check that the DOD is set to the correct angle.
2. Stop drilling but do not retract drill rod.
3. Clean rod if necessary and hold the DOD against the drill rod making sure that the V blocks seat properly.
4. Align the sighting marks on the prism with the appropriate sighting point; some rotation of the DOD on the drill rod will almost certainly be necessary.
5. Observe the bubble levels. If either, or both, of the bubbles are not central then re-alignment of the drill is required.
6. If re-alignment is required follow the procedures given in Section 8.1.2.7.
7. If both bubbles are in their zero position and the sighting marks line up with the sighting point then the drill rod is in the required orientation. Remove the DOD and recommence drilling.

Orientation checks are recommended at the following stages during drilling:-

(i) Immediately after the drill rod 'bites' into the rock.

(ii) Once the drill bit has penetrated 0.3 – 0.5 m into the rock.

Further checks are superfluous as rig adjustments after the first 0.5 m are not likely to prove successful.

8.3 Measurement of drill rod orientation

8.3.1 Requirements

1. Drill Orientation Device (DOD).
2. Surveyed-in reference line.

8.3.2 Actions

1. Clean the drill rod in the measurement area.
2. Slacken the clamping screw on the DOD arm.
3. Hold the DOD firmly against the drill rod making sure that both V blocks are in contact with the drill steel.
4. Zero both bubble levels by rotating the DOD around the drill rod. The V blocks must remain in contact with the rod throughout this operation.
5. Tighten the clamping screw.
6. View the reference line through the prism and mark the position of the sighting line intersection. Measure the offset to this position.
7. Remove the DOD and note the reading on the template. This is the dip of the drill rod.
8. Calculate the direction of dip (azimuth) from the measured offset on the reference line using simple trigonometry.

8.4 Measurement of drill hole orientation

8.4.1 Requirements

1. Drill Orientation Device (DOD).
2. Surveyed-in reference line.
3. A length of scaffolding or similar rigid metal tubing, perfectly straight and preferably lightweight. The diameter should be slightly smaller than that of the drill hole. A short cross bar should be clamped to the tubing approximately 1 m from one end.

8.4.2 Actions

1. Lower the longer portion of the tubing into the drill hole until it comes to rest on the cross bar.
2. Ensure that the tubing is aligned parallel to the drill hole by centralising it throughout its inserted length or adjusting it to lie down on side of the drill hole wall.
3. Attach DOD to the projecting portion of the tubing and secure loosely in place.
4. Zero both bubble levels by rotating the DOD around the tubing and adjusting the arm. Make sure that the V blocks remain in proper contact with the tubing throughout this procedure.
5. Tighten the securing cable screw.
6. View the reference line through the prism and mark the position of the sighting line intersection. Measure the offset to this position.

7. Remove the DOD from the tubing and note the template reading.
8. Remove the tubing from the drill hole.
9. The dip of the borehole is the template reading. The direction of dip or azimuth can be calculated from the measured offset on the reference line using simple trigonometry.

8.5 Measurement of the orientation of half-barrels on the final face

8.5.1 Requirements

1. Drill Orientation Device (DOD) with 'half-barrel' adaptor. This is a cylindrical fitting which can be attached across the two V blocks.
2. A surveyed-in reference line in front of the final face.

8.5.2 Actions

1. Clean off any loose dirt from the half-barrel in the area of measurement.
2. Free the DOD arm by slackening the clamping screw.
3. Place the DOD against the half-barrel making sure that the adaptor lies flush against one face.
4. Rotate the DOD and adjust the arm until both bubble levels are zeroed. Ensure that the adaptor remains tight against the rock throughout this operation.
5. Tighten the clamping screw.
6. View the reference line through the prism and mark the position of the sighting line intersection. Measure the offset to this position.
7. Remove DOD from the half-barrel and note the template reading. This is the dip of the original drill hole.
8. The azimuth of the original drill hole can be calculated from the measured offset intercept on the reference line by simple trigonometry.

NOTES

1. If the final face has been disturbed by blasting then movement of the rock blocks containing the half-barrels may have occurred. In such a case the measured orientation may differ substantially from the original orientation of the drill hole.

2. A compass can be used instead of the sighting prism in 8.4 and 8.5 above – providing that there are no materials nearby likely to influence readings. In such cases the azimuth can be read directly from a small compass accurately and securely mounted on the seating on the DOD arm. No surveyed-in reference line is therefore required. Use of this technique is however likely to reduce accuracy.

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