SOIL-NAIL HOLE MEASUREMENTS

GEO REPORT No. 245

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GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

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PREFACE

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R.K.S. Chan
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April 2009

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FOREWORD

As part of the development in enhancing the quality control of soil nailing works, a project involving the measurement of the geometry of soil-nail holes has been carried out. Field data on areas of concern during soil-nail installation including hole alignment (inclination and bearing) and hole diameter have been collected, with a view to identifying the possible variations and recommending any improvement measures to the existing design and construction practices of soil nailing.

The study was carried out by Ms B L S Lui under the supervision of Mr Y K Shiu initially and Dr R W M Cheung subsequently. Assistance from CGE/LPM1, CGE/LPM2 and CGE/LPM3 in facilitating the site measurement is gratefully acknowledged.

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ABSTRACT

As part of the soil nail related studies, a project about the as-built geometry of drillholes has been carried out. Field data on alignment (inclination and bearing) and diameter of the drillholes have been collected in the course of soil nail installation at four sites under the Landslip Preventive Measures (LPM) Programme. Similar measurements carried out by Ove Arup & Partners Hong Kong Ltd. at six sites under the LPM Programme have also been incorporated in the present study.

The alignment of the holes were measured by four different devices, namely Eastman Camera, Reflex Maxibor, Reflex Ezshot and RG Verticality Probe. The hole diameters were measured by another device called Borehole Caliper.

The measurements indicate that the measured and design values of hole inclination, bearing and diameter are subject to different degrees of disparity. In particular, the disparity in hole inclination increases as the length of hole increases. It is not uncommon that the deviation of hole inclination exceeds the current specification of ± 2°, and practically such specification is found to be not always achievable, particularly when long soil nails are required or there is presence of relatively less dense geological materials. Based on these site measurements, a few improvement measures to the existing design and construction practices of soil nailing are recommended.

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1. INTRODUCTION

As part of the development work in enhancing the quality control of soil-nail installation, a project of collecting field data of hole alignment (inclination and bearing) and diameter, and comparing them with the design values has been carried out.

The objective of the study is to better understand the possible extent of hole deviation and overbreak in soil-nail drilling works. The hole measurements were taken during the construction of soil nails at four slope sites under the Landslip Preventive Measures (LPM) Programme. Similar hole measurements taken by Ove Arup & Partners Hong Kong Ltd. at six other slope sites as part of the Consultancy Agreement No. CE15/2003 under the LPM Programme have also been included in the present study.

2. LOCAL PRACTICE OF HOLE DRILLING FOR SOIL NAILS

Soil nail construction involves the formation of holes followed by insertion of steel reinforcement, grouting and construction of soil-nail head typically in a recess on the slope surface. Ng et al (2004) provides the details of the general soil-nail construction practice in Hong Kong. The practice of drilling process is briefly discussed here for reference.

In Hong Kong, drilling of a soil-nail hole is commonly carried out by pneumatic percussive rigs (Plate 1) with air as the flushing medium. Temporary casing is normally not required in the typical saprolitic soils encountered in Hong Kong. In special circumstances, a more robust drilling rig, for example, the Odex type drilling equipment, is used for driving temporary casing into a hole concurrent with drilling to prevent the hole from collapsing in difficult ground conditions.

Soil nails are typically designed to incline downwards at 10° to 20° to the horizontal. The common practice to achieve the hole inclination is by setting the inclination of the drilling rig and drill rods using a protractor prior to drilling (Plate 2). To set the bearing of a soil nail as normal to the slope toe, the usual practice is by aligning the drilling rig to an approximately normal direction to the slope face. Typical lengths of soil nails range from less than 10 m to 20 m, although some may reach more than 20 m occasionally. The most common design diameters of soil-nail holes are 100 mm and 150 mm.

3. AREAS OF CONCERN

3.1 Hole Alignment

The current specification for soil-nail holes in Hong Kong permits a maximum deviation of ± 2° from the designed vertical and horizontal alignments (CEDD, 2006). During the course of drilling, a hole tends to bend down owing to the self-weight of drill bit and drill rod. The longer the hole, the larger the deviation may be. If obstructions, e.g. corestones, are encountered, the deviation may further increase. Soil nails, as well as raking drains, at close spacing may also intersect due to incorrect initial setting-out or excessive hole deviations during drilling. Cheung et al (2007) described two cases that soil nails installed on a slope were found damaged by the drilling works of raking drains located below them with insufficiently horizontal offset. Since soil nails are normally inclined downwards

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whereas raking drains are inclined upwards, it is possible that a soil nail at a higher level may crash with a raking drain below given that their horizontal clearance is often little. In the reported cases, the horizontal clearance between the soil nail and the raking drain below was only 300 mm.

GEO (2004a) pointed out that drilling for long soil nails, say with length exceeding 20 m, stands a higher chance of hitting groundwater tables and adverse geological features. This may lead to difficulties in construction such as hole collapses and excessive grout loss. Measurements on the hole alignment were therefore taken from holes with considerably long length exceeding 15 m to study the possible alignment deviation.

3.2 Hole Diameter

The current specification for soil nailing works in Hong Kong requires that the hole diameter shall not be smaller than the minimum diameter specified (CEDD, 2006). Discrepancy between the designed and the actual hole size may affect the pullout resistance.

4. REVIEW OF INTERNATIONAL PRACTICE

4.1 General

As part of the study, a review of overseas guidance on the control of hole alignment and diameter has been carried out. This includes the standards used in the United Kingdom (BSI, 2002; Phear et al, 2005), the United States of America (Byrne et al, 1998; Lazarte et al, 2003), France (French National Research Project, 1991), the Nordic countries including Norway, Sweden, Denmark, Finland and Iceland (Rogbeck et al, 2005) as well as Japan (Japan Highway Public Corporation, 1998). Their requirements are briefly outlined below and a summary of the requirements used in these countries and those in Hong Kong is also listed in Table 1.

4.2 The United Kingdom (UK)

Phear et al (2005) presents the guidance on the best practice for soil nailing works in the UK. It recommends a tolerance of orientation of the soil nail along its length to be ± 2°, the same as that recommended in the specification of Hong Kong. No allowable tolerance of diameter has been given in the guidelines.

BSI (2002) establishes general principles for the construction of special geotechnical works involving soil nailing. It specifies that the orientation at the head of the completed soil nail should be within ± 3° of the design alignment. It further states that hole deviation over the length of the hole should rarely exceed 1/30th of the hole length. Regarding hole diameter, BSI (2002) specifies that the drilling method used and the rate of drilling shall ensure that the nominal soil-nail diameter specified in the design is achieved along the entire length of the soil nail.

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4.3 The United States of America (USA)

Byrne et al (1998) provides guidance for soil nailing works for transportation construction practice in the USA. It suggests a tolerance of deviation of soil-nail inclination from design as ± 3°. No allowable tolerance of hole diameter has been specified. Lazarte et al (2003) also gives guidance for design and construction of soil-nail walls in highway engineering applications in the USA. It recommends that the soil-nail holes should be within the specified tolerances and points out that the angle of the drill mast is generally used for checking the angle of the hole.

4.4 France

French National Research Project (1991) summarizes the design and construction processes for soil nailing works in France. No allowable tolerance of inclination and diameter for soil nails has been given.

4.5 The Nordic Countries (Norway, Sweden, Denmark, Finland and Iceland)

Rogbeck et al (2005) gives guidelines on reinforced soil structures and soil nailing for Nordic countries in the northern Europe, including Denmark, Finland, Norway and Sweden. No allowable tolerance of inclination and diameter has been given in the guidelines. However, Rogbeck et al (2005) mentions that an allowable inclination tolerance of ± 3° is common for a soil nail.

4.6 Japan

Japan Highway Public Corporation (1998), which outlines the design and construction of soil nails in Japan, requires that the angle of all holes should be checked and should be within ± 2.5° of the design angle. For the hole diameter, it is required that the diameter of the bit used should be larger than the design diameter.

5. TEST SITES

Soil-nail hole measurements were taken in ten test sites, namely:

(a) slope No. 11SE-D/C201 at the branch of Cape Collinson Road,

(b) slope No. 11SW-B/C6 at Albany Road,

(c) slope No. 11SW-B/FR1 at Stubbs Road,

(d) slope No. 7SW-C/C115 at Wo Yi Hop Road,

(e) slope No. 11SE-C/C14 at Repulse Bay Road,

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(f) slope No. 11SW-D/FR401 at Stubbs Road,

(g) slope No. 11SE-C/FR22 at Tai Hang Road,

(h) slopes No. 11SW-A/C565 and FR230 at Pokfield Road, and

(i) slope No. 15NE-A/F24 at Tai Tam Road.

The locations of the test sites are illustrated on a geological map of Hong Kong as shown in Figure 1. Table 2 gives the details and geological conditions of the sites. In summary, soil of saprolites was encountered in all slopes, occasionally with fill and/or colluvium, except that the weathered tuff at slope C201 had a higher rock content.

To facilitate the investigation of the effect of hole length on alignment deviation, the ten sites were selected because the lengths of soil nails at these sites are relatively long, which range from 15 m to 22 m.

6. MEASUREMENTS OF HOLE ALIGNMENT

6.1 The Equipment

Four devices had been used in the measurement of hole alignment, namely Eastman Camera, Reflex Maxibor, Reflex Ezshot, and RG Verticality Probe. Their working principles are briefly discussed below.

(a) Eastman Camera

This device is a photographic survey tool (Plate 3) with a compass built in. Illuminated by a light source in the probe, the image of the compass which measures the dip and bearing of the hole is shot on a film disc (Plate 4). The device is a single-shot type and every measurement requires retrieval of the device from the hole back to the ground. The probe would not function properly in steel casing or in the presence of magnetic minerals which affect the compass in the probe. According to the manufacturer, the accuracy of the instrument is ± 20’ for inclination measurements and ± 0.5° for bearing measurements. In this study, four to five measurements at 5m-interval were taken using this device along a soil-nail hole. For the ease of use, the length of the Eastman Camera device is about 1.7 m. This instrument has long been used in the construction industry for directional surveying.

(b) Reflex Maxibor

Deviations in curvature of a hole are determined using video camera technology. The working principle of Reflex Maxibor is that an optical sensor in the device receives the reflected images by two reflector rings (Plate 5) and a vertical plane

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bubble upon illumination by a light source along the probe (Figure 2). The images will be passed to a microprocessor built in the probe for analysis by image processing techniques. Then displacements of the rings are calculated and therefore relative displacement of the dip and bearing of the hole can be determined. The maxibor itself is unable to measure the absolute dip and bearing of the holes. The absolute dip and bearing measurements along the hole are determined by running a survey of the initial position of the Maxibor. The whole Maxibor device is about 6 m-long. The manufacturer reports that the accuracy of the system for a 1000 m-long hole is ± 0.8 m. Usually readings were taken by the Maxibor at 1.5 m-intervals continuously along a soil-nail hole.

(c) Reflex Ezshot

Reflex Ezshot is similar to the Eastman Camera in that they both are single-shot hole survey tool equipped with a built-in compass. The difference is that Reflex Ezshot is an electronic device providing a digital readout (Figure 3). The device would not function properly in steel casing or in the presence of magnetic minerals which affect the compass. The manufacturer states that the accuracy of the instrument is ± 0.2° for inclination measurements and ± 0.5° for azimuth measurements. For the ease of use, the Reflex Ezshot device is about 0.9 m-long. In this study, usually four measurements at 5 m-intervals were taken using this device along a soil-nail hole.

(d) RG Verticality Probe

The RG Verticality Probe (Plate 6) contains a triaxial magnetometer to deduce the probe bearing relative to magnetic north and three accelerometers to measure inclination. The outputs from the transducers are processed by a downhole microprocessor to give continuous logs of borehole inclination and azimuth data at a real-time display on a computer. The probe would not function properly in steel casing or in the presence of magnetic minerals which affect the magnetometer. According to the manufacturer, the accuracy of the probe is ± 0.25° for inclination measurements and ± 2.5° for azimuth measurements. The device is about 1.65 m-long.

6.2 Inclination Measurements

6.2.1 The Results

Measurements of hole inclination were carried out on all the ten sites mentioned above. One or two devices were used in each site for the measurements. The average and maximum vertical deflections of the soil-nail holes against the design profiles on each site are

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presented. In order to check whether the soil-nail hole has bent down or not, the differences in inclinations between those measured along the soil-nail length and the one measured at the hole top has also been studied. Table 3 summarizes these values of each site. Detailed measurement data is contained in Appendix A. For the three sites, namely C14, FR22, and FR401, where both the devices, Eastman Camera and RG Verticality Probe, had been used, large deviations were noted in the inclination measurements taken by the two devices at slope C14 (See Table A5 in Appendix A).

Table 3 shows that the average difference between the measured and design inclinations at the bottom of the holes ranges from 0.8° to 8.6°, whereas the maximum difference ranges from 1.5° to 11°. This indicates that the average deviations of hole inclinations are greater than the specification of ± 2° from the design value. To investigate for the effect as a result of hole bending, the inclinations with respect to the initial readings at the top are also checked. It is shown in Table 3 that the average differences between hole inclinations at hole bottom and the initial readings at hole top in all sites range from 0.3° to 6°, with the maximum differences ranging from 0.5° to 9°.

Figure 4 shows the distribution of the differences between the measured and design inclinations at the hole bottom. It suggests that majority of the disparity falls below 5°, with the largest values largely coming from measurements on a particular site, i.e. slope C6. On this slope, a maximum hole deviation of 11° from design was recorded at the hole bottom, but the maximum hole deviation from initial readings is only 6°. This shows some initial hole inclinations at the beginning of the drilling were found to have deviated from the design inclination, e.g. the inclinations measured by Reflex Maxibor near the hole top of row N nails on this slope reached 29.5° at a maximum when compared to the designed inclination of 25° (Table A2). This highlights the significance in setting the correct initial design inclination of the drill rods before drilling for nails.

Obvious pattern of differences in inclinations can be seen on the four slope sites with greater number of measurements, i.e. slopes C201, C6, FR1 and C115. These slopes have nail lengths ranging from 15 m to 19 m. For slope C201 with 15 m- and 17 m-long nails, differences in inclinations were mainly between 0.5° to 2.5° downward, with occasional upward bending measurements probably owing to deposition of debris at hole base. No significant hole bending down was observed on this site. This may be due to the fact that the material on the slope belongs to grade III to IV material which might have minimised sagging during drilling. For the three slopes C6, FR1 and C115 with considerable amount of soil content when compared to slope C201, bending near the hole bottom was found to be significant, with the maximum difference between inclinations at hole bottom and that at hole top of 6° downward for slope C6, 2.9° downward for slope FR1 and 4° downward for slope C115.

No particular trend in the differences in inclinations can be observed from Figure 4 for the other six slopes, all with nail lengths of 22 m, probably owing to the relatively small number of measurements, i.e. one or two soil nail(s) selected on each slope.

The hole bending resulted in a vertical deflection of the hole away from the design profile. Table 3 shows the maximum downward deflections of the measured holes from their design profile. Figure 7 plots an inclination profile measured at a typical nail no. N7 tested on slope C6 using both Eastman Camera and Reflex Maxibor against its design profile.

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In short, apart from the possible uncertainty of the measuring devices, deviations from design values come from:

(1) initial hole deviations before drilling starts

(2) the hole bending when drilling proceeds

For (1), no particular trend can be observed as it may relate to workmanship and supervision. For (2), factors considered to have affected discrepancies are to be discussed in the following section.

6.2.2 The Analyses

An analysis of the vertical inclinations is carried out on three slope sites with the greatest number of hole inclination measurements in order to obtain representative results. The differences of inclinations of holes for advancements along the hole of every 5 m, 10 m, and the whole nail length are analysed. Plots of the differences of inclinations of the three slope sites are contained in Appendix B. Table 4 shows the general information of the three selected slopes as well as some statistical data of differences of inclinations of holes for various advancements along the holes measured at the three slopes.

Table 4 shows that, for each of the three sites, the inclinations of holes generally increase along the holes, but to different degrees. The average increases in inclination per 5 m length range from 0.31° and 1.53°. The rate of increase in inclination is found to be greater at slopes with relatively less dense geological material like colluvium and residual soil. Soil nails with a larger design hole diameter is also recorded with greater changes in inclinations.

The average increase in inclination per 10 m length is about twice of that per 5 m length. This indicates that the hole inclination increases monotonically downward at roughly a constant rate.

Table 4 also indicates the coefficient of variation (COV) (i.e. standard deviation/mean) of the differences of inclinations of holes of the three sites. This measures the variability of the measurements in relation to the mean values. Such variability may be due to errors encountered during the course of the measurements, probably including built-in error of the instruments, measuring error owing to hole irregularities or other random errors. The differences of inclinations measured at the hole bottom with respect to those at the top on slopes C6 and C115 lie, on average, within 22% to 33% of the means, which are 4.59° and 2.81° respectively. This implies that most hole inclination differences are greater than the 2° specification at these two slopes.

Based on the results of the analyses, the following factors are considered to have possibly affected discrepancies and create large vertical alignment deviations for soil nails:

(i) Length of the soil nail, since longer nails tend to have greater alignment devations between the hole bottom and the top,

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(ii) Presence of considerable amount of relatively less dense geological material, i.e. colluvium, residual soil and fill material, and

(iii) Size of drill bit, since a site using a bigger drill bit tends to record greater deflections.

However, from the measurement results obtained, it is not able to determine the relative contributions of these factors to the alignment deviations.

6.3 Bearing Measurements

6.3.1 The Results

Measurements of hole bearing had also been carried out at all the ten sites. The device(s) used in each site for measuring the hole bearing were the same for those measuring the hole inclinations. For each hole, the average and maximum differences between bearing measurements at depths and the initial reading of that hole are analysed to see the maximum horizontal deflection. The horizontally deflected value of the soil-nail hole from its initial alignment will also be studied. Table 5 summarizes these values of each site. Detailed measurement data is contained in Appendix A.

Hole bearing measurement results in Table 5 showed that the average hole bearings are between 0.2° and 3.6° with respect to the initial alignment, assuming the initial bearing reading as the design bearing, despite some extreme local maximum differences.

Obvious pattern of differences in bearings can be seen on the four slope sites with greater number of measurements and with nail lengths ranging from 15 m to 19 m, i.e. slopes C201, C6, FR1 and C115. For slopes C6 and FR1, differences in bearings were measured to be mainly between less than 1° to 6° (Tables A1 and A4 in Appendix A). Greater differences of hole bearings were obtained on slopes C201 and C115, ranging from 2° to 17.9°. Occasionally extreme differences greater than 20° were obtained, these two slopes. As mentioned in previous section, material on slope C201 belongs to grade III to IV tuff. Besides, hole inclination results obtained from these two slopes (Section 6.2) did not indicate large vertical deviations, so the chance of having large horizontal deviations on both slopes is not high. Such large deviations in hole bearings are considered not practical and have been ignored, since such large bearing deviation would have resulted in great difficulty during insertion of the soil-nail assembly, which had not actually occurred on site. The large deviations might be due to measuring errors and/or effects on the compass of the measuring device by anomalous magnetic field nearby.

The difference in bearing at certain depth of the hole with respect to the initial one resulted in a horizontal deflection of the hole away from its design profile. Table 6 shows the maximum horizontal deflections from design on each site as calculated from the bearing measurements. Figure 6 plots the orientation profile measured at a typical nail no. TN28-1 tested on slope FR22 using Eastman Camera against its design profile.

The bearing measurements of the holes on each slope are tabulated in Tables A1 to A10 in Appendix A.

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6.3.2 The Analyses

An analysis of the hole bearing measurements is carried out on three slope sites with the greatest number of hole inclination measurements, similar to those conducted for inclinations in Section 6.2.2. The differences of inclinations of holes for advancement along the hole of every 5 m, 10 m, and the whole nail length are analysed. Table 6 shows the general information of the three selected slopes and some statistical data of differences of hole bearings for various lengths of advancement along the holes measured at the three slopes. Plots of the differences of inclinations of the three slope sites are contained in Appendix C.

Table 6 shows that no particular trend for the means of differences of bearings of holes can be noted on the three slopes sites. The means tend to deviate around zero, except a comparatively larger value measured at slope C115, i.e. 5.12°. This means that the hole could deviate either to the left or to the right along the length of the hole.

Table 6 also indicates the coefficient of variation (COV) of the differences of hole bearings measured at the three sites. Very large variability are noted and they may be due to the measurements errors, probably including built-in error of the instruments and measurement error owing to hole irregularities.

7. MEASUREMENTS OF HOLE DIAMETER

7.1 The Equipment

The hole diameter is measured by a device called the Borehole Caliper. The caliper has three mechanically coupled and retractable arms. Opening and retracting of the motor-driven arms is controlled by a computer, so the probe can be inserted into the bottom of a hole with arms retracted before the measurement starts. Once opened, the spring-loaded arms will respond to variations of borehole diameter as the probe is raised up from hole bottom to the top in a continuous single run. A centralizer is used for centralizing the probe in the hole (Plate 7). The variation can be viewed at a real-time display on a computer (Plate 8).

The three legs of the caliper are coupled with each other and are not independent. At any instance if one of the legs is blocked by an obstacle and retreat, the other two legs will retreat together. The caliper will therefore measure the minimum hole "diameter" if the hole is not circular. The manufacturer reports the system accuracy is ± 6 mm. It can provide a continuous log of hole diameter when the probe is pulled out from the bottom up to the mouth of the hole at a typical speed of 5 m per minute.

7.2 The Measurements

Measurements of hole diameter were carried out at nine of the ten sites. Such measurement was not carried out on slope FR1 as the use of steel casings in the holes in this site hindered the advancement of the caliper along the hole. For the other nine sites with diameter measurement carried out, the diameter of drill bits used had been checked by site supervisory staff to be in accordance with the specifications.

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Table 7 shows a summary of the diameter measurements on the holes of the nine slope sites. The results showed that there were fluctuations in diameter measurements with respect to the design ones. Ignoring the local fluctuations, the diameter variations measured at the sites were found to vary between -28 % to +31 % from the design values. Plots of the variations of the diameter measurements on different sites against the design values are contained in Appendix D. Extreme diameter measurements recorded at the bottom and the top of the holes are normally ignored as this might have been due to the initial settling of the probe at the bottom or localized diameter variations near the hole top.

Table 7 also summarizes the maximum and minimum diameter readings as well as the range of variations. In particular, the maximum value recorded at a hole on slope C115 which was designed to have a diameter of 100 mm, was 209.7 mm. Ignoring these local fluctuations, the diameter variations measured at this site were found to vary between -28 % to +31 % from the design value as summarized in Table 76.

Slope C201 was found to be the slope measured with the smallest range of diameter variation among all sites. This would have been due to the presence of relatively strong Grade III to IV volcanic material along the hole, making drilling steady and hole size even. Much larger range of variations from the design diameter were encountered on slope C115 than those recorded in other sites. The enlarged diameter measured might have been due to hole collapse at weaker soil zone whereas the smaller diameter zone might have been where the debris was in place. However, as mentioned in Section 7.1, the coupled action between the three legs of the caliper render this device usually measuring the minimum hole diameter. The small hole diameter measured might have been due to this reason.

Of those six slopes with less number of measurements made on each site (Table 76), slope FR230 was measured to have a difference greater than 100 mm between the maximum diameter, i.e. 151 mm, and minimum one, i.e. 47 mm, along hole no. TN17/2. Ho et al (2007) suggested that the holes had experienced overbreaks and collapse at isolated locations probably associated with a high boulder content.

8. OTHER SOIL NAIL MEASUREMENTS

8.1 General

Other than the soil-nail hole measurements, information of soil nails during construction was also collected in order to see if any abnormality in drilling or grouting problems was found. Information collected included drilling time, grouting time and grout intake volume and has been tabulated in Tables E1 to E10 in Appendix E.

8.2 Drilling Time

For Slope C201, the time used for drilling each of the five 15-long and ten 17 m-long holes ranged from 40 to 96 minutes (Table E1), except two with longer drilling time, 137 and 140 minutes for holes CC15 and JJ7 respectively. Material on the slope belongs to grade III/IV material. Hole CC15 was found to result in hole collapse. The debris collapse would have piled up inside the bottom of the hole, probably resulting in an upward inclination of 1.75° at the hole bottom when comparing to the hole top (Table A1). No hole collapse

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was reported at hole JJ7. The long drilling time might have been due to the presence of grade III/IV material. Drilling in this material would have been steady. This explained the reason of no significant hold bending noted in the holes on this slope and the smallest diameter variations recorded.

For both Slopes C6 and FR1 using holes of 150 mm in diameter, the drilling time used for drilling each of the 18 m- and 19 m-long nails ranged from 28 to 45 minutes, with one reaching 52 minutes (Tables E2 and E3). No abnormality was noted in the drilling of the nails. The slope-forming material of these two slopes are mainly soil in nature, thus probably resulting in the shorter time used in drilling a nail in these two slopes.

The time used for drilling each of four 18 m-long holes on Slope C115 was found to be between 18 and 23 minutes (Table E4). The much faster drilling rate on this slope indicated a very high soil content of the slope-forming material. This may have explained the large variation of hole diameter recorded as mentioned in Section 7.2 above. No abnormality was noted in the drilling.

The time used for drilling each of the ten 22 m-long holes on the remaining six sites was found to range from 70 to 120 minutes, with two holes on slopes FR401 and F24 requiring 192 and 210 minutes respectively (Tables E9 and E10). Since the geology of these two sites comprises fill and completely decomposed material in general (Ho et al, 2007), the relatively long drilling time indicate probably the presence of boulders or corestones in the soil matrix. This may have explained the large difference of hole diameter recorded as mentioned in Section 7.2 above; in particular the drilling time of TN17/2, which was measured with large diameter difference, was 192 minutes.

8.3 <u>Grouting Time</u>

The grouting processes of all soil-nail holes in the ten sites were finished in one single goal, except a hole no. TN28/2 of slope FR22 which required two times of grouting (Table E6). The time used for grouting up each of those holes in one single goal was found to range from 7 to 15 minutes in general, with two holes requiring 20 and 21 minutes. Hole no. TN28/2 took 40 minutes in the first run of grouting and another 25 minutes in the second run, indicating significant grout loss in the hole. The cement grout used for filling the nail hole was made up of ordinary Portland cement and water in a water-cement ratio of not exceeding 0.45. The grouting time was found to be within the initial setting time of 45 minutes for cement paste using ordinary Portland cement (Neville and Brooks, 1987).

8.4 <u>Grout Volume</u>

The volume of grout used for grouting each soil-nail hole on the ten slopes was estimated by means of the conventional method of counting the number of bags of cement used in each grouting operation, as a bag of cement requires a predetermined volume of water for mixing to fulfill the required water cement ratio. The volume of grout used for grouting up a hole could therefore be estimated by counting the number of bags of cement used. The volume of grout left in the mixing tank after grouting and also the volume of grout in all pipings should be discounted.

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For slopes C6, FR1 and C115, the ratio of estimated grout volume used for grouting each of the soil-nail holes on these slopes to the calculated theoretical gross volume of that particular hole was found to range from 0.99 to 1.5 (Tables E2 to E4 of Appendix E). The ratio for Slope C201 was found to be higher, ranging from 1.06 to 3.17 (Table E1). GEO (2004b) defined an excessive grout take case as a situation where a nail cannot be fully grouted after injecting a volume of grout equal to five times the calculated gross volume of the hole, neglecting the volume of all cast-in components. Therefore no excessive grout take had been found in the four sites according to the definition. However, the greater ratio recorded at Slope C201 indicated possible hole collapse or presence of loose material or open rock joints.

In addition to the conventional method, the grout intake in the six sites with 22m-long nails was measured with the use of a Doppler Flow Meter (Ho et al, 2007), which comprises an ultrasonic sensor attached to the outlet pipe of a grout mixing tank. The sensor transmits a continuous high frequency sound through the pipe wall and into the grout flowing along the pipe. Sound is reflected back to the sensor from the particles or gas bubbles in the grout at an altered frequency, i.e. the Doppler effect. The sensor continuously measures this frequency shift to accurately measure flow rate of the grout.

The grout volumes used for grouting each of the ten holes on these six sites estimated from the conventional method and those determined using the flow meter are shown in Tables E5 to E10 of Appendix E. The grout volumes determined from the two methods are within a difference of 9%. The ratio of the estimated grout volume to the calculated theoretical gross volume was found to range from 0.68 to 1.57 in general, except that the ratio for hole no. TN28/2 with prolonged grouting time as mentioned in Section 8.3 was about 7.6. This indicate that no significant grout loss in these soil-nail holes except hole TN28/2. Diameter measurements of this hole as shown in Figure D4(b) do not show significant overbreak. The grout loss at hole TN28/2 may have been due to presence of loose material in the fill layer.

9. CONCLUSION

Soil-nail hole measurements in respect of alignment and diameter had been made at a number of sites. The results indicate that the measured and design values of hole inclination, bearing, and diameter are subject to different degrees of disparity. In particular, the disparity in hole inclination increases as the length of hole increases. It is probably not uncommon to have deviations of hole inclination from the design value exceeding the current specification of ± 2° and practically such specification is found to be not always achievable, in particular for long nails or in sites with the presence of relatively less dense geological materials (Section 6.2.2). The disparity in hole bearing does not show a trend to either the left or the right and may change course along the length of a hole.

10. RECOMMENDATIONS

Based on the results of the site measurements, a few improvement measures to the existing design and construction practices of soil nailing are recommended as follows:

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(a) Review the current specification for soil-nail holes of allowing a maximum deviation of ± 2° from design alignments.

(b) Review the need to strengthen checking of inclination of drill rods, e.g. the initial values for sensitive slope sites, etc.

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Table 1 - Comparison between Requirements on Soil Nail Hole Inclination and Diameter in Different Countries and in Hong Kong

Countries / Areas	References	Requirements on Soil Nail Hole Inclination	Requirements on Soil Nail Hole Diameter
United Kingdom	Soil Nailing - Best Practice Guidance (CIRIA C637)	± 2° from the orientation of the soil nail along its length	Not mentioned
	European Standard No. prEN 14490:2002	• Orientation at the head of the completed soil nail should be within ± 3° of the design alignment. • Borehole deviation over the length of the bore should rarely exceed 1/30 of the bore length.	Nominal nail diameter specified in the design is achieved along the entire length of the nail
United States	Manual for Design and Construction Monitoring of Soil Nail Walls	± 3° from the designed nail inclination	Not mentioned
	Geotechnical Engineering Circular No. 7 - Soil Nail Walls	Soil nail drillholes should be within the specification tolerances	Not mentioned
France	Recommendations Clouterre 1991	Not mentioned	Not mentioned
Nordic Countries	Nordic Guidelines for Reinforced Soils and Fills	No requirement given, but it is mentioned that an allowable inclination tolerance of ± 3° is common	Not mentioned
Japan	Design and Works Outlines on the Soil-Cutting Reinforcement Soil Works	± 2.5° from the design angle	Diameter of the bit used should be larger than the projected diameter in design
Hong Kong	General Specification for Civil Engineering Works	± 2° from the designed vertical and horizontal alignments	Drillhole diameter shall be the minimum diameter as specified

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Table 2 - Details and Geological Conditions of the Ten Slope Sites

Slope No.	Location	Geological Conditions	Measuring Devices used for Hole Alignment Measurement	No. of Holes for Hole Alignment Measurement	No. of Holes for Hole Diameter Measurement	Length of Holes for Measurements (m)
11SE-D/C201	Branch of Cape Collinson Road	HDV to MDV	Eastman Camera	20	10	15 and 17
11SW-B/C6	Albany Road	Colluvium, RS and CDG	Eastman Camera and Reflex Maxibor	8	5	18
11SW-B/FR1	Stubbs Road	Fill and CDG	Reflex Maxibor	7	Nil	19
7SW-C/C115	Wo Yi Hop Road	CDG	Reflex Ezshot	10	4	18
11SE-C/C14	Repulse Bay Road	Colluvium (1 - 2 m thick) and CDG	Eastman Camera and RG Verticality Probe	2	2	22
11SE-C/FR22	Tai Hang Road	Fill (≈ 3m thick) and CDG	Eastman Camera and RG Verticality Probe	2	2	22
11SW-A/C565	Pokfield Road	Fill/Colluvium (2 - 3 m thick) and CDV	Eastman Camera	1	1	22
11SW-A/FR230	Pokfield Road		Eastman Camera	1	1	22
11SW-D/FR401	Stubbs Road	Fill/Colluvium (≈ 3 m thick) and CDG	Eastman Camera	2	2	22
15NE-A/F24	Tai Tam Road	Fill (a thin layer) and CD Eutaxite	Eastman Camera and RG Verticality Probe	2	2	22

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Table 3 - Summary of Hole Inclination Measurements

Slope No.	No. of Holes for Hole Inclination Measurement	Difference between the Inclination measured at hole bottom and the Design Inclination (°)		Difference between the Inclination measured at hole bottom and the First Measured Inclination (°)		Maximum Downward Deflection from Design Value (m)
		Averages of all measurements	Maximum	Averages of all measurements	Maximum	
11SE-D/C201	20	1.4°	3.5°	1.1°	2.0°	0.9 m
11SW-B/C6	8	8.6°	11.0°	4.0 °	6.0°	2.4 m
11SW-B/FR1	7	2.3°	5.0°	2.1°	2.9°	1.0 m
7SW-C/C115	10	3.0°	4.5°	2.8°	4.0°	0.9 m
11SE-C/C14	2	0.8°	1.0°	0.3°	0.5°	0.4 m
11SE-C/FR22	2	2.8°	3.5°	1.5°	2.5°	0.8 m
11SW-A/C565	1	6.5°		6.0°		1.5 m
11SW-A/FR230	1	5.0°		5.0°		1.1 m
11SW-D/FR401	2	5.8°	8.0°	6.0°	9.0°	1.7 m
15NE-A/F24	2	0.8°	1.5°	0.5°	1.0°	0.4 m

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Table 4 - Means of Differences of Hole Inclinations for Various Advancements along the Holes at Three Selected Slopes

Slope No.	Geology	Design Hole Diameter (mm)	No. of Holes Measured	Differences of Inclinations every 5 m Advancement along the Hole		Differences of Inclinations every 10 m Advancement along the Hole		Differences of Inclinations at Hole Bottom with respect to those at Hole Top	
				Mean	Coefficient of Variance	Mean	Coefficient of Variance	Mean	Coefficient of Variance
11SE-D/C201	HDV to MDV	100	20	0.31°	228%	0.67°	133%	0.93°	94%
11SW-B/C6	Colluvium, RS and CDG	150	8	1.53°	77%	3.39°	34%	4.59°	22%
7SW-C/C115	CDG	100	10	0.93°	97%	2.07°	37%	2.81°	33%

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Table 5 - Summary of Hole Bearing Measurements

Slope No.	No. of Holes for Hole Bearing Measurement	Average Difference between Measured and the First Measured Bearing (°)	Maximum Horizontal Deflection from Design (m)
11SE-D/C201 *	20	2.8°	2.9 m
11SW-B/C6	8	1.2°	0.7 m
11SW-B/FR1	7	0.2°	0.1 m
7SW-C/C115 *	10	2.8°	2.0 m
11SE-C/C14	2	0.5°	0.3 m
11SE-C/FR22	2	1.4°	0.9 m
11SW-A/C565	1	0.6°	0.3 m
11SW-A/FR230	1	3.6°	1.6 m
11SW-D/FR401	2	2.7°	1.5 m
15NE-A/F24	2	1.3°	0.7 m

Note: (*) There are extreme bearing measurements values on these sites which were considered to be affected by anomalous magnetic field and had been ignored.

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Table 6 - Means of Differences of Hole Bearings of Drillholes for Various Advancements along the Holes at Three Selected Slopes

Slope No.	Geology	Design Hole Diameter (mm)	No. of Holes Measured	Differences of Bearings every 5 m Advancement along the Hole		Differences of Bearings every 10 m Advancement along the Hole		Differences of Bearings at Hole Bottom with respect to those at Hole Top	
				Mean	Coefficient of Variance	Mean	Coefficient of Variance	Mean	Coefficient of Variance
11SE-D/C201	HDV to MDV	100	20	-0.36°	1403%	-0.16°	4039%	-0.75°	661%
11SW-B/C6	Colluvium, RS and CDG	150	8	0.50°	316%	0.96°	193%	1.50°	160%
7SW-C/C115	CDG	100	10	1.24°	683%	5.12°	126%	2.55°	56%

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Table 7 - Summary of Hole Diameter Measurements

Slope No.	No. of Holes for Diameter Measurement	Design Diameter/Drill Bit Size (mm)	Max. Diameter Measured (mm)	Min. Diameter Measured (mm)	Range of Variations from the Design Value (ignoring locally max. or min. readings)	Average Diameter Measured (mm)
11SE-D/C201	10	100	151.7	79.9	-9 % to +26 %	106.3
11SW-B/C6	5	150	168.2 *	97.3	-21 % to +6 %	141.3
7SW-C/C115	4	100	209.7 *	61.7	-28 % to +31 %	116.2
11SE-C/C14	2	115	164.8	84.8	-14 % to +13 %	115.3
11SE-C/FR22	2	115	163.7	64.6	-20 % to +23 %	117.5
11SW-A/C565	1	115	119.6	87.7	-16 % to +4 %	111.2
11SW-A/FR230	1	115	122.6	88.2	-15 % to +4 %	108.1
11SW-D/FR401	2	120	150.5	47.1	-26 % to +10 %	107.5
15NE-A/F24	2	115	150.8	84.8	-15 % to +10 %	112.2
Note: (*) Extreme diameter fluctuations recorded at the top end of holes have been ignored.						

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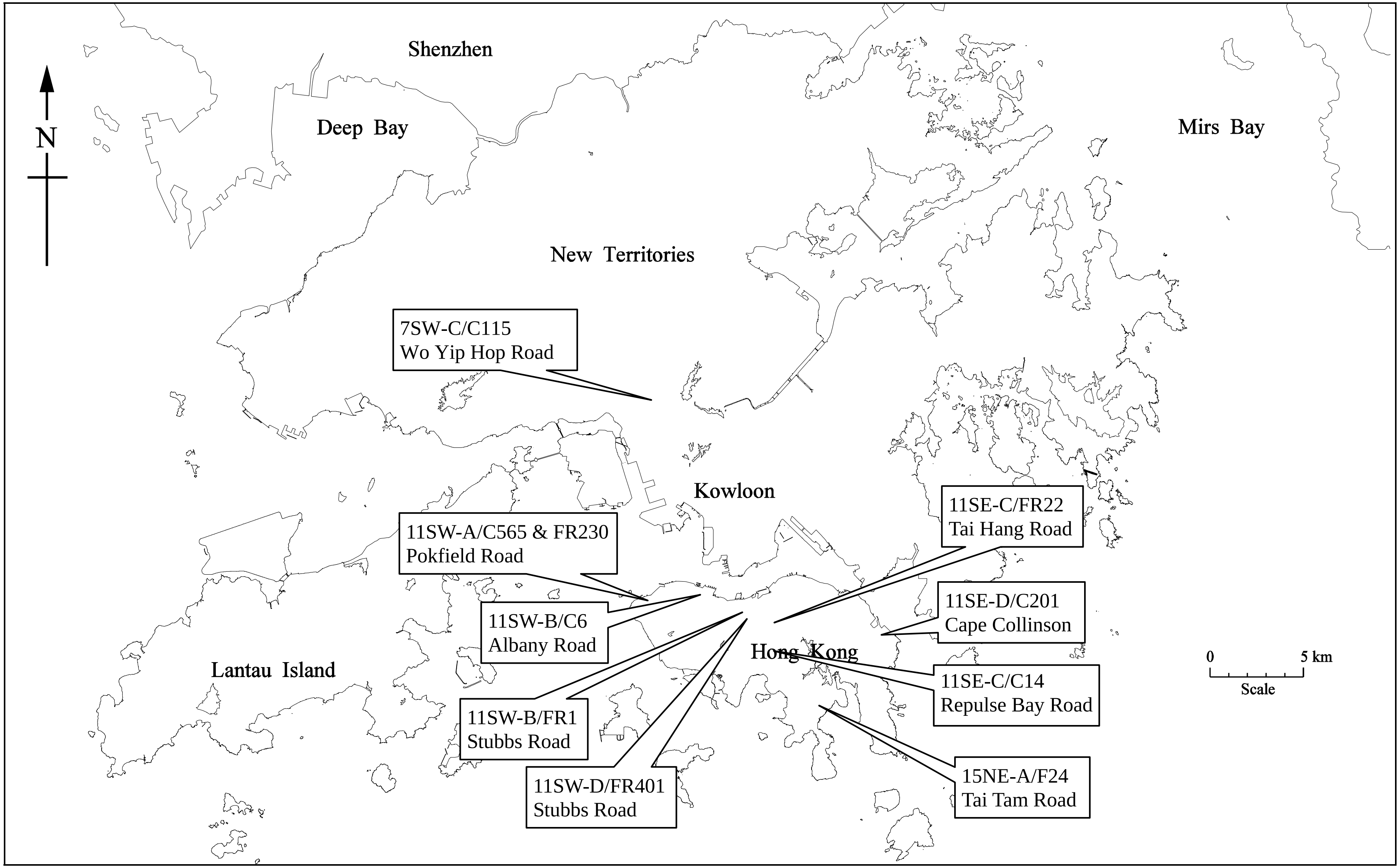

Figure 1 - Location of the Ten Sites

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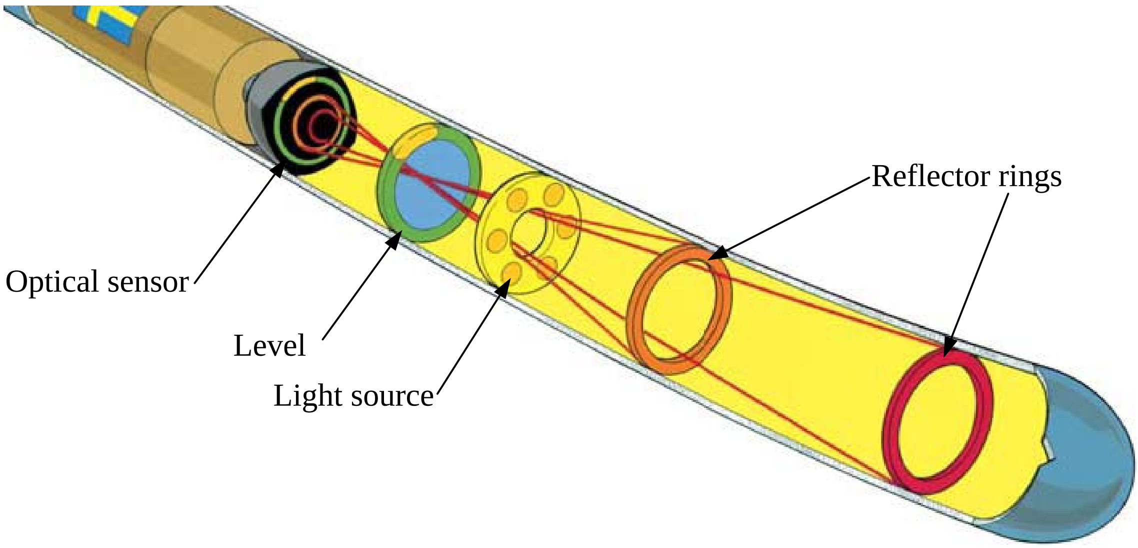

Note: Image downloaded from http://www.reflex.se

Figure 2 - Longitudinal Section of the Survey Probe of the Reflex Maxibor

Note: Image downloaded from http://www.reflex.se

Figure 3 - Survey Tool of the Reflex Ezshot

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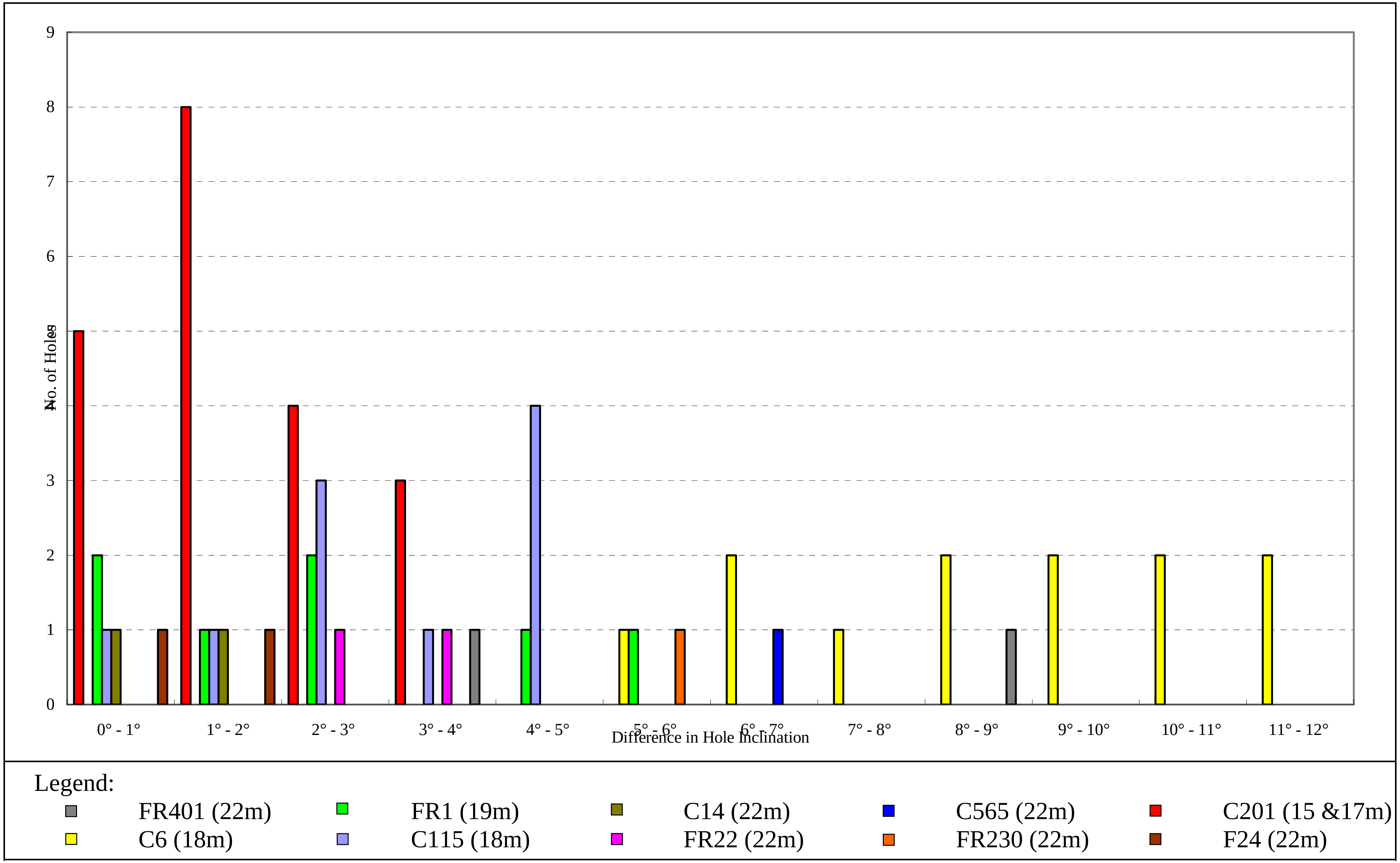

Figure 4 - Distribution of Differences between Hole Inclinations Measured at Hole Bottom of the Nails and the Design Inclinations of the Ten Slopes

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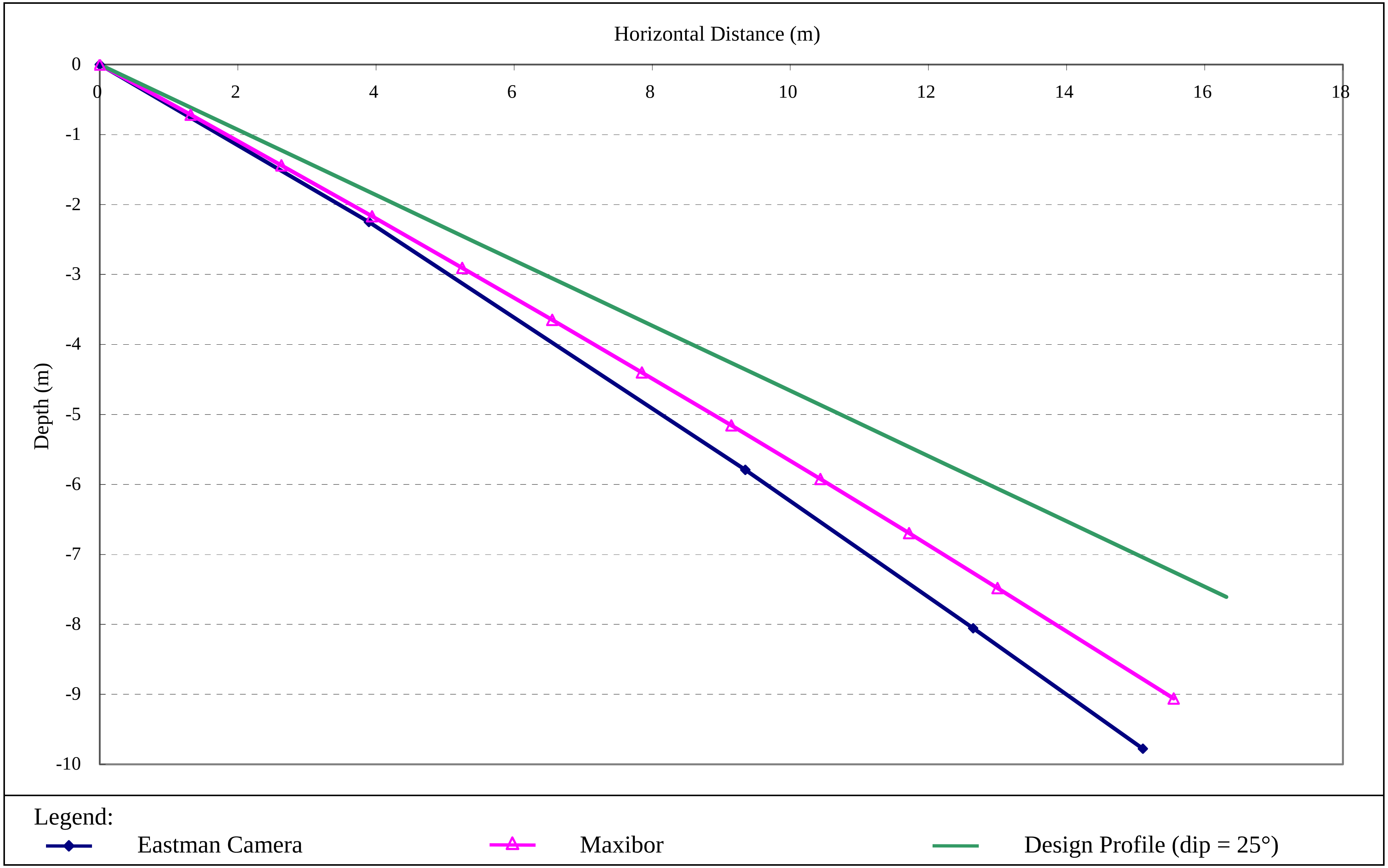

Figure 5 - Inclination Profile of a Typical Nail No. N7 on Slope C6 against the Design Profile

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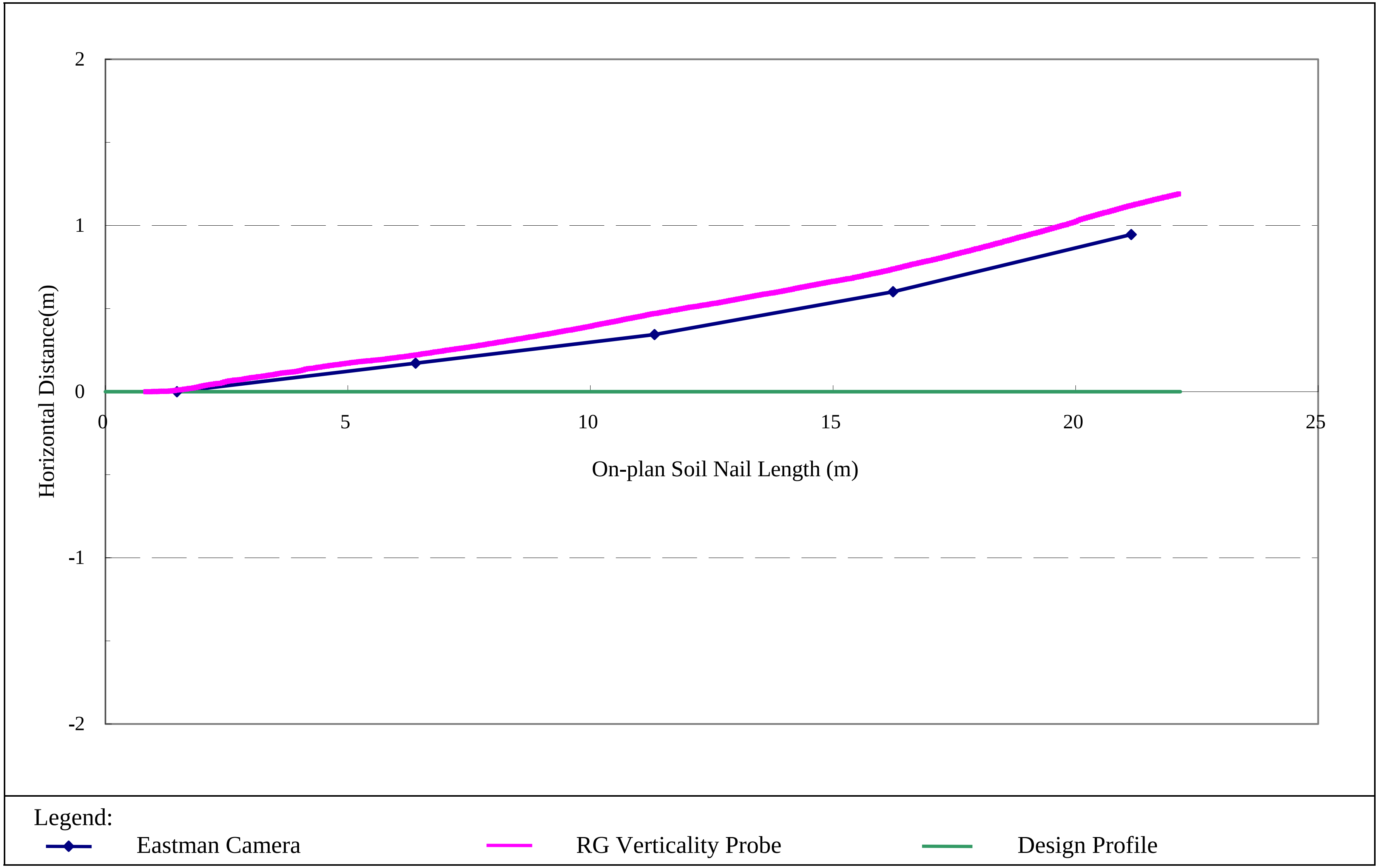

Figure 6 - On-plan Horizontal Deflection Profile of a Typical Nail No. TN28-1 on Slope FR22 against the Design Profile

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Plate 2 - Common Practice of Setting the Inclination of the Drilling Rig using a Protractor

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Plate 3 - Survey Tool of the Eastman Camera

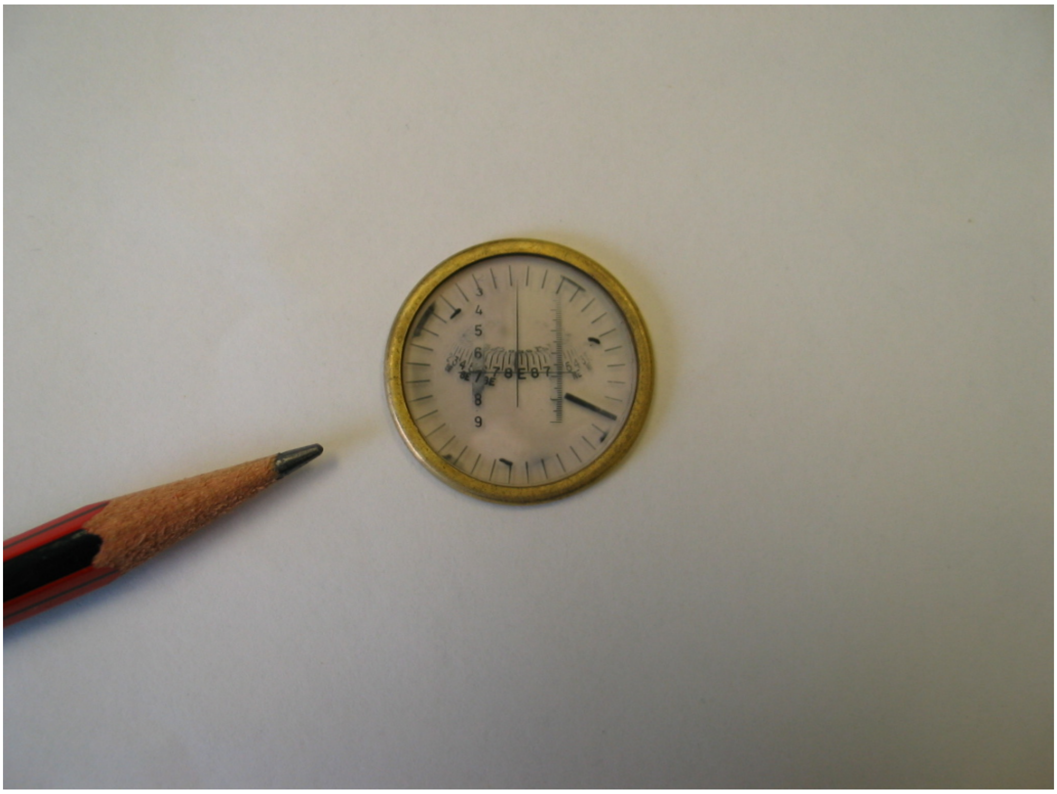

Plate 4 - Film of Eastman Camera

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Plate 5 - Reflector Ring of the Reflex Maxibor

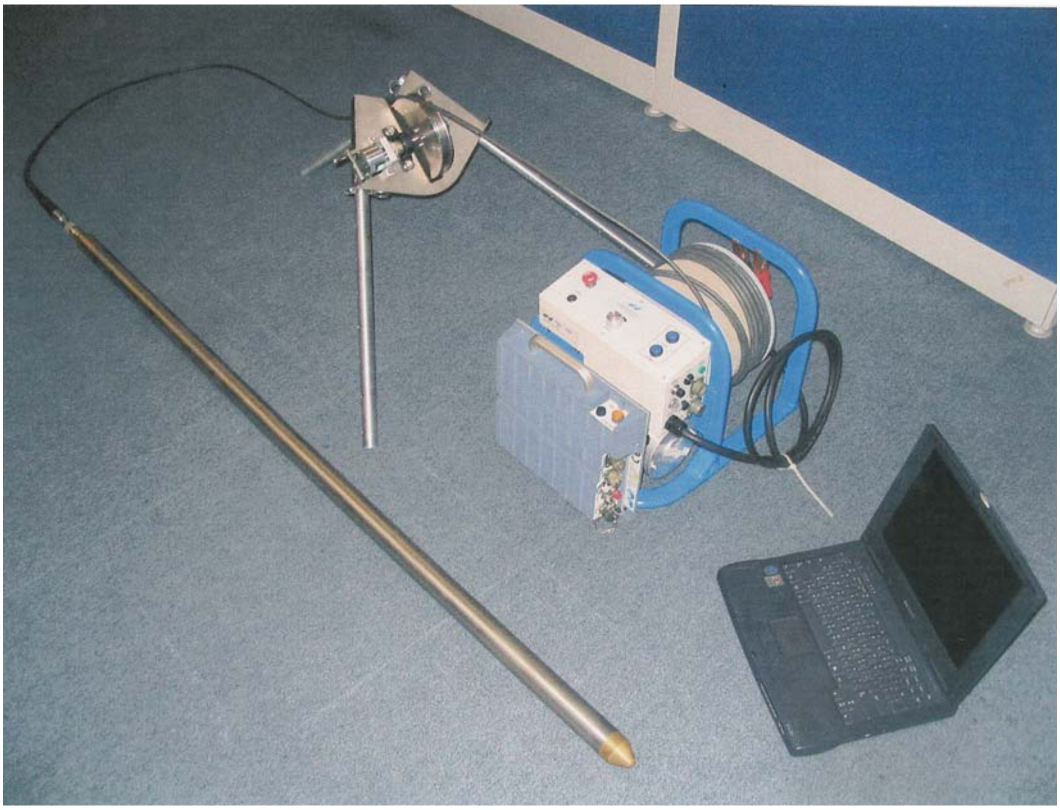

Plate 6 - RG Verticality Probe

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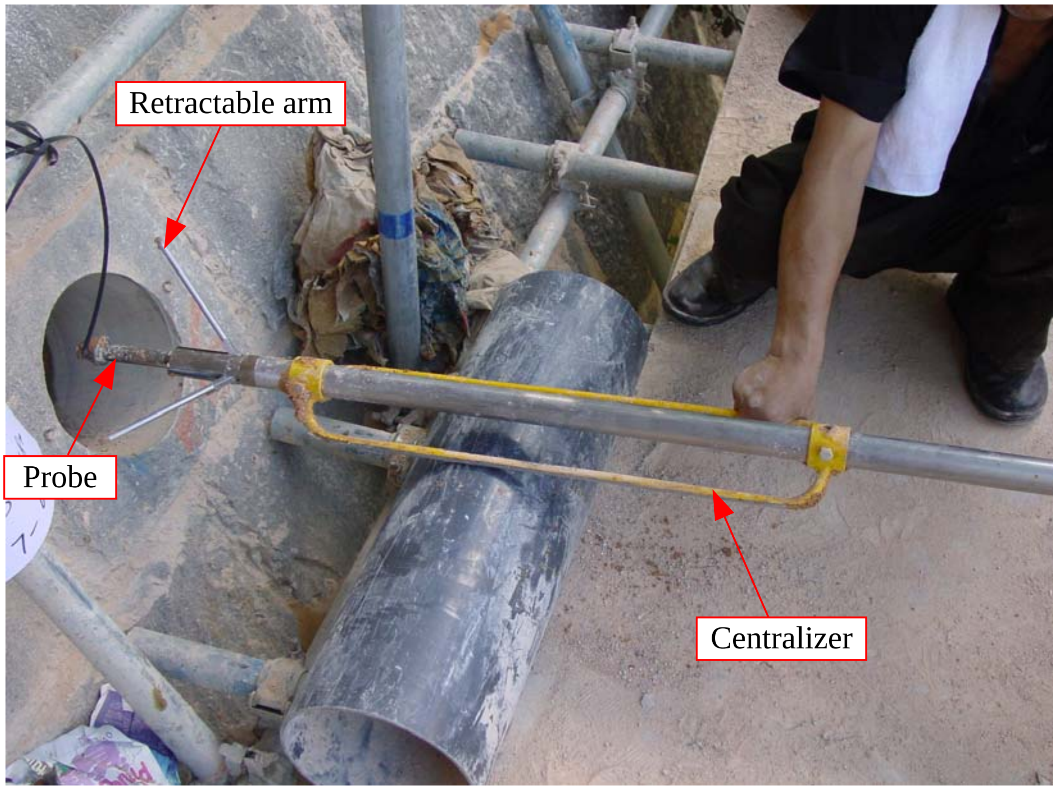

Plate 7 - Survey Probe and Centralizer of the Borehole Caliper

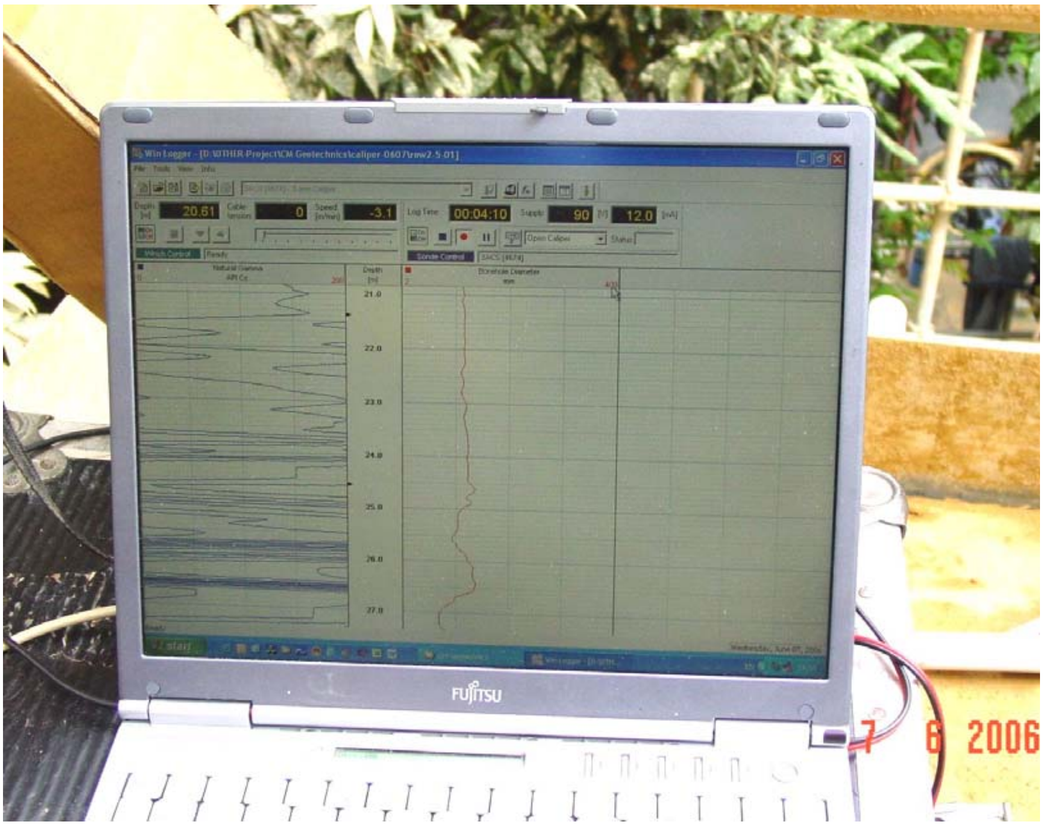

Plate 8 - Real-time Display of Diameter Measurements by Borehole Caliper on a Computer

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APPENDIX A

RESULTS OF HOLE ALIGNMENT MEASUREMENTS OF SOIL NAILS ON THE TEN SITES

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Table A1 - Hole Alignment Results Measured by Eastman Camera from Slope No. 11SE-D/C201 (Sheet 1 of 4)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[1] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
CC9	17	20	2.0	18.75	75.00	-1.25	0.00	0.00	0.22	0.55
			7.0	19.75	73.75	-0.25	1.00	-1.25		
			12.0	20.00	81.00	0.00	1.25	6.00		
			17.0	20.50	77.00	0.50	1.75	2.00		
CC11	17	20	2.0	19.75	81.00	-0.25	0.00	0.00	0.02 upward	0.32
			7.0	20.75	77.50	0.75	1.00	-3.50		
			12.0	21.00	86.00	1.00	1.25	5.00		
			17.0	21.00	77.00	1.00	1.25	-4.00		
CC13	17	20	2.0	18.50	75.00	-1.50	0.00	0.00	0.34 upward	1.02
			7.0	18.50	77.00	-1.50	0.00	2.00		
			12.0	19.00	81.50	-1.00	0.50	6.50		
			17.0	19.00	79.00	-1.00	0.50	4.00		
CC15	17	20	2.0	20.75	81.50	0.75	0.00	0.00	0.26 upward	0.45
			7.0	19.00	84.50	-1.00	-1.75	3.00		
			12.0	18.50	84.00	-1.50	-2.25	2.50		
			17.0	19.00	75.00	-1.00	-1.75	-6.50		
CC17	17	20	2.0	20.00	103.00	0.00	0.00	0.00	0.2	2.85
			7.0	20.50	93.00	0.50	0.50	-10.00		
			12.0	21.00	87.00	1.00	1.00	-16.00		
			17.0	21.00	94.00	1.00	1.00	-9.00		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A1 - Hole Alignment Results Measured by Eastman Camera from Slope No. 11SE-D/C201 (Sheet 2 of 4)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
DD1	17	20	2.0	21.00	83.00	1.00	0.00	0.00	0.60	0.37
			7.0	21.50	84.50	1.50	0.50	1.50		
			12.0	22.75	84.00	2.75	1.75	1.00		
			17.0	22.75	85.00	2.75	1.75	2.00		
DD3	17	20	2.0	21.25	87.00	1.25	0.00	0.00	0.63	0.45
			7.0	22.00	89.00	2.00	0.75	2.00		
			12.0	22.75	89.00	2.75	1.50	2.00		
			17.0	22.50	88.50	2.50	1.25	1.50		
DD5	17	20	2.0	19.00	83.00	-1.00	0.00	0.00	0.01 upward	0.16
			7.0	20.25	81.00	0.25	1.25	-2.00		
			12.0	20.00	85.00	0.00	1.00	2.00		
			14.6	20.00	84.50	0.00	1.00	1.50		
DD7	17	20	2.0	21.00	89.00	1.00	0.00	0.00	0.26	0.9
			7.0	21.00	87.00	1.00	0.00	-2.00		
			12.0	20.75	97.00	0.75	-0.25	8.00		
			16.5	21.00	94.00	1.00	0.00	5.00		
DD9	17	20	2.0	20.25	109.00	0.25	0.00	0.00	0.44	2.44
			7.0	21.25	103.00	1.25	1.00	-6.00		
			12.0	22.00	96.00	2.00	1.75	-13.00		
			17.0	22.00	98.00	2.00	1.75	-13.00		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A1 - Hole Alignment Results Measured by Eastman Camera from Slope No. 11SE-D/C201 (Sheet 3 of 4)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[1] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
FF47	15	20	2.0	22.00	113.00	2.00	0.00	0.00	0.76	0.53
			7.0	22.50	113.50	2.50	0.50	0.50		
			12.0	23.00	119.00	3.00	1.00	6.00		
			15.0	23.00	111.50	3.00	1.00	-1.50		
FF49	15	20	2.0	20.00	105.00	0.00	0.00	0.00	0.20	0.37
			7.0	20.00	106.00	0.00	0.00	1.00		
			12.0	21.50	104.00	1.50	1.50	-1.00		
			15.0	21.00	109.50	1.00	1.00	4.50		
FF51	15	20	2.0	19.00	102.50	-1.00	0.00	0.00	0.07 upward	4.78
			7.0	19.50	98.00	-0.50	0.50	-4.50		
			12.0	20.00	75.00	0.00	1.00	-27.50		
			15.0	20.00	74.00	0.00	1.00	-28.50		
FF53	15	20	2.0	23.00	106.00	3.00	0.00	0.00	0.75	0.25
			7.0	22.50	105.00	2.50	-0.50	-1.00		
			12.0	22.50	104.00	2.50	-0.50	-2.00		
			15.0	23.00	106.00	3.00	0.00	0.00		
FF55	15	20	2.0	19.00	115.50	-1.00	0.00	0.00	0.12 upward	0.29
			7.0	20.00	115.00	0.00	1.00	0.50		
			12.0	20.00	116.00	0.00	1.00	0.50		
			15.0	19.00	119.00	-1.00	0.00	3.50		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A1 - Hole Alignment Results Measured by Eastman Camera from Slope No. 11SE-D/C201 (Sheet 4 of 4)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection(1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
JJ1	17	20	2.0	18.50	101.00	-1.50	0.00	0.00	0.01 upward	0.57
			7.0	20.00	94.00	0.00	1.50	-7.00		
			12.0	20.00	109.00	0.00	1.50	8.00		
			17.0	20.50	96.00	0.50	2.00	-5.00		
JJ3	17	20	2.0	21.50	94.00	1.50	0.00	0.00	0.90	0.61
			7.0	23.50	89.00	3.50	2.00	-5.00		
			12.0	23.50	94.00	3.50	2.00	0.00		
			17.0	23.50	91.50	3.50	2.00	-2.50		
JJ5	17	20	2.0	20.00	89.50	0.00	0.00	0.00	0.20	0.70
			7.0	20.00	95.00	0.00	0.00	5.50		
			12.0	21.50	91.00	1.50	1.50	1.50		
			17.0	21.00	91.00	1.00	1.00	1.50		
JJ7	17	20	2.0	19.00	96.50	-1.00	0.00	0.00	0.13	0.78
			7.0	21.00	94.00	1.00	2.00	-2.50		
			12.0	21.50	92.00	1.50	2.50	-4.50		
			17.0	20.00	94.00	0.00	1.00	-2.50		
JJ9	17	20	2.0	21.00	90.50	1.00	0.00	0.00	0.48	0.37
			7.0	21.50	92.50	1.50	0.50	2.00		
			12.0	22.00	91.50	2.00	1.00	1.00		
			17.0	22.00	92.00	2.00	1.00	1.50		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A2 - Hole Alignment Results from Slope No. 11SE-B/C6 (Sheet 1 of 5)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination by Eastman Camera (°)	Measured Bearing by Eastman Camera (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
E6	18	20	5	26.00	208.50	6.00	0.00	0.00	2.37	0.66
			11	28.00	211.00	8.00	2.00	2.50		
			15	30.00	211.00	10.00	4.00	2.50		
			18	30.50	213.50	10.50	4.50	5.00		
E8	18	20	5	25.00	211.50	5.00	0.00	0.00	2.13	0.2
			11	27.00	209.50	7.00	2.00	-2.00		
			15	28.50	212.00	8.50	3.50	0.50		
			18	31.00	212.50	11.00	6.00	1.00		
E10	18	20	5	22.50	207.00	2.50	0.00	0.00	1.33	0.1
			11	23.00	207.00	3.00	0.50	0.00		
			15	27.00	205.50	7.00	4.50	-1.50		
			18	28.00	208.00	8.00	5.50	1.00		
E12	18	20	5	24.00	204.00	4.00	0.00	0.00	1.43	0.15
			11	23.00	204.00	3.00	-1.00	0.00		
			15	26.00	204.00	6.00	2.00	0.00		
			18	29.00	207.00	9.00	5.00	3.00		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

Table A2 - Hole Alignment Results from Slope No. 11SE-B/C6 (Sheet 2 of 5)

Soil Nail No.	Nail Length (m)	Design Inclinat'n (°)	Distance of Measurem't from Hole Top (m)	Measured Inclination (°)		Measured Bearing (°)		Difference in Measured Inclination w.r.t. Design (°)		Difference in Measured Inclination w.r.t. First Reading (°)		Difference in Measured bearing w.r.t. First Reading (°)		Maximum Vertical Deflection[(1)] from Design (m)		Maximum Horizontal Deflection from Initial Profile (m)	
				Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor
N1	18	25	0.0	-	29.45	-	197.36	-	4.45	-	0.00	-	0.00	0.62	0.13	0.04	0.04
			1.5	-	29.58	-	197.39	-	4.58	-	0.13	-	0.03				
			3.0	-	29.67	-	197.34	-	4.67	-	0.22	-	-0.02				
			4.5	-	29.82	-	197.34	-	4.82	-	0.37	-	-0.02				
			5	31.00	-	199.00	-	6.00	-	0.00	-	0.00					
			6.0	-	30.09	-	197.44	-	5.09	-	0.64	-	0.08				
			7.5	-	30.36	-	197.48	-	5.36	-	0.91	-	0.12				
			9.0	-	30.55	-	197.54	-	5.55	-	1.10	-	0.18				
			10	31.00	-	199.50	-	6.00	-	0.00	-	0.50	-				
			10.5	-	30.78	-	197.59	-	5.78	-	1.33	-	0.23				
			12.0	-	31.09	-	197.64	-	6.09	-	1.64	-	0.28				
			13.5	-	31.36	-	197.68	-	6.36	-	1.91	-	0.32				
			15.0	34.00	31.45	199.00	197.65	9.00	6.45	3.00	2.00	0.00	0.29				
			18.0	34.00	31.29	198.50	197.55	9.00	6.29	3.00	1.84	-0.50	0.19				

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A2 - Hole Alignment Results from Slope No. 11SE-B/C6 (Sheet 3 of 5)

Soil Nail No.	Nail Length (m)	Design Inclinat'n (°)	Distance of Measurem't from Hole Top (m)	Measured Inclination (°)		Measured Bearing (°)		Difference in Measured Inclination w.r.t. Design (°)		Difference in Measured Inclination w.r.t. First Reading (°)		Difference in Measured bearing w.r.t. First Reading (°)		Maximum Vertical Deflection[1] from Design (m)		Maximum Horizontal Deflection from Initial Profile (m)	
				Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor
N3	18	25	0.0	-	29.11	-	205.57	-	4.11	-	0.00	-	0.00	1.85	1.41	0.66	0.03
			1.5	-	29.37	-	205.59	-	4.37	-	0.26	-	0.02				
			3.0	-	29.40	-	205.64	-	4.40	-	0.29	-	0.07				
			4.5	-	29.45	-	205.68	-	4.45	-	0.34	-	0.11				
			5	30.00	-	200.00	-	5.00	-	0.00		0.00	-				
			6.0	-	29.63	-	205.67	-	4.63	-	0.52	-	0.10				
			7.5	-	29.80	-	205.64	-	4.80	-	0.69	-	0.07				
			9.0	-	29.98	-	205.62	-	4.98	-	0.87	-	0.05				
			10	31.00	-	202.50	-	6.00	-	1.00		2.50	-				
			10.5	-	30.31	-	205.66	-	5.31	-	1.20	-	0.13				
			12.0	-	30.67	-	205.70	-	5.67	-	1.56	-	0.13				
			12.6	32.50	-	204.00	-	7.50	-	2.50		4.00	-				
			13.5	-	30.97	-	205.70	-	5.97	-	1.86	-	0.13				
			15.0	-	31.11	-	205.70	-	6.11	-	2.00	-	0.13				
			18.0	33.50	30.92	203.50	205.83	8.50	5.92	3.50	1.81	3.50	0.26				

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A2 - Hole Alignment Results from Slope No. 11SE-B/C6 (Sheet 4 of 5)

Soil Nail No.	Nail Length (m)	Design Inclinat'n (°)	Distance of Measurem't from Hole Top (m)	Measured Inclination (°)		Measured Bearing (°)		Difference in Measured Inclination w.r.t. Design (°)		Difference in Measured Inclination w.r.t. First Reading (°)		Difference in Measured bearing w.r.t. First Reading (°)		Maximum Vertical Deflection(1) from Design (m)		Maximum Horizontal Deflection from Initial Profile (m)	
				Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor
N5	18	25	0.0	-	28.53	-	194.88	-	3.53	-	0.00	-	0.00	2.12	1.39	0.24	0.04
			1.5	-	28.82	-	194.91	-	3.82	-	0.29	-	0.03				
			3.0	-	29.09	-	194.94	-	4.09	-	0.56	-	0.06				
			4.5	-	29.36	-	194.92	-	4.36	-	0.83	-	0.04				
			5.0	30.75	-	198.00	-	5.75	-	0.00	-	0	0.00				
			6.0	-	29.65	-	194.88	-	4.65	-	1.12	-	-0.03				
			7.5	-	29.92	-	194.85	-	4.92	-	1.39	-	0.02				
			9.0	-	30.24	-	194.90	-	5.24	-	1.71	-	0.09				
			10	32.50	-	196.00	-	7.50	-	1.75	-	-2	0.17				
			10.5	-	30.51	-	194.97	-	5.51	-	1.98	-	0.26				
			12.0	-	30.73	-	195.05	-	5.73	-	2.20	-	0.17				
			13.5	-	30.95	-	195.14	-	5.95	-	2.42	-	0.26				
			15.0	33.50	31.15	197.00	195.21	8.50	6.15	2.75	2.62	-1.00	0.33				
			18.0	35.00	31.33	199.00	195.29	10.00	6.33	4.25	2.80	1.00	0.41				

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A2 - Hole Alignment Results from Slope No. 11SE-B/C6 (Sheet 5 of 5)

Soil Nail No.	Nail Length (m)	Design Inclinat'n (°)	Distance of Measurem't from Hole Top (m)	Measured Inclination (°)		Measured Bearing (°)		Difference in Measured Inclination w.r.t. Design (°)		Difference in Measured Inclination w.r.t. First Reading (°)		Difference in Measured bearing w.r.t. First Reading (°)		Maximum Vertical Deflection(1) from Design (m)		Maximum Horizontal Deflection from Initial Profile (m)	
				Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor	Eastman Camera	Maxibor
N7	18	25	0.0	-	28.57	-	195.89	-	3.57	-	0.00	-	0.00	2.17	1.45	0.25	0.06
			1.5	-	28.85	-	195.85	-	3.85	-	0.28	-	-0.04				
			3.0	-	29.07	-	195.80	-	4.07	-	0.50	-	-0.09				
			4.5	-	29.35	-	195.76	-	4.35	-	0.78	-	-0.13				
			5	30.00	-	198.00	-	5.00	-	0.00	-	0.00	-				
			6.0	-	29.69	-	195.74	-	4.69	-	1.12	-	-0.15				
			7.5	-	30.03	-	195.73	-	5.03	-	1.46	-	-0.16				
			9.0	-	30.38	-	195.69	-	5.38	-	1.81	-	-0.20				
			10.5	-	30.72	-	195.64	-	5.72	-	2.15	-	-0.25				
			11	33.00	-	197.50	-	8.00	-	3.00	-	2.50	-				
			12.0	-	31.06	-	195.60	-	6.06	-	2.49	-	-0.29				
			13.5	-	31.43	-	195.59	-	6.43	-	2.86	-	-0.30				
			15.0	34.50	31.77	197.00	195.65	9.50	6.77	4.50	3.20	2.00	-0.24				
			18.0	36.00	32.28	195.00	195.65	11.00	7.28	6.00	3.71	0.00	-0.24				

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 1 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection(1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
A1	19	25	0.0	25.37	247.02	0.37	0.00	0.00	0.31	0.02
			1.5	25.57	247.03	0.57	0.20	0.01		
			3.0	25.44	246.96	0.44	0.07	-0.06		
			4.5	25.37	246.90	0.37	0.00	-0.12		
			6.0	25.54	246.89	0.54	0.17	-0.13		
			7.5	25.86	246.96	0.86	0.49	-0.06		
			9.0	26.13	247.00	1.13	0.76	-0.02		
			10.5	26.39	247.05	1.39	1.02	0.03		
			12.0	26.57	247.16	1.57	1.20	0.14		
			13.5	26.84	247.24	1.84	1.47	0.22		
			15.0	27.12	247.31	2.12	1.75	0.29		
			18.0	27.45	247.38	2.45	2.08	0.36		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 2 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection(1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
A3	19	25	0.0	27.58	244.87	2.58	0.00	0.00	0.79	0.04
			1.5	27.66	244.92	2.66	0.08	0.05		
			3.0	27.42	244.92	2.42	-0.16	0.05		
			4.5	27.24	244.90	2.24	-0.34	0.03		
			6.0	27.27	244.84	2.27	-0.31	-0.03		
			7.5	27.31	244.88	2.31	-0.27	0.01		
			9.0	27.54	244.94	2.54	-0.04	0.07		
			10.5	27.85	244.99	2.85	0.27	0.12		
			12.0	28.13	245.04	3.13	0.55	0.17		
			13.5	28.39	245.08	3.39	0.81	0.21		
			15.0	28.67	245.12	3.67	1.09	0.25		
			18.0	29.06	245.24	4.06	1.48	0.37		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 3 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
A5	19	25	0.0	27.56	240.79	2.56	0.00	0.00	0.96	0.05
			1.5	27.70	240.81	2.70	0.14	0.02		
			3.0	27.54	240.78	2.54	-0.02	-0.01		
			4.5	27.61	240.63	2.61	0.05	-0.16		
			6.0	27.84	240.62	2.84	0.28	-0.17		
			7.5	28.15	240.63	3.15	0.59	-0.16		
			9.0	28.43	240.60	3.43	0.87	-0.19		
			10.5	28.74	240.57	3.74	1.18	-0.22		
			12.0	29.04	240.55	4.04	1.48	-0.24		
			13.5	29.31	240.53	4.31	1.75	-0.26		
			15.0	29.61	240.52	4.61	2.05	-0.27		
			18.0	30.02	240.51	5.02	2.46	-0.28		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 4 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
A7	19	25	0.0	25.50	237.94	0.50	0.00	0.00	0.33	0.01
			1.5	25.79	238.01	0.79	0.29	0.07		
			3.0	25.63	237.95	0.63	0.13	0.01		
			4.5	25.53	237.90	0.53	0.03	-0.04		
			6.0	25.67	237.94	0.67	0.17	0.00		
			7.5	25.91	237.96	0.91	0.41	0.02		
			9.0	26.17	237.96	1.17	0.67	0.02		
			10.5	26.46	237.93	1.46	0.96	-0.01		
			12.0	26.70	237.89	1.70	1.20	-0.05		
			13.5	26.76	237.89	1.76	1.26	-0.05		
			15.0	26.98	237.85	1.98	1.48	-0.09		
			18.0	27.44	237.81	2.44	1.94	-0.13		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 5 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection(1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
B10	19	25	0.0	24.76	247.49	-0.24	0.00	0.00	0.05	0.05
			1.5	24.91	247.55	-0.09	0.15	0.06		
			3.0	24.69	247.53	-0.31	-0.07	0.04		
			4.5	24.53	247.39	-0.47	-0.23	-0.10		
			6.0	24.50	247.25	-0.50	-0.26	-0.24		
			7.5	24.64	247.19	-0.36	-0.12	-0.30		
			9.0	24.92	247.20	-0.08	0.16	-0.29		
			10.5	25.17	247.19	0.17	0.41	-0.30		
			12.0	25.38	247.16	0.38	0.62	-0.33		
			13.5	25.65	247.17	0.65	0.89	-0.32		
			15.0	25.90	247.21	0.90	1.14	-0.28		
			16.5	26.11	247.25	1.11	1.35	-0.24		
			18.0	-	-	-	-	-		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 6 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection[(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
B14	19	25	0.0	22.65	241.29	-2.35	0.00	0.00	0.30 upward	0.11
			1.5	22.91	241.41	-2.09	0.26	0.12		
			3.0	23.06	241.48	-1.94	0.41	0.19		
			4.5	23.19	241.51	-1.81	0.54	0.22		
			6.0	23.45	241.53	-1.55	0.80	0.24		
			7.5	23.78	241.57	-1.22	1.13	0.28		
			9.0	24.09	241.61	-0.91	1.44	0.32		
			10.5	24.37	241.69	-0.63	1.72	0.40		
			12.0	24.63	241.78	-0.37	1.98	0.49		
			13.5	24.89	241.88	-0.11	2.24	0.59		
			15.0	25.20	241.90	0.20	2.55	0.61		
			18.0	25.57	241.98	0.57	2.92	0.69		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A3 - Hole Alignment Results Measured by Reflex Maxibor from Slope No. 11SW-B/FR1 (Sheet 7 of 7)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection(1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
B16	19	25	0.0	23.39	240.10	-1.61	0.00	0.00	0.19 upward	0.08
			1.5	23.67	240.12	-1.33	0.28	0.02		
			3.0	23.86	240.14	-1.14	0.47	0.04		
			4.5	23.84	240.19	-1.16	0.45	0.09		
			6.0	24.02	240.28	-0.98	0.63	0.18		
			7.5	24.24	240.31	-0.76	0.85	0.21		
			9.0	24.29	240.32	-0.71	0.90	0.22		
			10.5	24.56	240.41	-0.44	1.17	0.31		
			12.0	24.74	240.52	-0.26	1.35	0.42		
			13.5	25.00	240.57	0.00	1.61	0.47		
			15.0	25.28	240.56	0.28	1.89	0.46		
			18.0	25.72	240.59	0.72	2.33	0.49		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A4 - Hole Alignment Results Measured by Reflex Ezshot from Slope No. 7SW-C/C115 (Sheet 1 of 2)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection (1) from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
R6-5	18.0	15.0	1.0	15.00	292.00	0.00	0.00	0.00	0.45	1.96
			6.0	15.10	274.10	0.10	0.10	-17.90		
			12.0	16.60	287.30	1.60	1.60	-4.70		
			18.0	17.80	297.90	2.80	2.80	5.90		
R6-6	18.0	15.0	1.0	15.80	272.50	0.80	0.00	0.00	0.90	3.38
			6.0	16.80	267.60	1.80	1.00	-4.90		
			12.0	18.10	285.10	3.10	2.30	12.60		
			18.0	19.20	298.40	4.20	3.40	25.90		
R6-7	18.0	15.0	1.0	14.00	284.20	-1.00	0.00	0.00	0.13	0.81
			6.0	15.40	274.60	0.40	1.40	-9.60		
			12.0	15.30	288.00	0.30	1.30	3.80		
			14.4	17.00	285.70	2.00	3.00	1.50		
R6-8	18.0	15.0	1.0	13.00	284.80	-2.00	0.00	0.00	0.18 upward	0.91
			6.0	13.80	273.90	-1.20	0.80	-10.90		
			12.0	14.40	287.80	-0.60	1.40	3.00		
			14.4	15.40	287.10	0.40	2.40	2.30		
R6-9	18.0	15.0	1.0	13.20	281.70	-1.80	0.00	0.00	0.00	0.49
			6.0	13.60	275.90	-1.40	0.40	-5.80		
			12.0	15.20	287.20	0.20	2.00	5.50		
			18.0	16.30	278.90	1.30	3.10	-2.80		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A4 - Hole Alignment Results Measured by Reflex Ezshot from Slope No. 7SW-C/C115 (Sheet 2 of 2)

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured bearing w.r.t. First Reading (°)	Maximum Vertical Deflection [(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
R6-10	18.0	15.0	1.0	14.50	280.40	-0.50	0.00	0.00	0.58	1.15
			6.0	15.60	282.40	0.60	1.10	2.00		
			12.0	16.90	287.50	1.90	2.40	7.10		
			18.0	18.50	283.00	3.50	4.00	2.60		
R6-11	18.0	15.0	1.0	16.90	281.20	1.90	0.00	0.00	0.67	0.73
			6.0	16.10	282.10	1.10	-0.80	0.90		
			12.0	17.80	286.00	2.80	0.90	4.80		
			18.0	17.60	282.90	2.60	0.70	1.70		
R6-12	18.0	15.0	1.0	16.40	286.70	1.40	0.00	0.00	0.63	0.33
			6.0	16.90	284.30	1.90	0.50	-2.40		
			12.0	17.70	286.70	2.70	1.30	0.00		
			18.0	19.50	283.60	4.50	3.10	-3.10		
R6-13	18.0	15.0	1.0	15.80	283.30	0.80	0.00	0.00	0.59	0.56
			6.0	16.10	283.70	1.10	0.30	0.40		
			12.0	18.10	288.10	3.10	2.30	4.80		
			18.0	19.20	284.30	4.20	3.40	1.00		
R6-14	18.0	15.0	1.0	17.50	281.20	2.50	0.00	0.00	0.91	0.68
			6.0	15.70	281.20	0.70	-1.80	0.00		
			12.0	18.60	287.10	3.60	1.10	5.90		
			18.0	19.50	283.30	4.50	2.00	2.10		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A5 - Hole Alignment Results Measured from Slope No. 11SE-C/C14

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measure-ment from Hole Top (m)	Measurements by Eastman Camera							Measurements by RG Verticality Probe						
				Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection (1) from Design (m)	Max. Horizontal Deflection from Initial Profile (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection (1) from Design (m)	Max. Horizontal Deflection from Initial Profile (m)
TN16/1	22	10	1.5	10.00	147	0	0	0	0.17	0.26	12.91	148.73	2.91	0	0	1.65	0.05
			6.5	10.50	148	0.5	0.5	1			12.28	145.71	2.28	-0.63	-3.02		
			11.5	10.50	148	0.5	0.5	1			14.79	147.47	4.79	1.88	-1.26		
			16.5	10.50	148	0.5	0.5	1			15.96	148.05	5.96	3.05	-0.68		
			21.5	10.50	147	0.5	0.5	0			18.01	147.33	8.01	5.10	-1.40		
TN16/2	22	10	1.5	11.00	24	1	0	0	0.37	0.17	11.05	21.14	1.05	0	0	2.13	0.38
			6.5	11.00	24	1	0	0			12.33	21.51	2.33	1.28	0.37		
			11.5	11.00	25	1	0	1			12.87	22.61	2.87	1.82	1.47		
			16.5	11.00	25	1	0	1			15.87	23.17	5.87	4.82	2.03		
			21.5	11.00	24	1	0	0			16.60	22.91	6.60	5.55	1.77		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A6 - Hole Alignment Results Measured from Slope No. 11SE-C/FR22

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measure-ment from Hole Top (m)	Measurements by Eastman Camera							Measurements by RG Verticality Probe						
				Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection [(1)] from Design (m)	Max. Horizontal Deflection from Initial Profile (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection [(1)] from Design (m)	Max. Horizontal Deflection from Initial Profile (m)
TN28/1	22	10	1.5	11.00	77	1	0	0	0.8	0.94	10.24	79.25	0.24	0	0	0.82	1.16
			6.5	10.00	79	0	-1	2			10.01	79.35	0.01	-0.23	0.1		
			11.5	12.50	79	2.5	1.5	2			12.99	80.35	2.99	2.75	1.1		
			16.5	13.00	80	3	2	3			13.36	81.36	3.36	3.12	2.11		
			21.5	13.50	81	3.5	2.5	4			13.34	81.40	3.34	3.10	2.15		
TN28/2	22	10	1.5	12.50	135	2.5	0	0	0.24	0.26	12.28	134.29	2.28	0	0	0.19	0.12
			6.5	10.00	135	0	-2.5	0			8.99	133.34	-1.01	-3.29	-0.95		
			11.5	9.00	136	-1	-3.5	1			8.18	131.24	-1.82	-4.1	-3.05		
			16.5	11.00	137	1	-1.5	2			13.07	132.66	3.07	0.79	-1.63		
			21.5	12.00	135	2	-0.5	0			13.97	133.25	3.97	1.69	-1.04		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A7 - Hole Alignment Results Measured from Slope No. 11SW-A/C565

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection [(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
TN52/1	22	10	1.5	10.50	82	0.5	0	0	1.5	0.26
			6.5	12.00	82	2	1.5	0		
			11.5	14.00	83	4	3.5	1		
			16.5	15.00	83	5	4.5	1		
			21.5	16.50	83	6.5	6	1		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

Table A8 - Hole Alignment Results Measured from Slope No. 11SW-A/FR230

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection [(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
TN61/1	22	10	1.5	10.00	196	0	0	0	1.07	1.55
			6.5	11.50	200	1.5	1.5	4		
			11.5	12.50	200	2.5	2.5	4		
			16.5	13.50	200	3.5	3.5	4		
			21.5	15.00	202	5	5	6		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A9 - Hole Alignment Results Measured from Slope No. 11SW-D/FR401

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measurement from Hole Top (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Maximum Vertical Deflection [(1)] from Design (m)	Maximum Horizontal Deflection from Initial Profile (m)
TN17/2	22	10	1.5	9.50	195	-0.5	0	0	0.53 upward	1.54
			6.5	10.00	197	0	0.5	2		
			11.5	9.00	199	-1	-0.5	4		
			16.5	8.50	201	-1.5	-1	6		
			21.5	6.50	201	-3.5	-3	6		
TN17/3	22	10	1.5	9.00	220	-1	0	0	1.72	0.77
			6.5	12.00	221	2	3	1		
			11.5	14.50	222	4.5	5.5	2		
			16.5	16.00	223	6	7	3		
			21.5	18.00	223	8	9	3		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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Table A10 - Hole Alignment Results Measured from Slope No. 15NE-A/F24

Soil Nail No.	Nail Length (m)	Design Inclination (°)	Distance of Measure-ment from Hole Top (m)	Measurements by Eastman Camera							Measurements by RG Verticality Probe						
				Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection (1) from Design (m)	Max. Horizontal Deflection from Initial Profile (m)	Measured Inclination (°)	Measured Bearing (°)	Difference in Measured Inclination w.r.t. Design (°)	Difference in Measured Inclination w.r.t. First Reading (°)	Difference in Measured Bearing w.r.t. First Reading (°)	Max. Vertical Deflection (1) from Design (m)	Max. Horizontal Deflection from Initial Profile (m)
			1.5	10.50	327	0.5	0	0			10.10	327.57	0.10	0	0		
			6.5	11.00	330	1	0.5	3			11.54	330.47	1.54	1.44	2.90		
TN142/1	22	10	11.5	11.00	328	1	0.5	1	0.4	0.69	11.64	329.07	1.64	1.54	1.50	0.51	1.82
			16.5	11.00	328	1	0.5	1			12.28	328.33	2.28	2.18	0.76		
			21.5	11.50	330	1.5	1	3			11.44	331.37	1.44	1.34	3.80		
			1.5	10.00	338	0	0	0			9.29	338.21	-0.71	0	0		
			6.5	9.50	336	-0.5	-0.5	-2			10.90	339.10	0.90	1.61	0.89		
TN142/2	22	10	11.5	11.00	337	1	1	-1	0.04	0.43	10.31	338.45	0.31	1.02	0.24	0.13	0.17
			16.5	10.00	336	0	0	-2			10.23	338.96	0.23	0.94	0.75		
			21.5	10.00	338	0	0	0			9.77	339.40	-0.23	0.48	1.19		

Note: (1) Maximum vertical deflection of the soil-nail hole from the design is downward unless specified otherwise.

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APPENDIX B

PLOTS OF ANALYSES OF HOLE INCLINATION MEASUREMENTS OF THREE SELECTED SLOPE SITES

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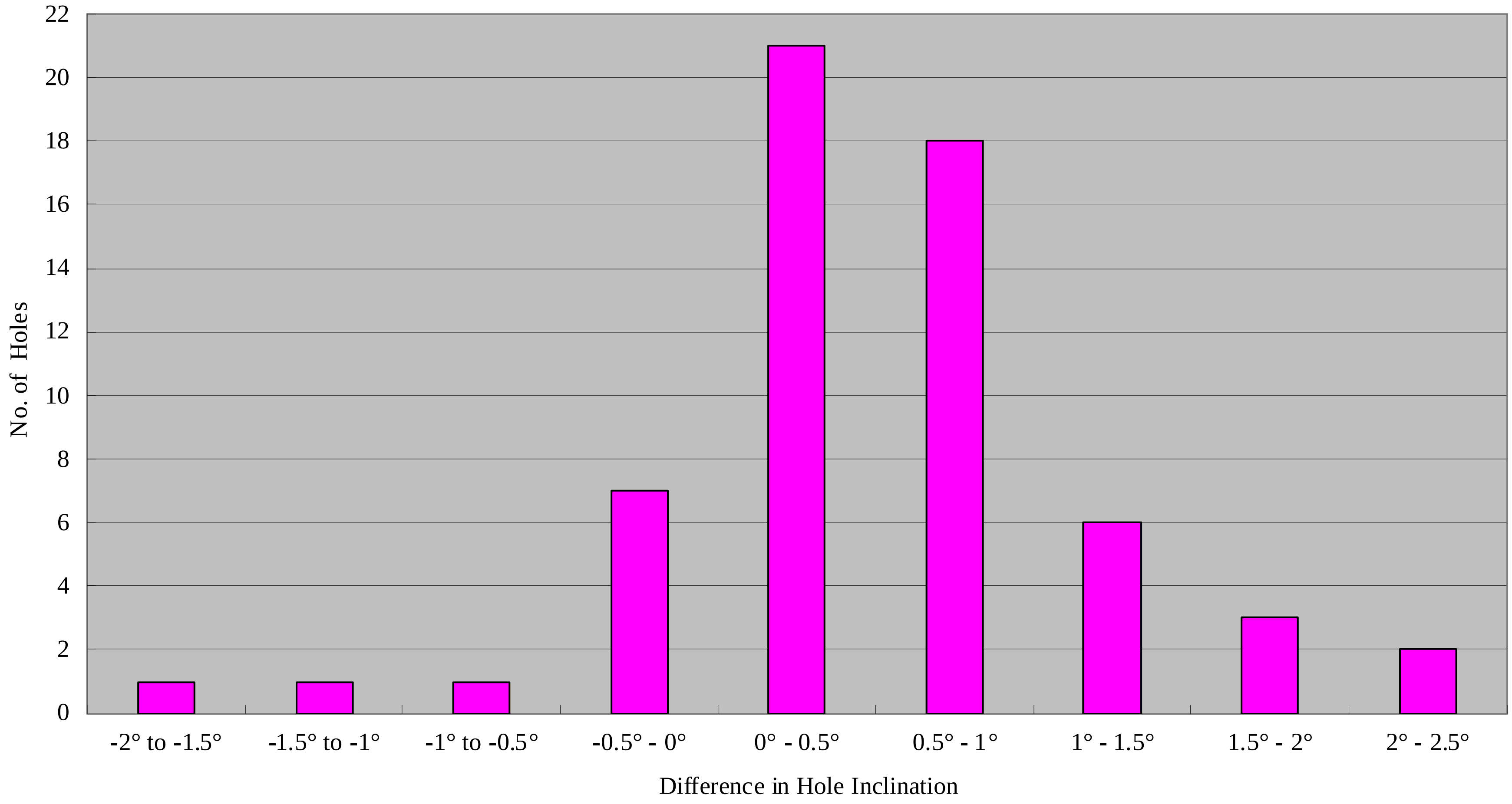

Legend:

From 2 m to 7 m, 7 m to 12 m and 12 m to 17 m

Figure B1 - Difference of Hole Inclinations every 5 m on Slope C201

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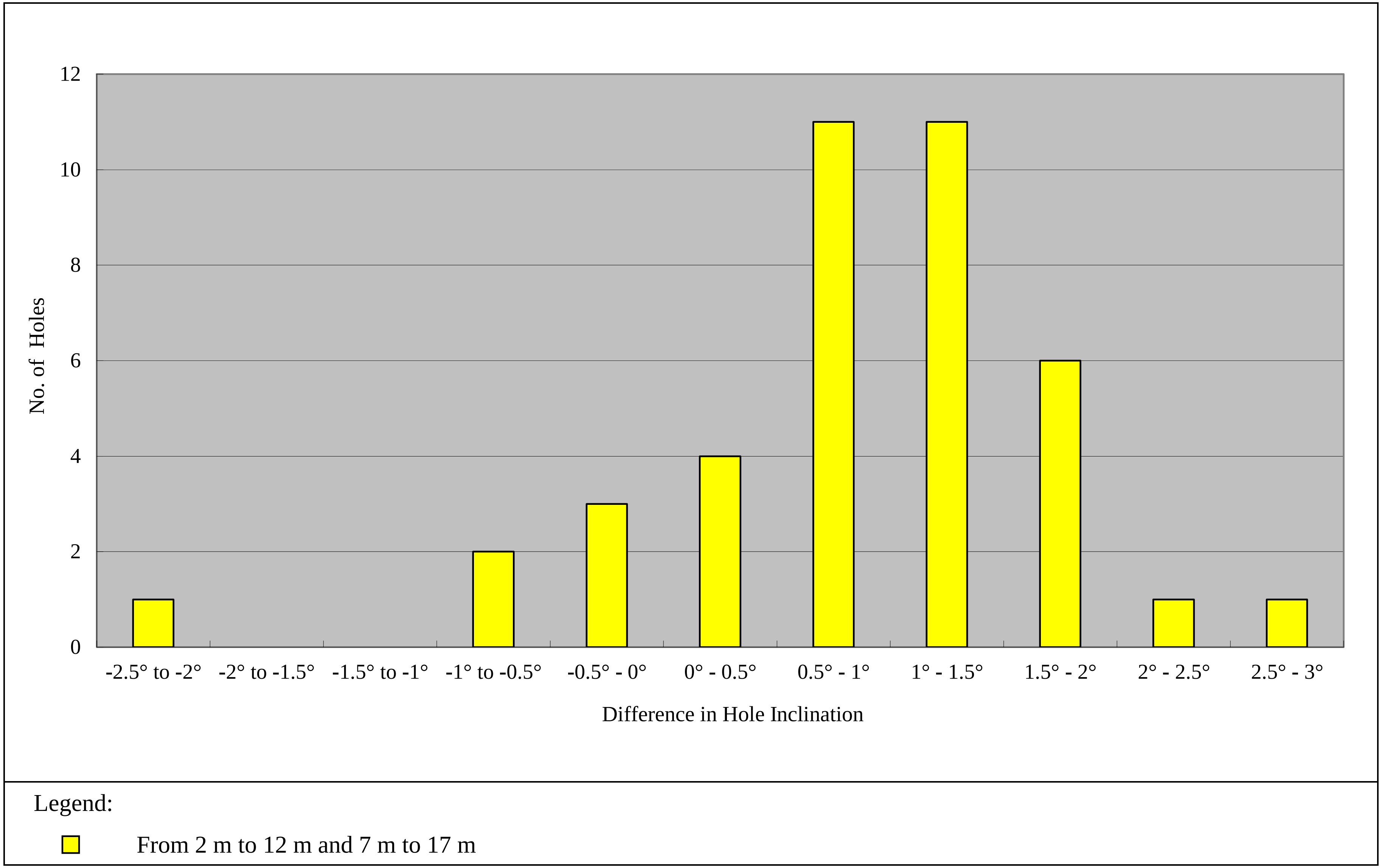

Figure B2 - Difference of Hole Inclinations every 10 m on Slope C201

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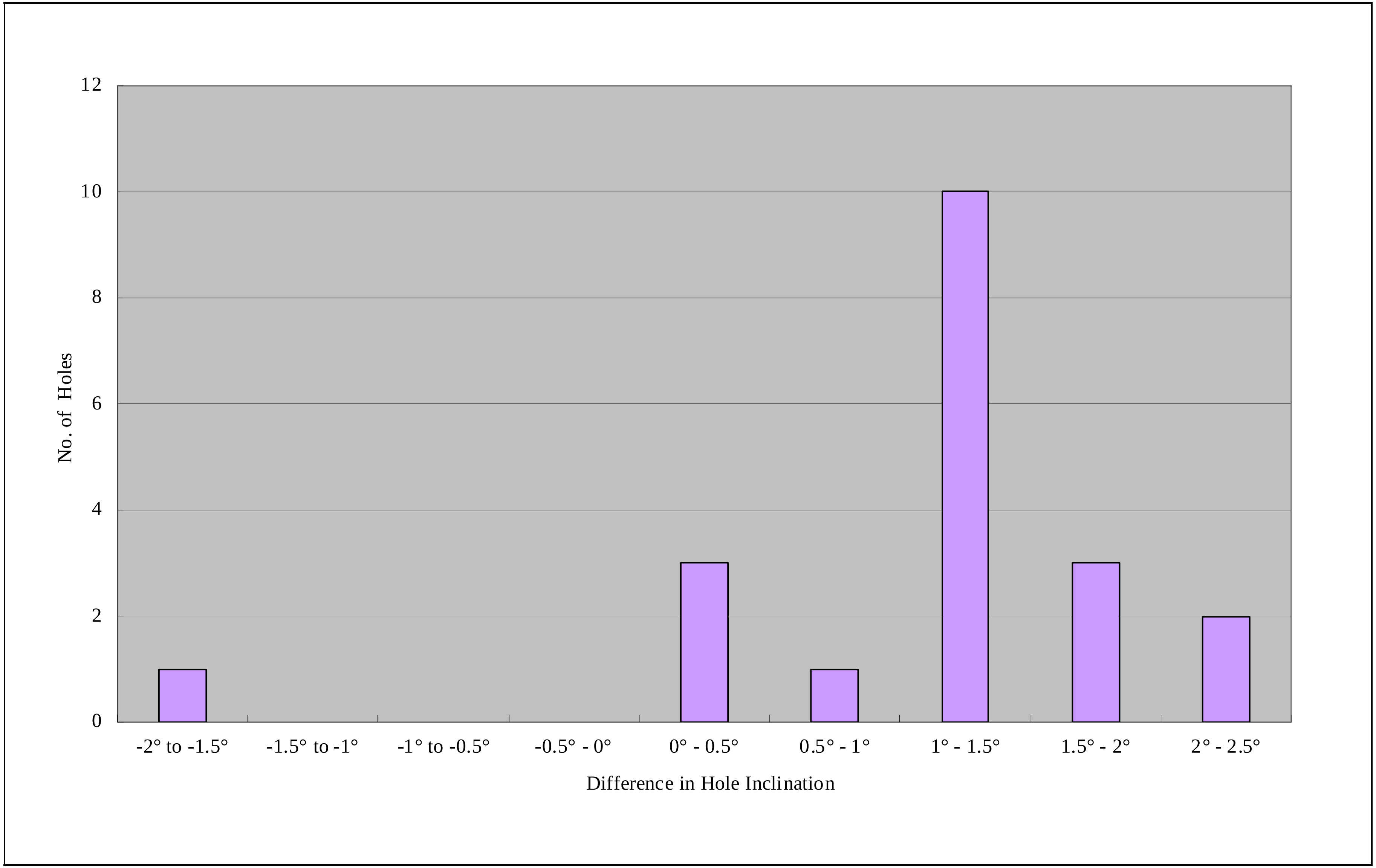

Figure B3 - Difference of Hole Inclinations at Hole Bottom on Slope C201

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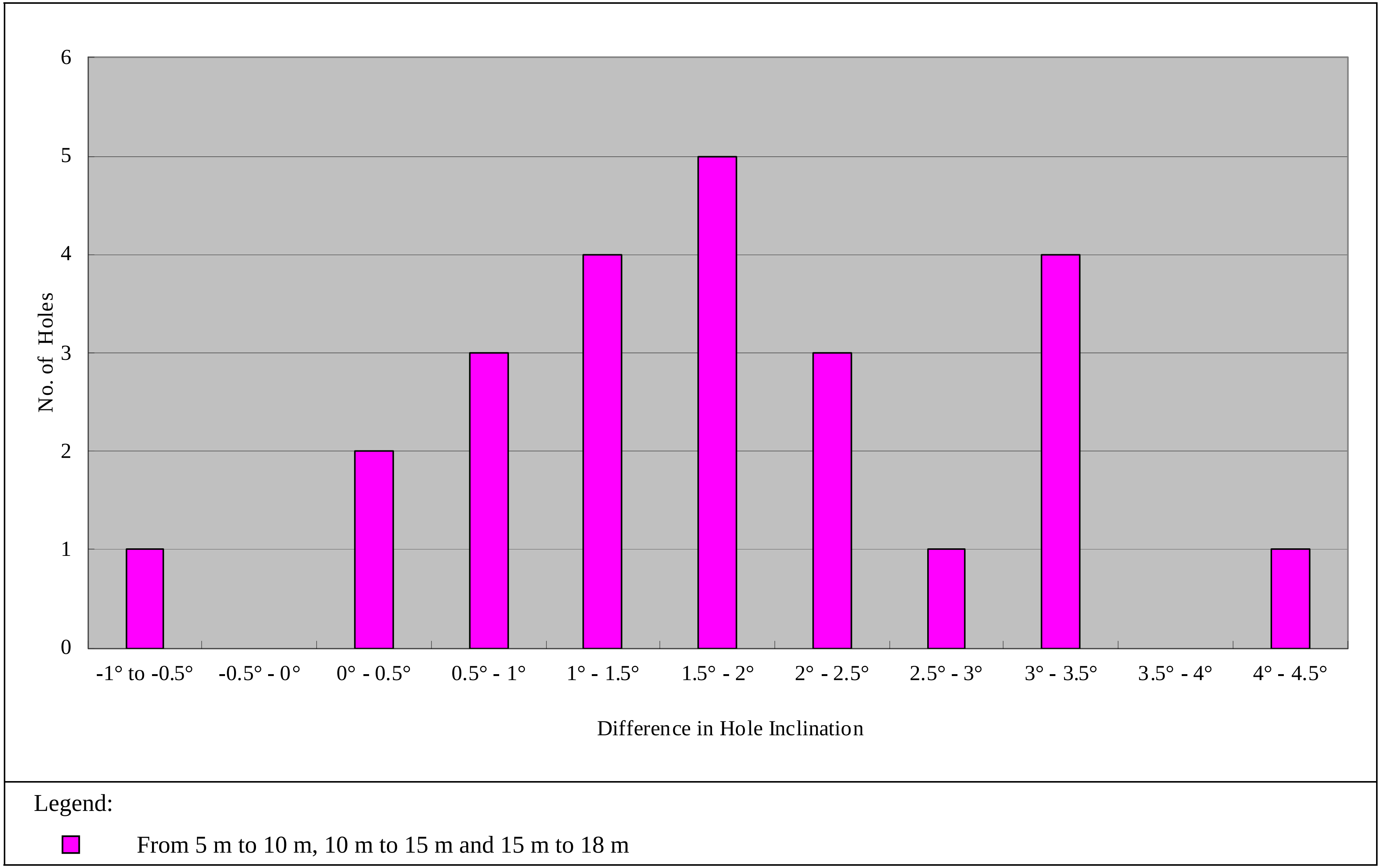

Figure B4 - Difference of Hole Inclinations every 5 m at Slope C6

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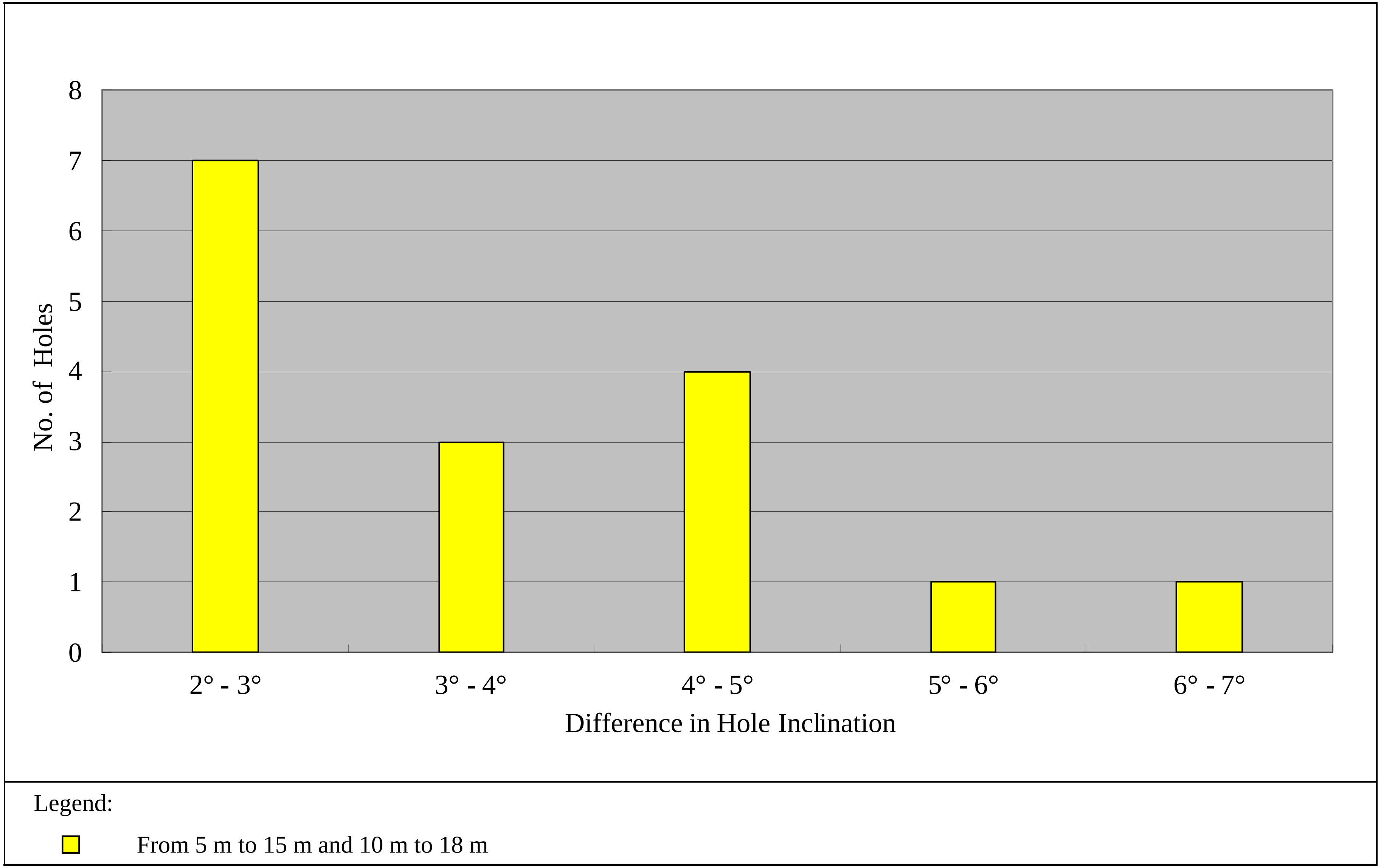

Figure B5 - Difference of Hole Inclinations every 10 m on Slope C6

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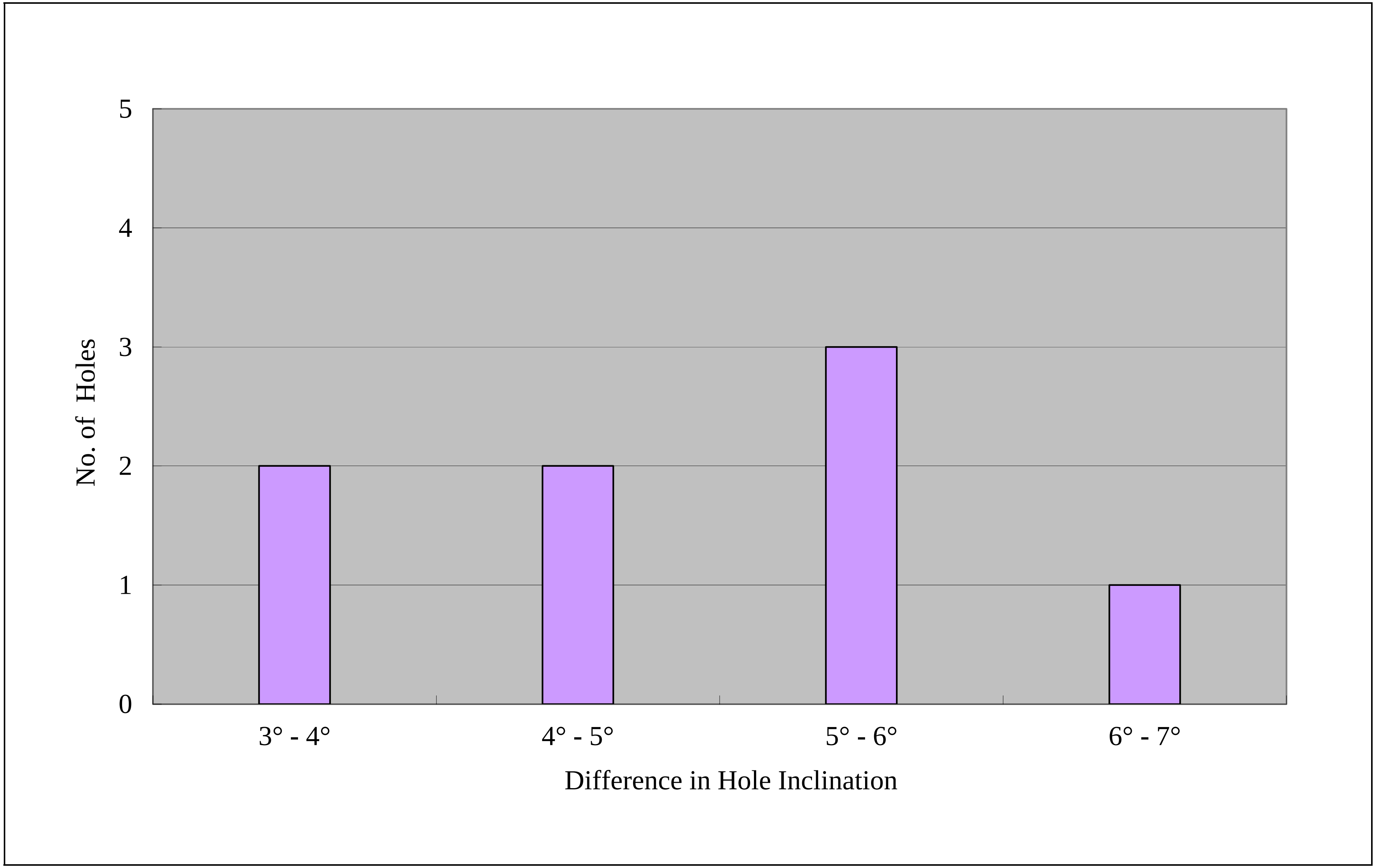

Figure B6 - Difference of Hole Inclinations Hole Bottom on Slope C6

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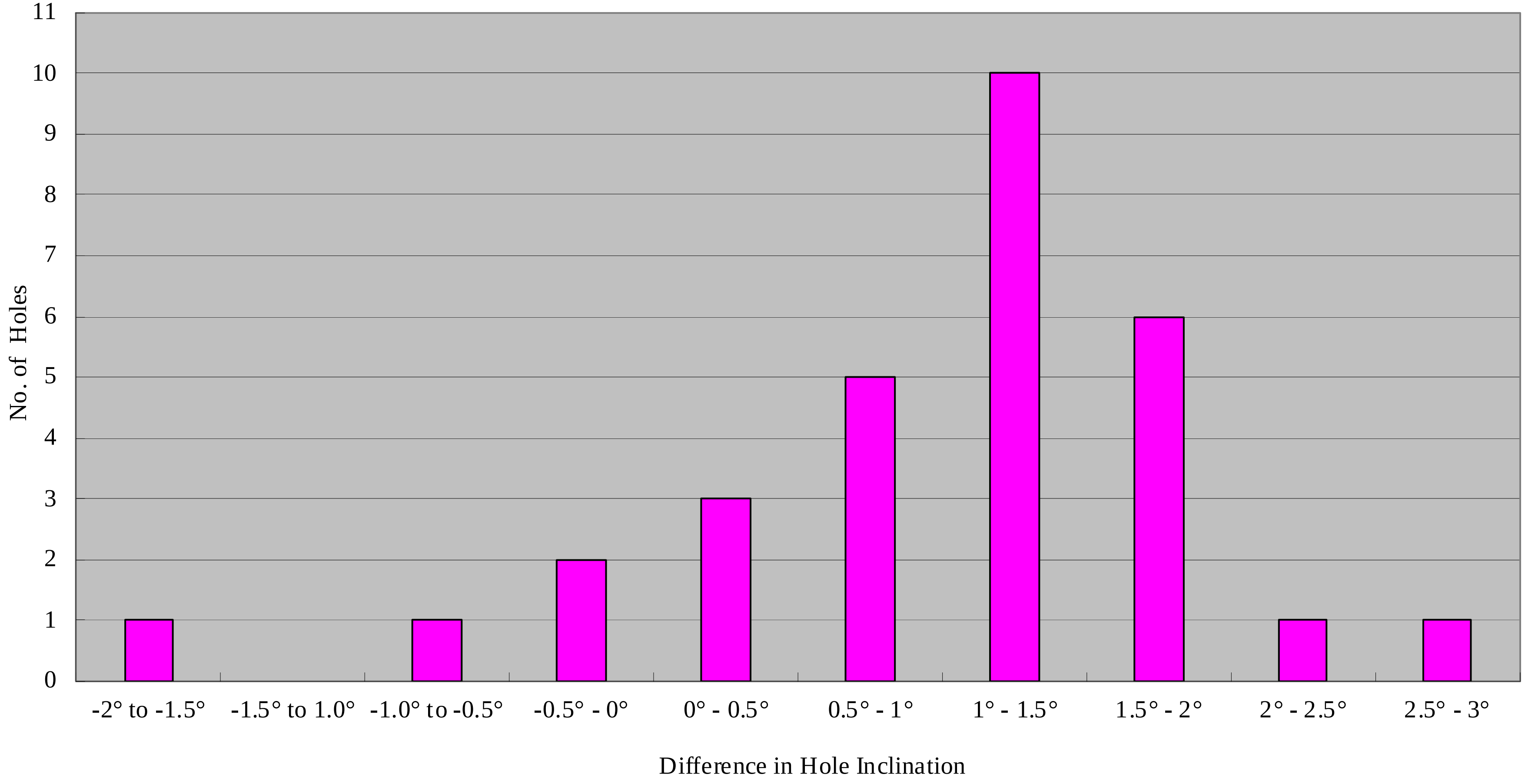

Legend:

From 1 m to 6 m, 6 m to 12 m and 12 m to 18 m

Figure B7 - Difference of Hole Inclinations every 6 m on Slope C115

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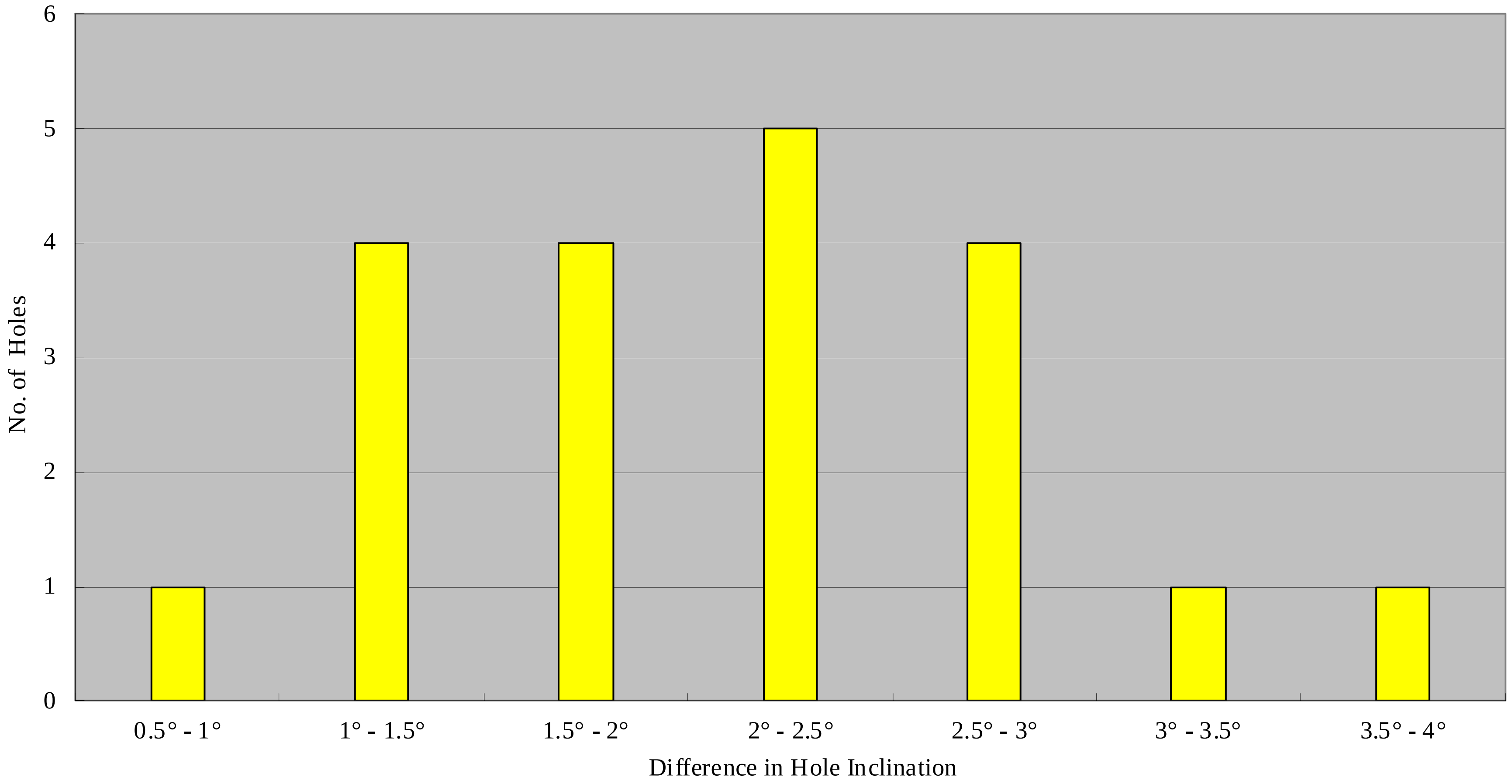

Legend:

From 1 m to 12 m and 6 m to 18 m

Figure B8 - Difference of Hole Inclinations every 12 m on Slope C115

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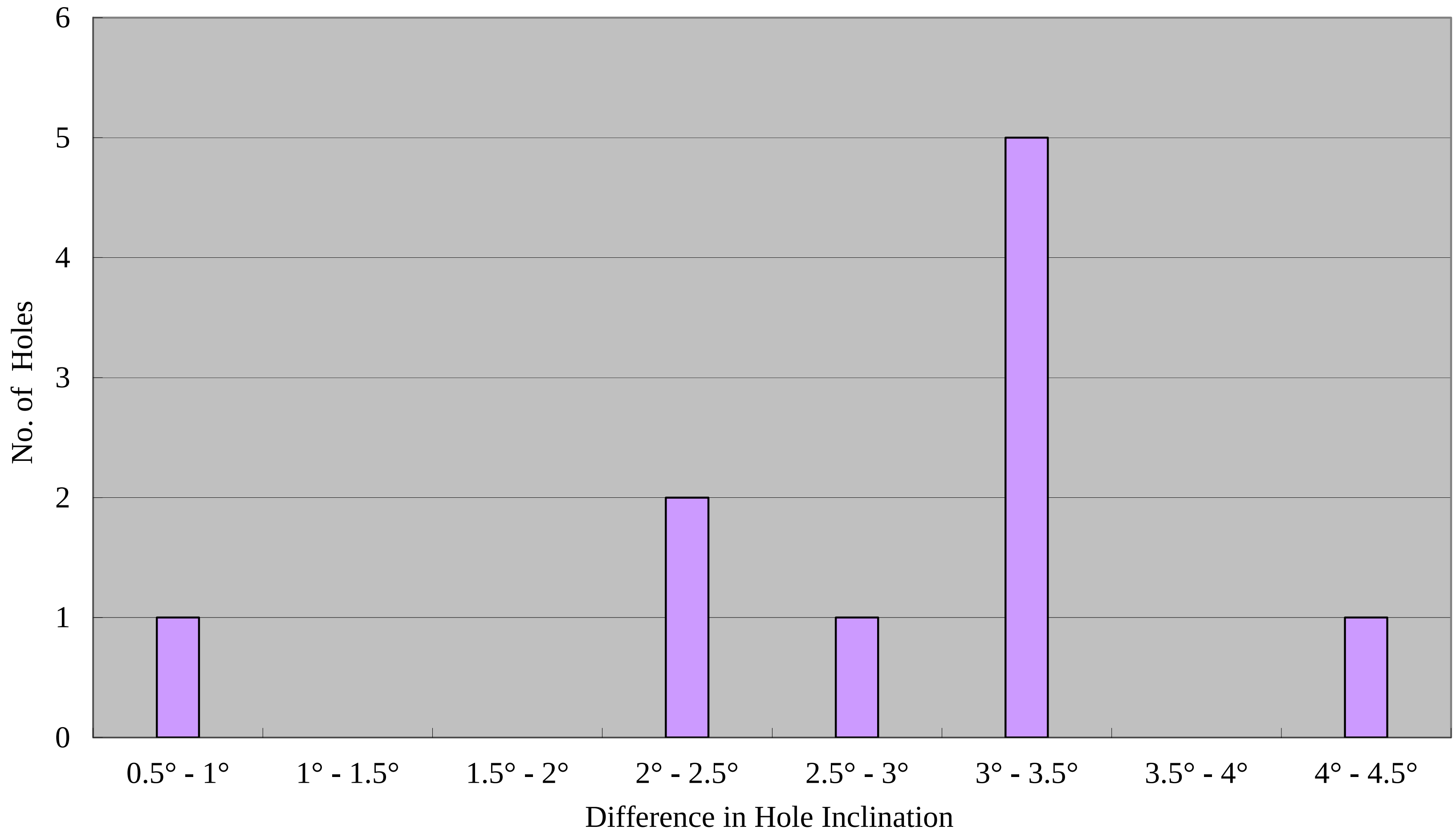

Figure B9 - Difference of Hole Inclinations Hole Bottom on Slope C115

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APPENDIX C

PLOTS OF ANALYSES OF HOLE BEARING MEASUREMENTS
OF THREE SELECTED SLOPE SITES

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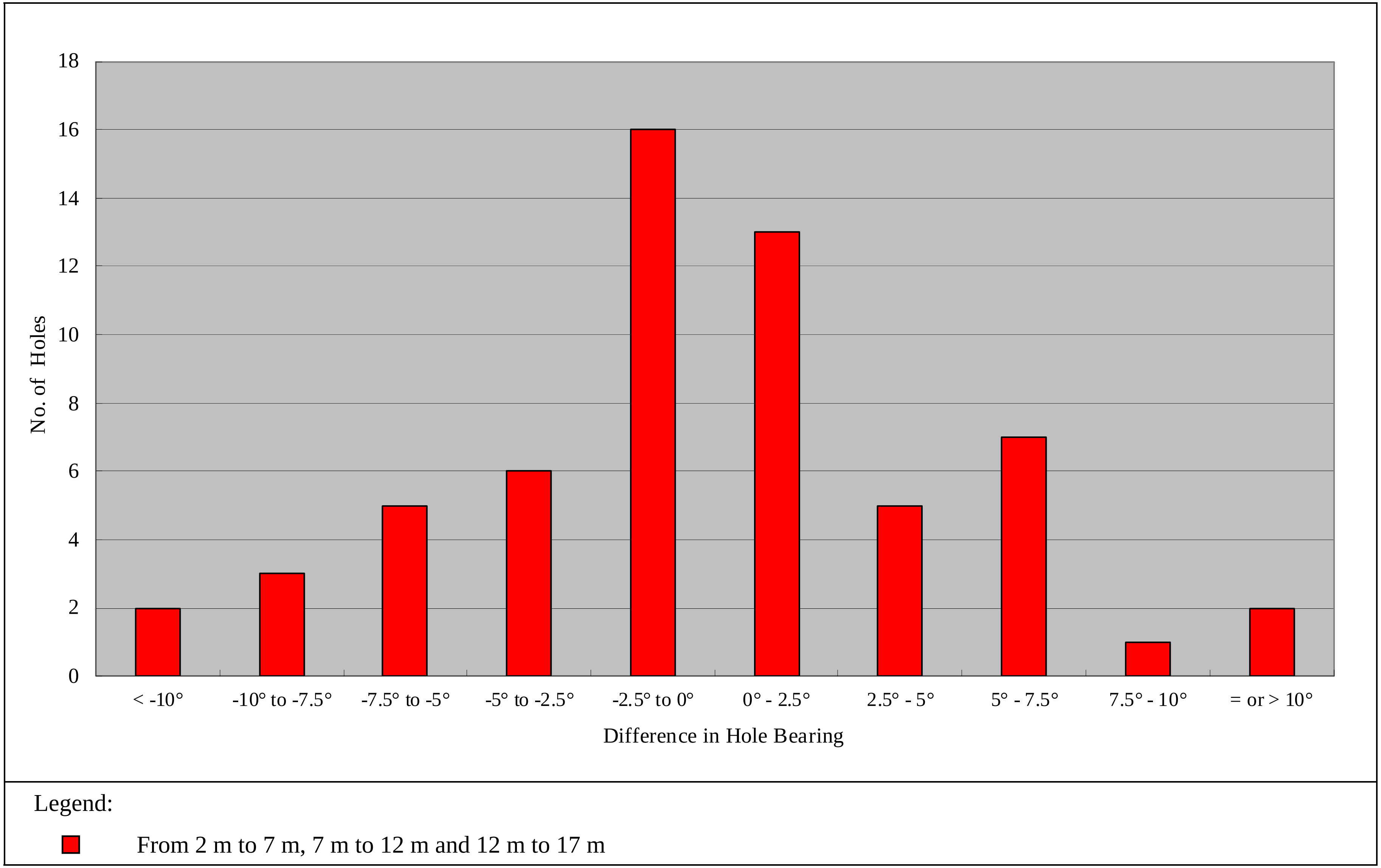

Figure C1 - Difference of Hole Bearings every 5 m on Slope C201

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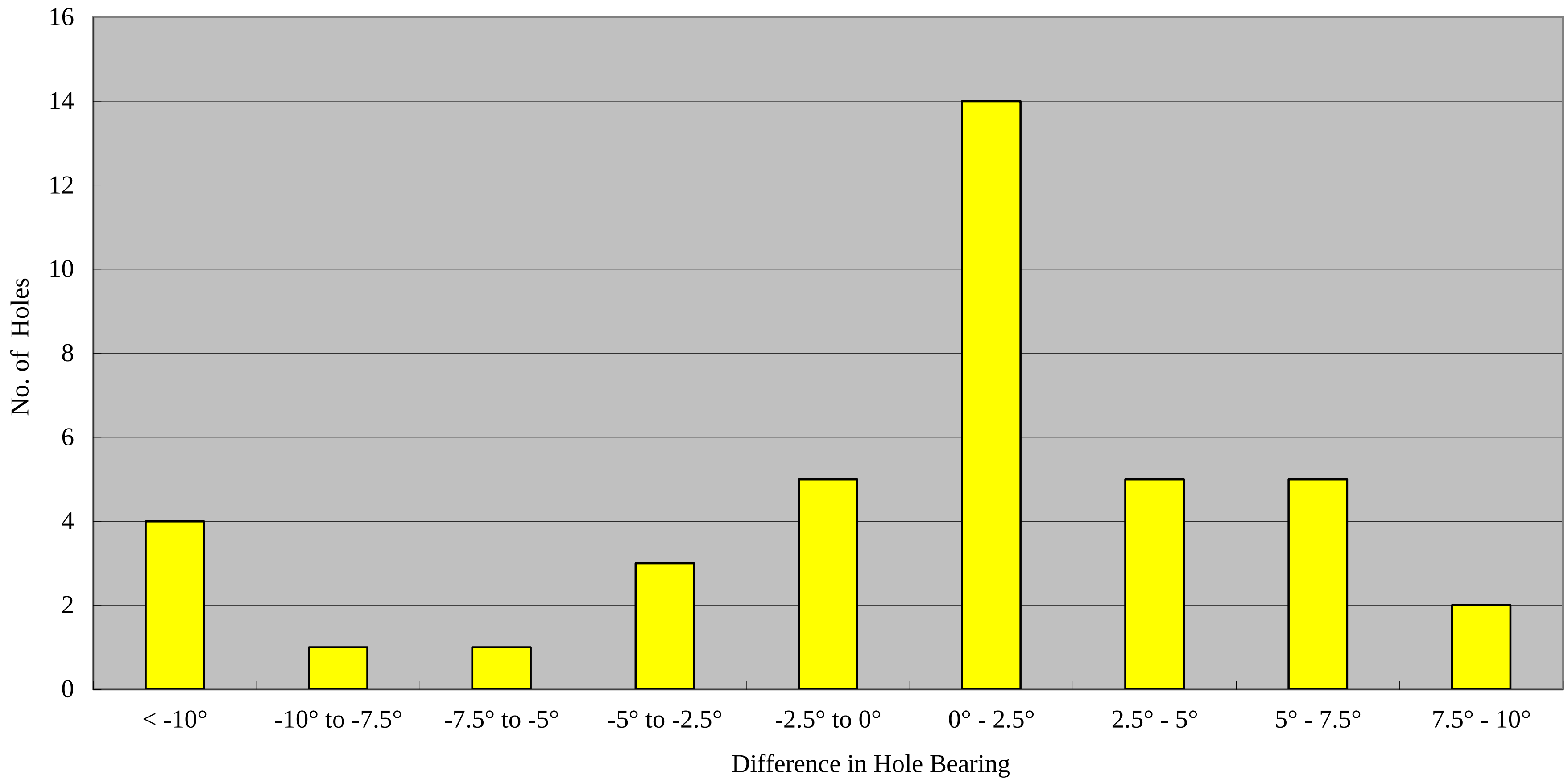

Legend:

2 m to 12 m and 7 m to 17 m

Figure C2 - Difference of Hole Bearings every 10 m on Slope C201

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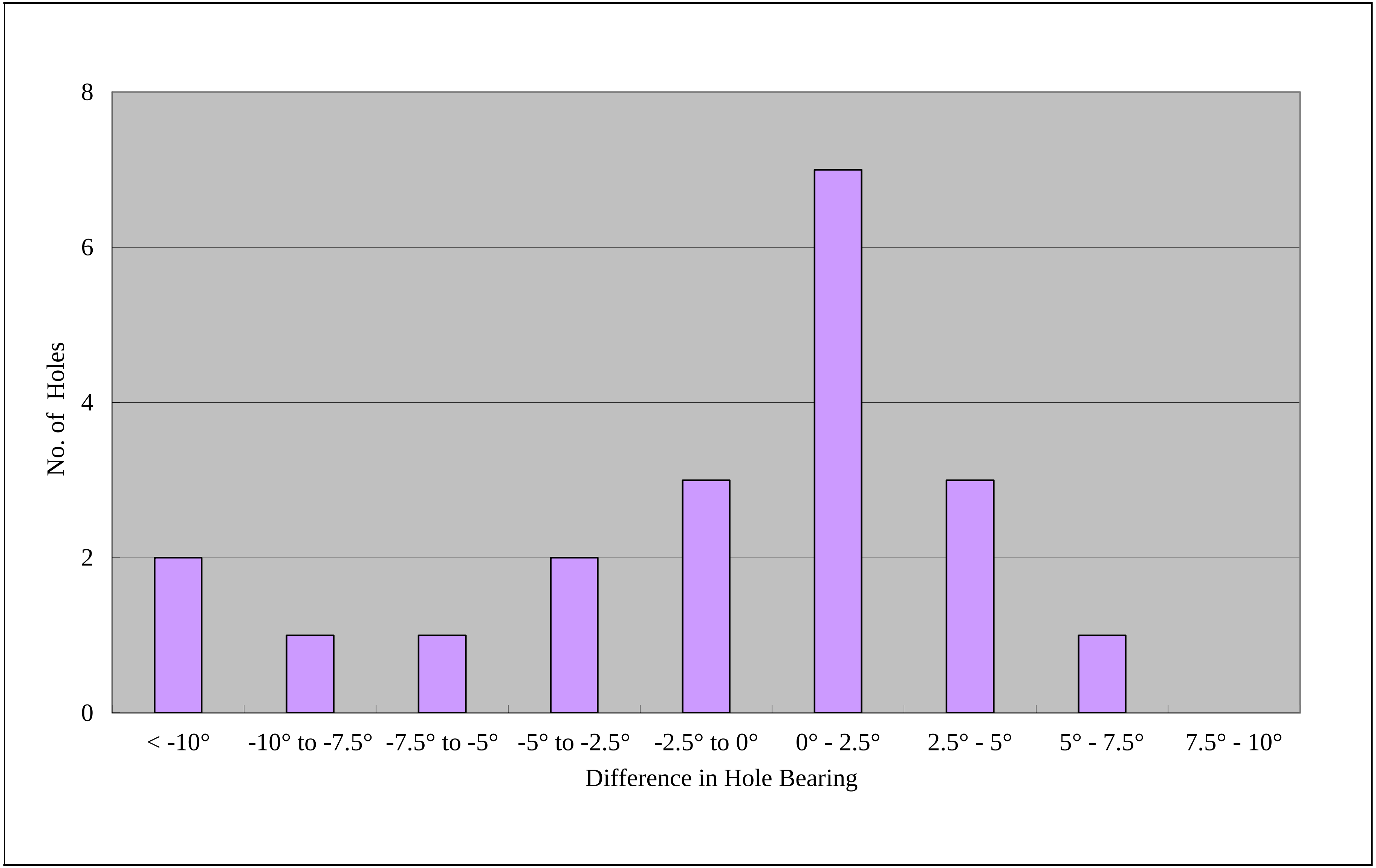

Figure C3 - Difference of Hole Bearings at Hole Bottom on Slope C201

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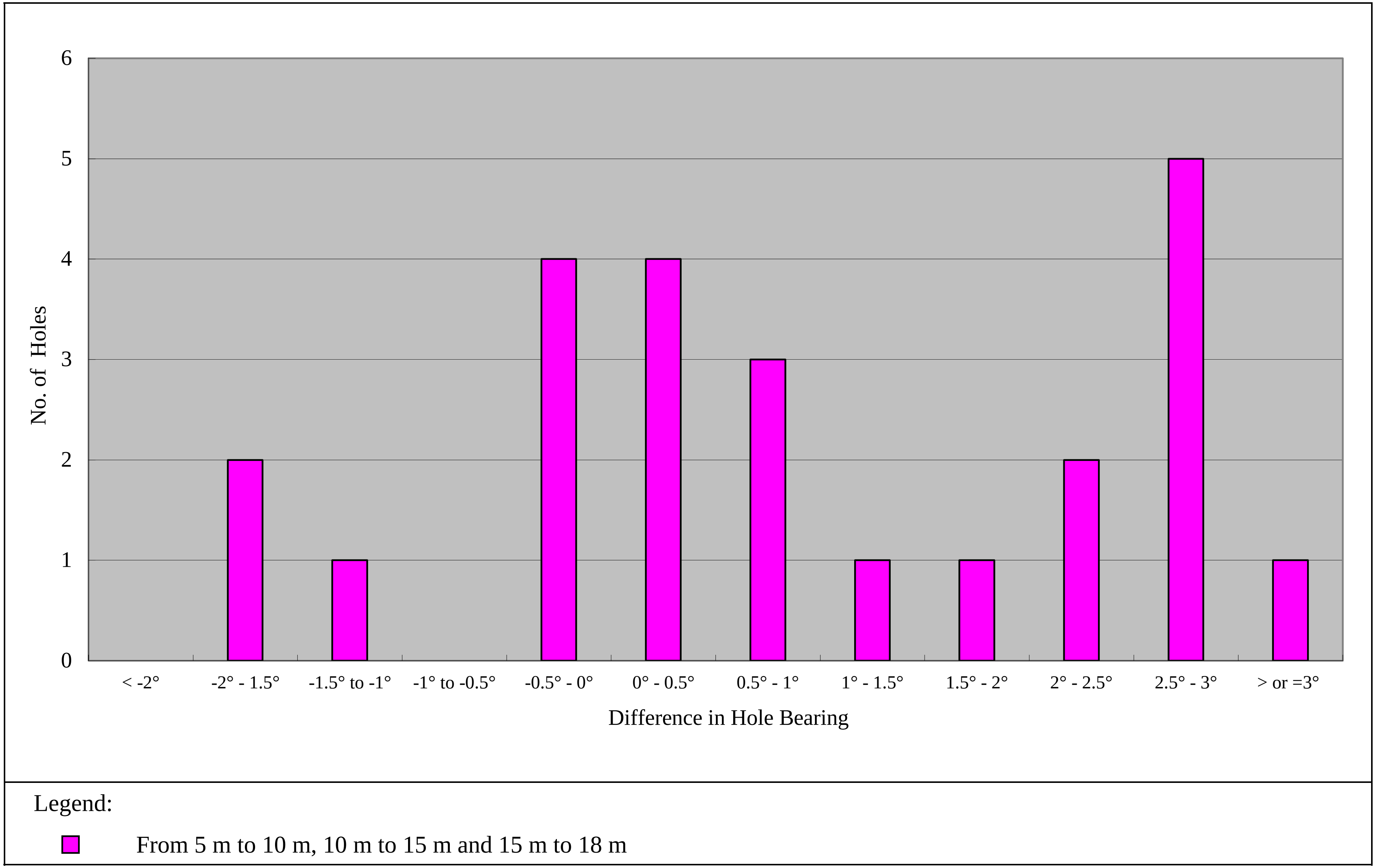

Figure C4 - Difference of Hole Bearings every 5 m on Slope C6

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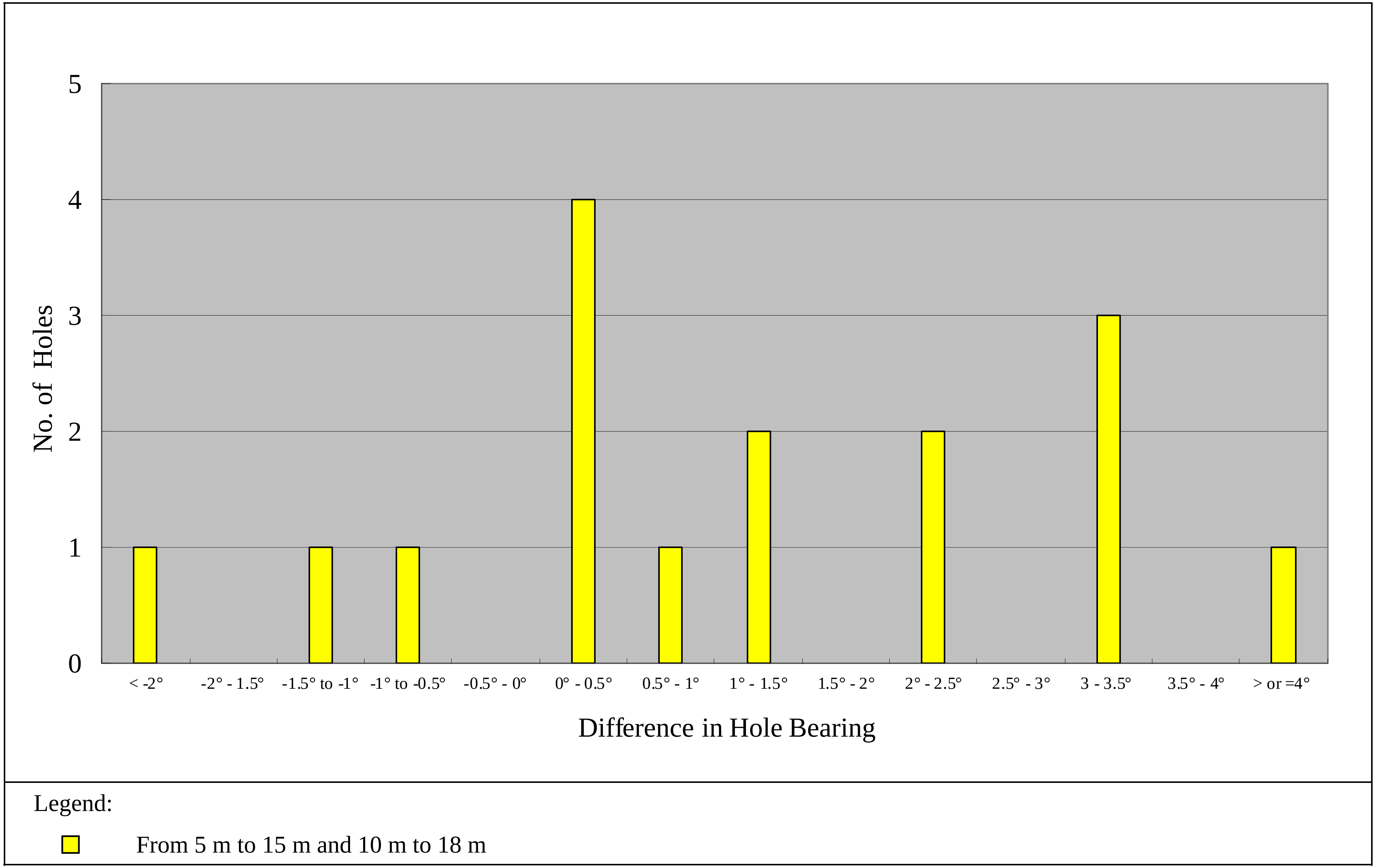

Figure C5 - Difference of Hole Bearings every 10 m on Slope C6

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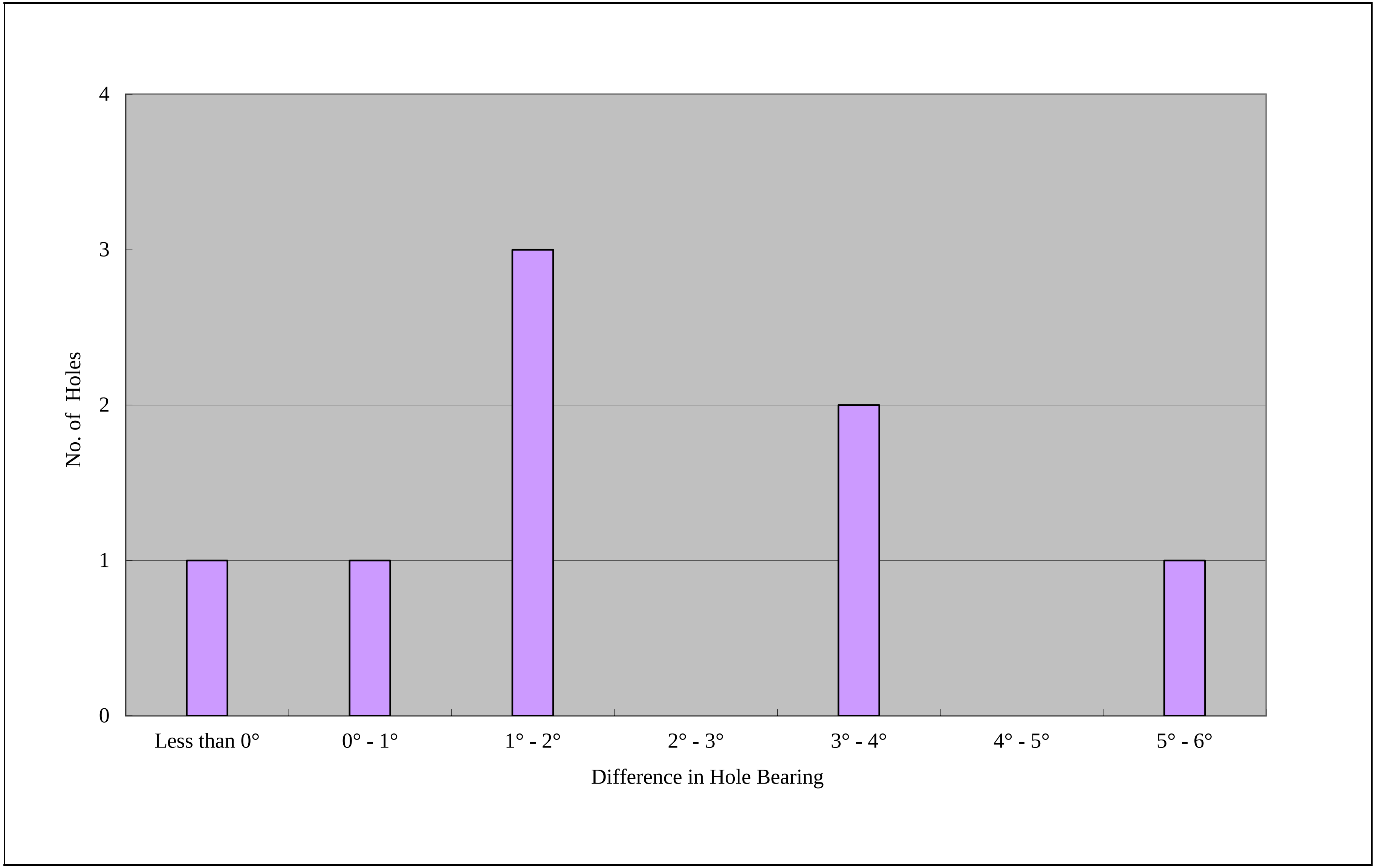

Figure C6 - Difference of Hole Bearings at Hole Bottom on Slope C6

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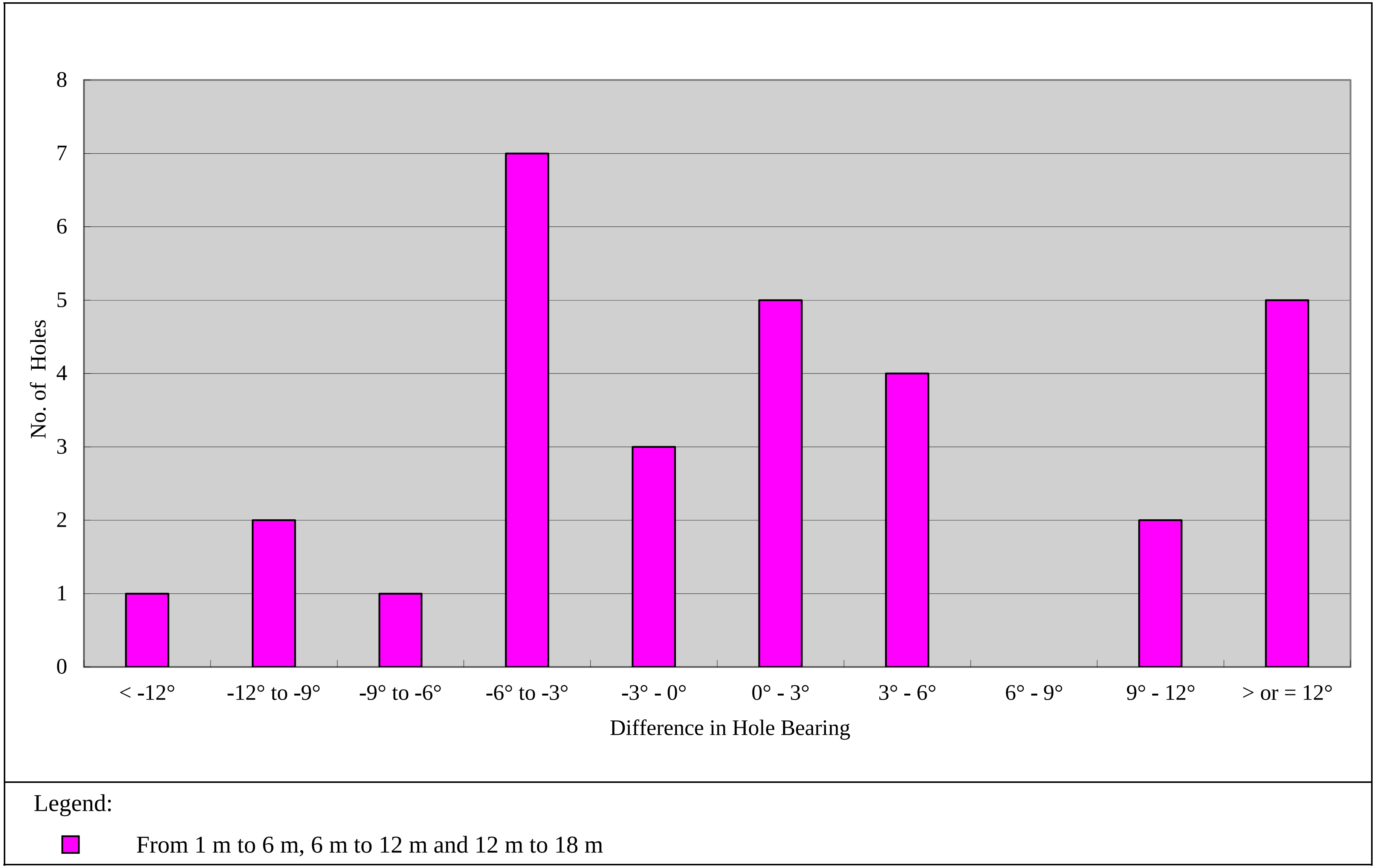

Figure C7 - Difference of Hole Bearings every 6 m on Slope C115

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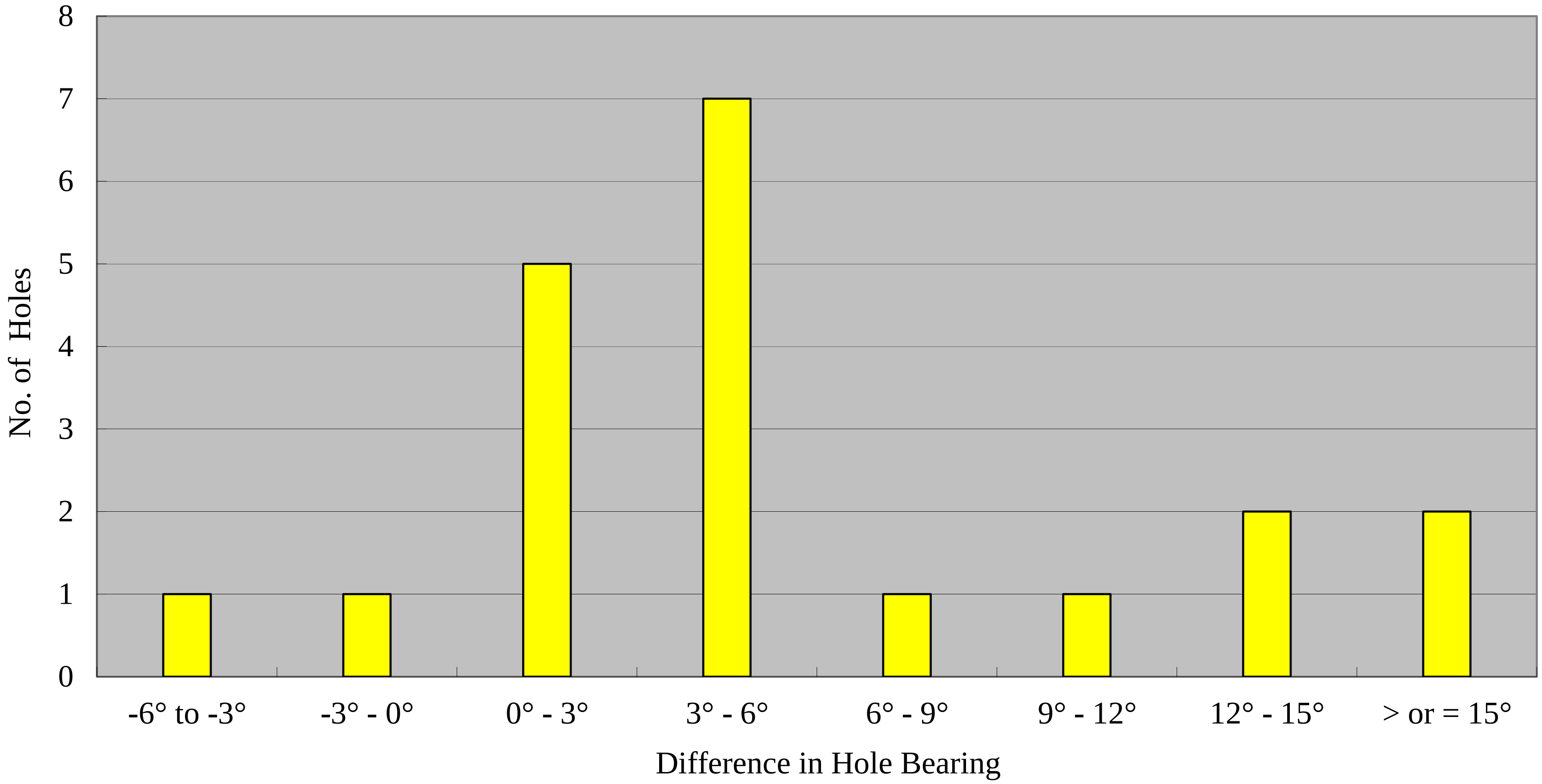

Legend:

From 1 m to 12 m and 6 m to 18 m

Figure C8 - Difference of Hole Bearings every 12 m on Slope C115

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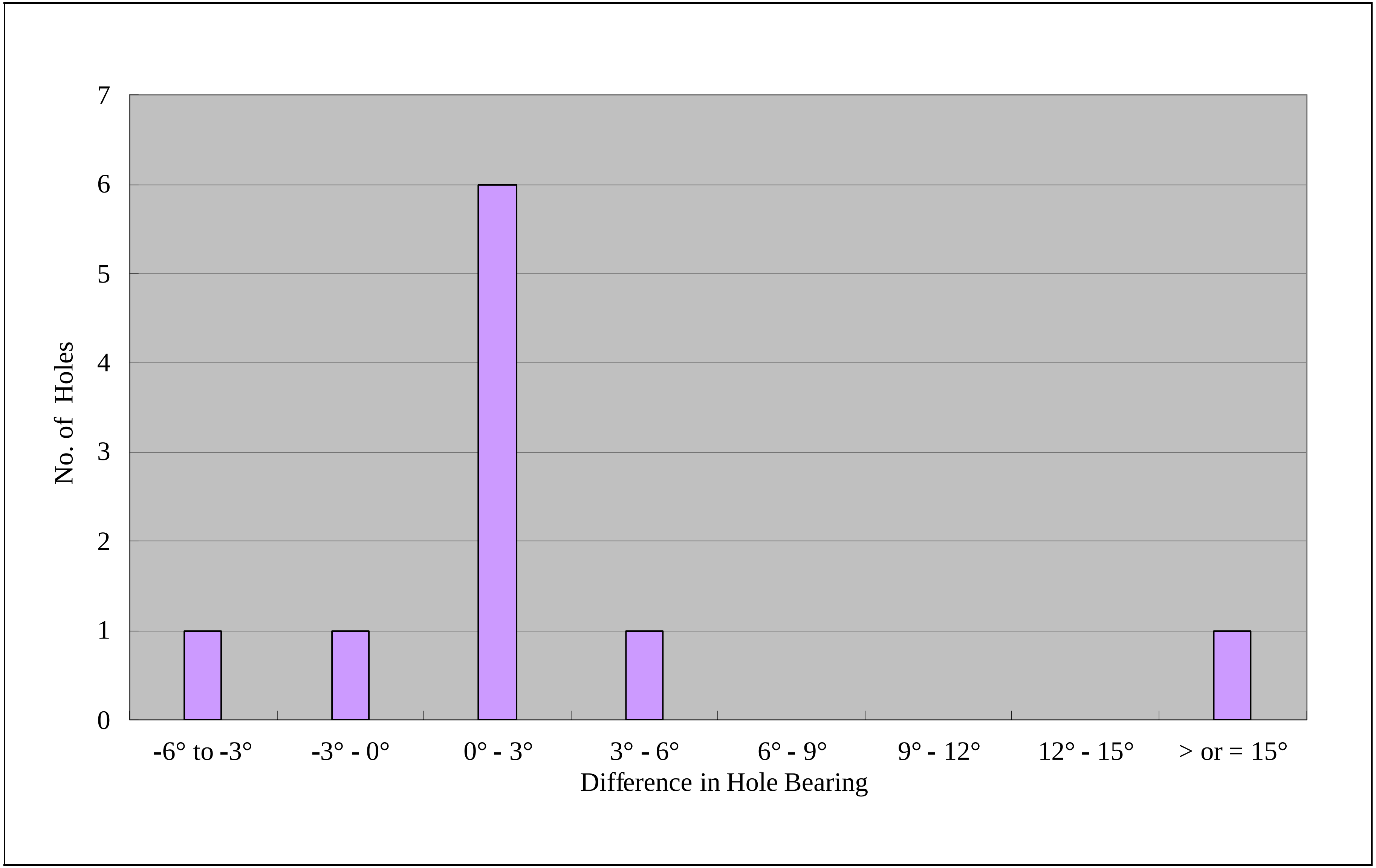

Figure C9 - Difference of Hole Bearings at Hole Bottom on Slope C115

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APPENDIX D

PLOTS OF DIAMETER MEASUREMENT OF SOIL NAILS HOLES ON THE TEN SITES AGAINST THEIR DESIGN VALUES

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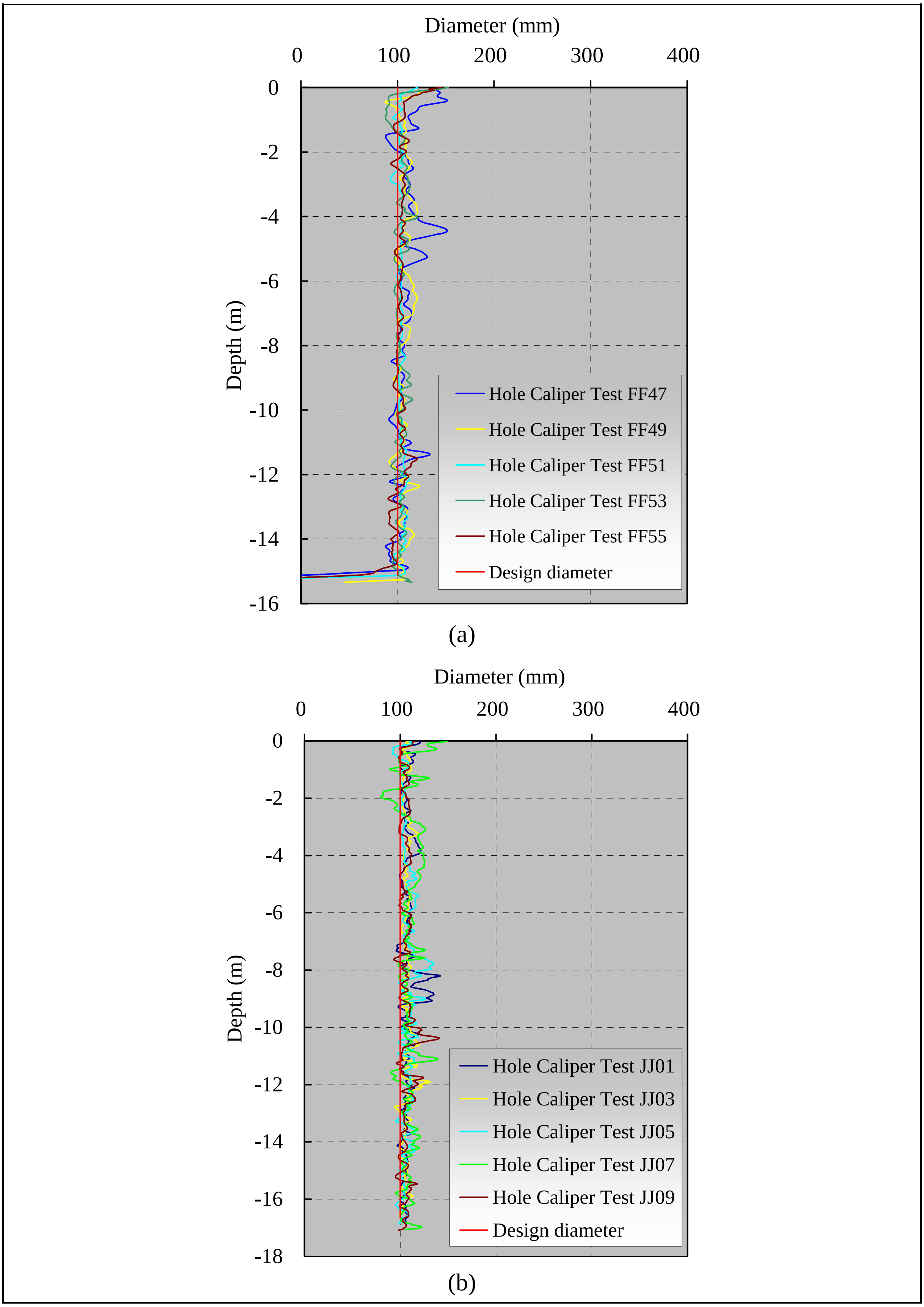

Figure D1 - Diameter Measurements of Ten Drillholes against the Design Value on Slope C101

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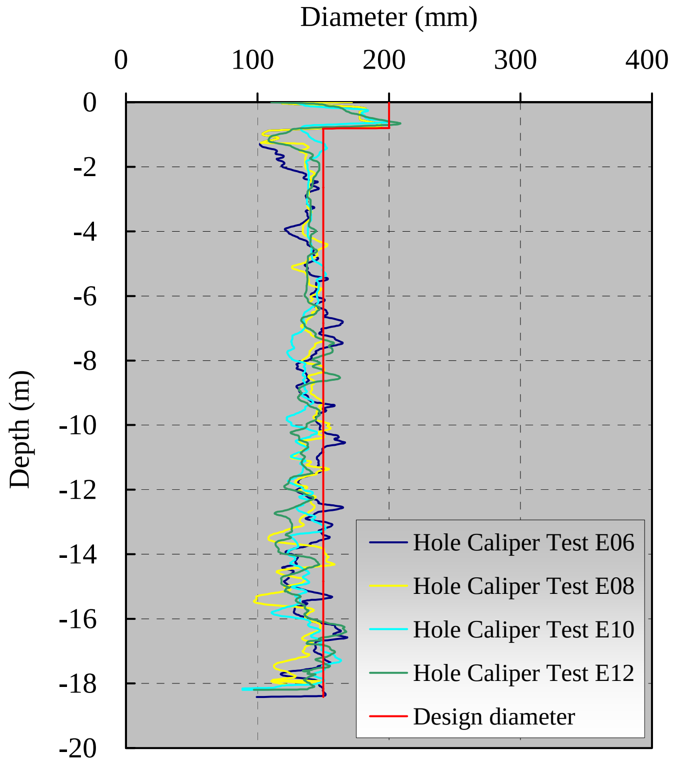
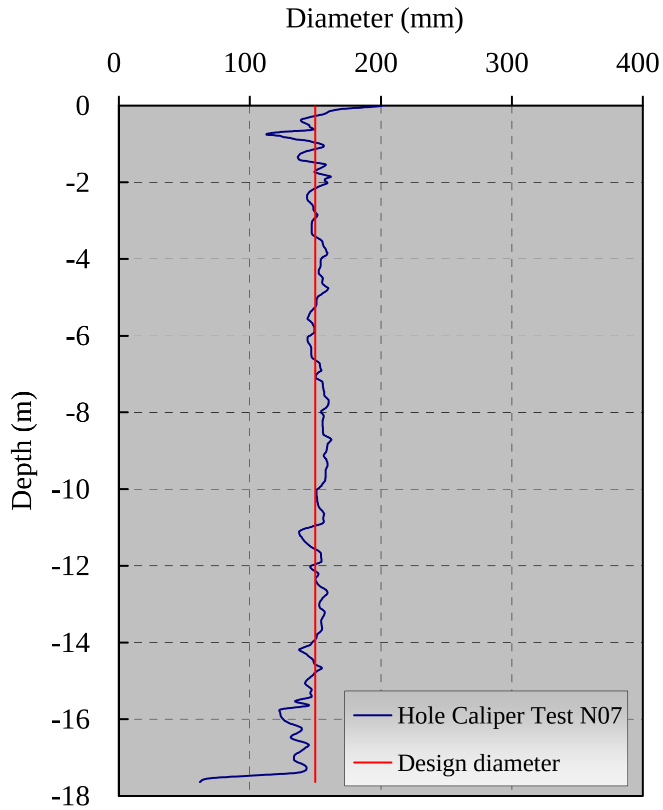


(a)



(b)

Figure D2 - Diameter Measurements of Five Drillholes against the Design Value on Slope C6

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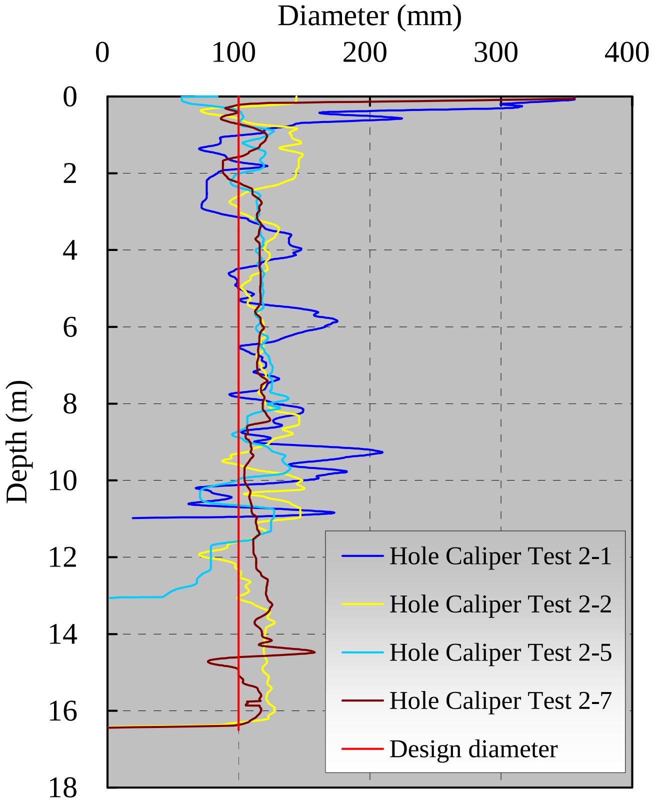

Figure D3 - Diameter Measurements of Four Drillholes against the Design Value on Slope C115

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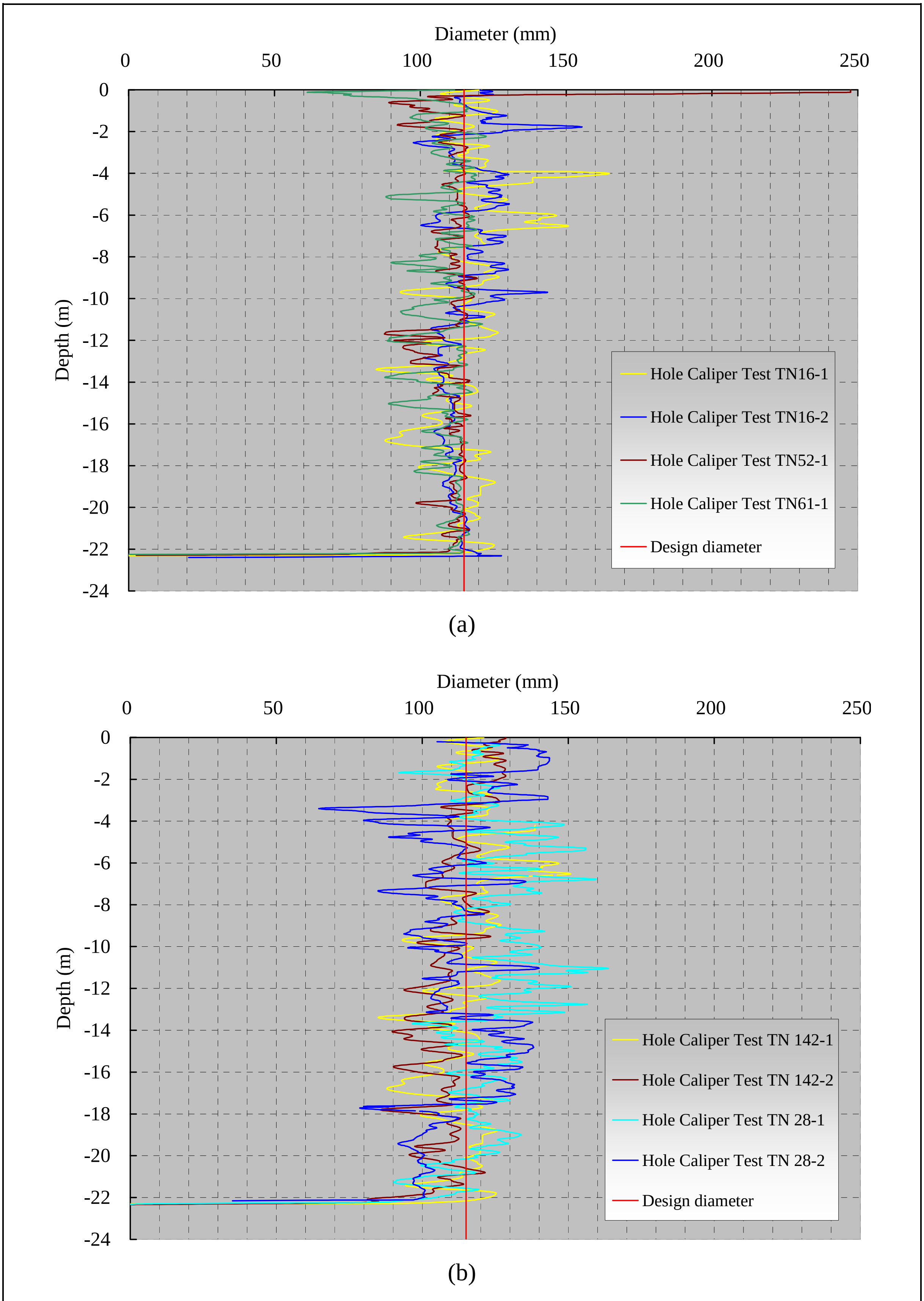

Figure D4 - Diameter Measurements of the Drillholes against the Design Value on slopes C565, FR230, C14, FR22 and F24

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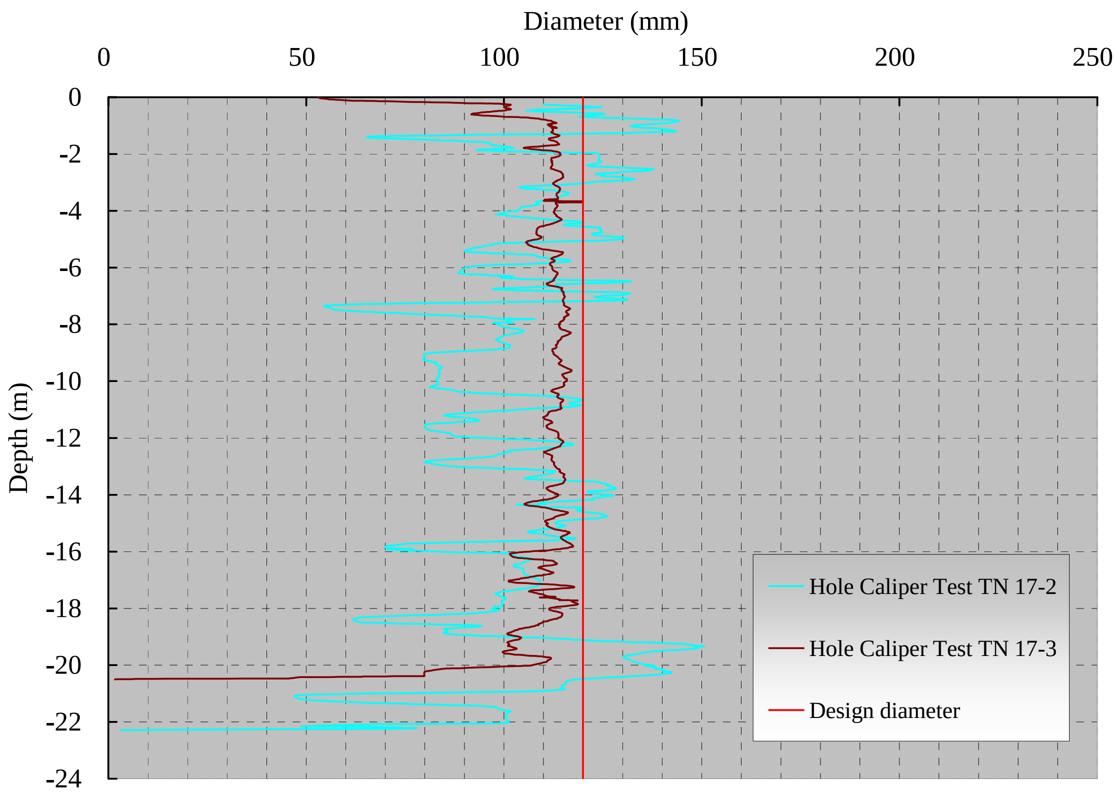

(c)

Figure D5 - Diameter Measurements of the Drillholes against the Design Value on slope FR401

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APPENDIX E

INFORMATION OF DRILLING AND GROUTING OF SOIL NAILS
ON THE TEN SITES

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Table E1 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SE-D/C201

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Corrugated Sheath (Y/N)	Diameter of Sheath	Date of Drilling	Date of Grouting	Drilling Time (min.)	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Estimated Volume of Grout Used (Litre)	Grout Ratio	Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
CC9	100	17	40	20	N	N/A	28/02/2005	03/03/2005	49	15	133.52	302.40	2.26	H/MDV	N	N	N/A	N
CC11	100	17	40	20	N	N/A	28/02/2005	03/03/2005	50	10	133.52	201.60	1.51	H/MDV	N	N	N/A	N
CC13	100	17	40	20	N	N/A	28/02/2005	03/03/2005	58	16	133.52	322.56	2.42	H/MDV	N	N	N/A	N
CC15	100	17	40	20	N	N/A	01/03/2005	N/A	137	N/A	133.52	N/A	0.00	H/MDV	Y	N	N/A	Y
CC17	100	17	40	20	N	N/A	01/03/2005	03/03/2005	67	14	133.52	282.24	2.11	H/MDV	N	N	N/A	N
DD1	100	17	40	20	N	N/A	23/02/2005	25/02/2005	-	11.5	133.52	231.84	1.74	H/MDV	N	N	N/A	N
DD3	100	17	40	20	N	N/A	22/02/2005	25/02/2005	-	10	133.52	201.60	1.51	H/MDV	N	N	N/A	N
DD5	100	17	40	20	N	N/A	22/02/2005	25/02/2005	-	13	133.52	262.08	1.96	H/MDV	N	N	N/A	N
DD9	100	17	40	20	N	N/A	21/05/2005	25/02/2005	-	20	133.52	309.13	2.32	H/MDV	N	N	N/A	N
FF47	100	15	32	20	N	N/A	18/4/2005	22/4/2005	61	12	133.52	241.92	1.81	H/MDG	N	N	N/A	N
FF49	100	15	32	20	N	N/A	19/4/2005	22/4/2005	96	13	133.52	262.08	1.96	H/MDG	N	N	N/A	N
FF51	100	15	32	20	N	N/A	18/4/2005	22/4/2005	40	7	133.52	141.12	1.06	H/MDG	N	N	N/A	N
FF53	100	15	32	20	N	N/A	19/4/2005	22/4/2005	58	8	133.52	161.28	1.21	H/MDG	N	N	N/A	N
FF55	100	15	32	20	N	N/A	19/4/2005	22/4/2005	51	10	133.52	201.60	1.51	H/MDG	N	N	N/A	N
JJ1	100	17	32	20	N	N/A	25/4/2005	29/4/2005	74	19	133.52	383.04	2.87	H/MDG	N	N	N/A	N
JJ3	100	17	32	20	N	N/A	25/4/2005	29/4/2005	93	14	133.52	282.24	2.11	H/MDG	N	N	N/A	N
JJ5	100	17	32	20	N	N/A	25/4/2005	29/4/2005	77	17	133.52	342.72	2.57	H/MDG	N	N	N/A	N
JJ7	100	17	32	20	N	N/A	25/4/2005	29/4/2005	140	21	133.52	423.36	3.17	H/MDG	Y	N	N/A	N
JJ9	100	17	32	20	N	N/A	25/4/2005	29/4/2005	78	14	133.52	282.24	2.11	H/MDG	N	N	N/A	N

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Table E2 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SE-B/C6

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Corrugated Sheath (Y/N)	Diameter of Sheath	Date of Drilling	Date of Grouting	Drilling Time (min.)	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Estimated Volume of Grout Used (Litre)	Grout Ratio	Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
N1	150	18	32	25	Y	75	06/07/2005	-	32.5	-	-	-	-	CDG	-	-	-	-
N3	150	18	32	25	Y	75	06/07/2005	14/07/2005	42.5	9	318.1	320.0	1.01	CDG	N	N	-	N
N5	150	18	32	25	Y	75	06/07/2005	14/07/2005	32.5	10	318.1	368.0	1.16	CDG	N	N	-	N
N7	150	18	32	25	Y	75	06/07/2005	-	33	-	-	-	-	CDG	-	-	-	-
E6	150	18	32	20	Y	75	11/07/2005	14/07/2005	35.5	10	318.1	352.0	1.11	CDG	N	N	1	N
E8	150	18	32	20	Y	75	11/07/2005	14/07/2005	35	9	318.1	316.0	0.99	CDG	N	N	1	N
E10	150	18	32	20	Y	75	11/07/2005	14/07/2005	31.5	10	318.1	389.0	1.22	CDG	N	N	1	N
E12	150	18	32	20	Y	75	11/07/2005	14/07/2005	28	12	318.1	441.0	1.39	CDG	N	N	1	N

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Table E3 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SW-B/FR1

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Corrugated Sheath (Y/N)	Diameter of Sheath	Date of Drilling	Date of Grouting	Drilling Time (min.)	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Estimated Volume of Grout Used (Litre)	Grout Ratio	Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
A1	150	19	40	25	Y	110	09/09/2005	14/09/2005	44.5	9	335.8	421.740	1.26	Fill, CDG	N	N	6	N
A3	150	19	40	25	Y	110	08/09/2005	14/09/2005	35	10	335.8	468.600	1.40	Fill, CDG	N	N	6	N
A5	150	19	40	25	Y	110	07/09/2005	14/09/2005	36	10	335.8	468.600	1.40	Fill, CDG	N	N	6	N
A7	150	19	40	25	Y	110	09/09/2005	14/09/2005	36.5	8.5	335.8	398.310	1.19	Fill, CDG	N	N	6	N
B4	150	19	40	25	Y	110	30/08/2005	06/09/2005	26	8	335.8	374.880	1.12	Fill, CDG	N	N	6	N
B8	150	19	40	25	Y	110	05/09/2005	08/09/2005	36	9	335.8	421.740	1.26	Fill, CDG	N	N	3	N
B10	150	19	40	25	Y	110	29/08/2005	01/09/2005	35	9.5	335.8	445.170	1.33	Fill, CDG	N	N	6	N
B12	150	19	40	25	Y	110	03/09/2005	08/09/2005	41	10.5	335.8	492.030	1.47	Fill, CDG	N	N	6	N
B14	150	19	40	25	Y	110	29/08/2005	01/09/2005	29	7.5	335.8	351.450	1.05	Fill, CDG	N	N	6	N
B16	150	19	40	25	Y	110	27/08/2005	01/09/2005	52	7.5	335.8	351.450	1.05	Fill, CDG	N	N	6	N

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Table E4 - Information of Drilling and Grouting of Soil Nails on Slope No. 7SW-C/C115

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Corrugated Sheath (Y/N)	Diameter of Sheath	Date of Drilling	Date of Grouting	Drilling Time (min.)	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Estimated Volume of Grout Used (Litre)	Grout Ratio	Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
R6--6	100	18	32	15	N	N/A	25/05/2006	03/06/2006	-	11	141.370	167.06	1.18	CDG	N	N	N/A	N
R6--7	100	18	32	15	N	N/A	25/05/2006	03/06/2006	-	13	141.370	197.43	1.40	CDG	N	N	N/A	N
R6--8	100	18	32	15	N	N/A	25/05/2006	03/06/2006	-	14	141.370	212.62	1.50	CDG	N	N	N/A	N
R6--9	100	18	32	15	N	N/A	25/05/2006	03/06/2006	-	9.5	141.370	144.28	1.02	CDG	N	N	N/A	N
R6--10	100	18	32	15	N	N/A	26/05/2006	03/06/2006	22	10	141.370	151.87	1.07	CDG	N	N	N/A	N
R6--11	100	18	32	15	N	N/A	26/05/2006	03/06/2006	22.5	10.5	141.370	159.46	1.13	CDG	N	N	N/A	N
R6--12	100	18	32	15	N	N/A	26/05/2006	03/06/2006	16	9.5	141.370	144.28	1.02	CDG	N	N	N/A	N
R6--13	100	18	32	15	N	N/A	26/05/2006	03/06/2006	18	9.5	141.370	144.28	1.02	CDG	N	N	N/A	N
R6--14	100	18	32	15	N	N/A	27/05/2006	03/06/2006	-	11	141.370	167.06	1.18	CDG	N	N	N/A	N

Table E5 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SE-C/C14

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN16/1	115	22.5	32	10	14.3.05	90	16.3.05	15	228.51	332.5	1.46	315	1.38	CDG	N	N/A	Not used	N/A
TN16/2	115	22.5	32	10	11.3.05	120	16.3.05	10.5	228.51	262.5	1.15	250	1.09	CDG	N	N/A	Not used	N/A

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Table E6 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SE-C/FR22

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN28/1	115	22.5	32	10	4.3.05	120	9.3.05	11	228.51	358.8	1.57	329	1.44	Fill & CDG	N	N/A	Not used	N/A
TN28/2	115	22.5	32	10	4.3.05	120	7.3.05 18.3.05	40 25	228.51	1750	7.66	1739	7.61	Fill & CDG	N	N/A	Not used	N/A

Table E7 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SW-A/C565

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN52/1	115	22.5	32	10	2.2.05	70	4.2.05	7	228.51	192.5	0.84	190	0.83	Fill & CDT	N	N/A	Not used	N/A

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Table E8 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SW-A/F230

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN61/1	115	22.5	32	10	1.2.05	75	4.2.05	8	228.51	210	0.92	213	0.93	Fill & CDT	N	N/A	Not used	N/A

Table E9 - Information of Drilling and Grouting of Soil Nails on Slope No. 11SW-D/FR401

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN17/2	120	22.5	32	10	25.1.05	192	27.1.05	11	248.81	192.5	0.77	183	0.74	Fill, Coll & CDG	N	N/A	Not used	N/A
TN17/3	120	22.5	32	10	26.1.05	85	27.1.05	7.5	248.81	175	0.70	169	0.68	Fill, Coll & CDG	N	N/A	Not used	N/A

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Table E10 - Information of Drilling and Grouting of Soil Nails on Slope No. 15NE-A/F24

Soil Nail No.	Drillhole Diameter (mm)	Nail Length (m)	Bar Size (mm)	Inclination (°)	Date of Drilling	Drilling Time (min.)	Date of Grouting	Grouting Time (min.)	Theoretical Volume of Grout (Litre)	Measured by Conventional Method		Measured by Digital Flowmeter		Material Types e.g. CDG	Abnormal Drilling Rate (Y/N)	Water Seepage (Y/N)	Length of Casing used (m)	Hole Collapse (Y/N)
										Estimated Volume of Grout Used (Litre)	Grout Ratio	Measured Volume of Grout Used (Litre)	Grout Ratio					
TN142/1	115	22.5	32	10	11.3.05	210	15.3.05	10.5	228.51	271.3	1.19	259	1.13	Fill & CD Eutaxite	N	N/A	Not used	N/A
TN142/2	115	22.5	32	10	12.3.05	90	15.3.05	10	228.51	253.8	1.11	234	1.02	Fill & CD Eutaxite	N	N/A	Not used	N/A

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部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

<u>書面訂購</u>
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

<u>或</u>

- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址爲 http://www.bookstore.gov.hk
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
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地政總署測繪處
電話: 2231 3187
傳真: (852) 2116 0774

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

<u>地質調查報告及地質圖</u>:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

<u>其他免費刊物</u>:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5346
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

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