UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF SURVEYING

29.032/29.103G

PRACTICAL: Settlement Survey Retaining Wall, Library Road

1. AIM

To determine the relative position of benchmarks along Library Road and (in future) to determine likely settlements of individual bolts with respect to the reference bolts.

2. EQUIPMENT (per Group)

1 New Zeiss NI2 or NI1 Automatic Levelling Instrument
1 10mm Range Plane Parallel Plate Micrometer
1 Zeiss Tripod
1 Wild Invar Staff (3m) (Grad. 0-300cm, 300-600cm)
with cm graduation (10mm) (→no 'NEDO' staves!)
1 Spot Bubble (+ rubber bands) if not already on staff
2 Ranging Rods
1 Clipboard
1 Pocket Tape
1 Thermometer

Demonstrator:

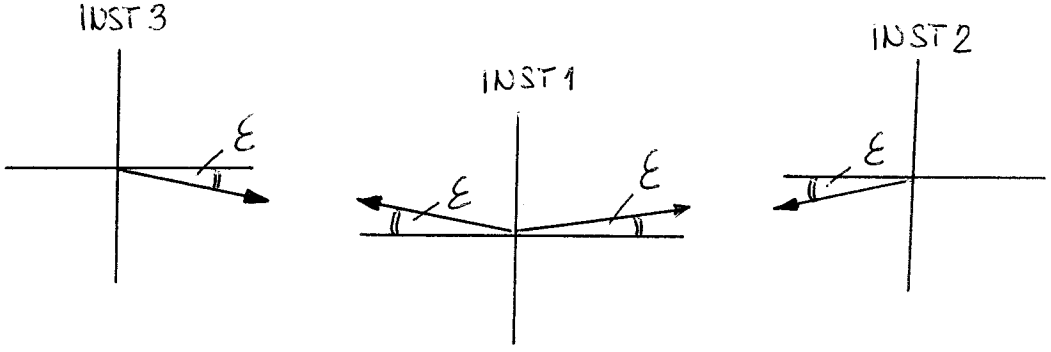
Adjustment Pins (level adjustment)
2 Screw Drivers (bubble adjustment)

3. EXERCISE

3.1 Near the store, set up 3 instruments on the circumference of a circle of ~ 1m diameter. All telescopes in same level. Any other instruments to be set up on second circle going through two of the first 3 instruments. Telescope again in same level. All instruments in shade.

3.2 Check and adjust (demonstrator) spot bubble of NI2.

3.3 Adjust the line of sight of first three levels to horizontal, using the technique described in appendix:



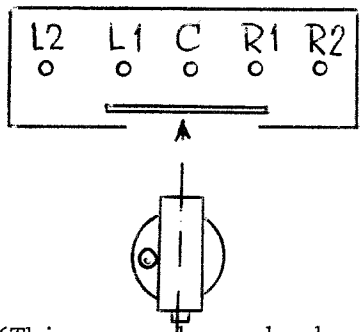
Adjust level J_4 to J_3 and check with J_2 (or J_1).
(Adjust level J_5 to J_1 and check with J_2 (or J_3).
1ST NOTE: Do not fix plane/plates for this adjustment!
2ND NOTE: All adjustments by demonstrator!

3.4 (Concurrently with (3.1) to (3.3))

On the staff bubble calibration facility near the Survey Store, GAS Building, set-up the staff and attach the staff bubble. See Appendix for detailed procedure.

3.5 On U50, U5, 302, 15, 21:

Set up levelling instrument 4m from staff on bolt. Centre staff over bolt and level bubble (of staff) accurately and support staff with 2 ranging rods. Attach plane plate micrometer to instrument, level and read to staff. Measure width (w) of staff.



Shift staff $\frac{w}{5}$ to left, support now at R1. Read and book both scales.

Shift staff $\frac{w}{5}$ to left → R2 is now support. Read both scales.

Continue so that you have finally the following

Sequence: C→R1→R2→R1→C→L1→L2→L1→C→R2→C→L2→C.

(This procedure checks the bottom face of the staff is horizontal and even. In the level run to follow, most set ups will be made on positions L2 and R2; therefore, there is possibly a necessity to apply corrections (to centre).

3.6 Levelling-Run-Allocation:

1st Group: 10 →11 →12 →13 →16 →14 →101 →15 →102 →103 →104 →105 →21 → 22 →23 →22 →24 →25 and back

2nd Group: 25 →24 →22 →23 →22 →21 →105 →104 →103 →102 →15 →101 →14 → 16 →13 →12 →11 →10 and back

3rd Group: 203 →204 →105 →21 →22 →23 →22 →24 →25 →back to 203 →202 → 201 →302 →301 →14 →16 →13 →12 →11 →10 and back to 203

4th Group: 202 →201 →302 →301 →14 →16 →13 →12 →11 →10 →back to 202 → 203 →105 →21 →22 →23 →22 →24 →25 and back to 202

3.7 Levelling Technique:

(i) Set up levelling mid-way between the bolt (See ▲ mark on ground). Do change focus between forward + backward NOT or only if really necessary.

(ii) Set up staff, using either of L2, L1, C, R1, R2 support point. BOOK WHICH ONE YOU USE FOR EVERY SHOT!!

(iii) Sequence:

- level spot bubble while pointing to B.S.
- read B.S. (I) (scale 0-300cm)
- read F.S. (I)
- level spot bubble while pointing to F.S.
- read F.S. (II) (scale 300-600cm)
- read B.S. (II)

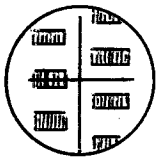
NOTE: This technique eliminates obliquity of horizon for every single set up.

(iv) Eliminate hysteresis with quick turn on slow motion screw before every reading. (Check also if comp. reacts in doing so!).

(v) Micrometer drum is graduated to 0.5mm, estimate $\frac{1}{10}$ of grad. inverval!. The $\frac{1}{100}$mm are therefore either 0 or 5.

Booker to compute immediately BSII - BSI and FSII - FSI. Should not differ by more than 0.3mm. Bookings in cm (centimetre).

(vi) Parallax to be avoided in all circumstances.

(vii) Pointing 

(viii) Avoid shocks while transporting and setting up instrument.

(ix) Measure air temperature on every staff point.

3.8 Work out BI-FI, BII-FI and ΔH and check if ΔH agree in forward and backward run. If difference (FORW - BACKW) > 0.3mm → re-measure the leg.

4. REPORT

4.1 Check all field computation on field form.

4.2 List all differences d between pairs of BI-FI and BII-FII. Compute:

$$S_{\overline{\Delta h}} = \pm\sqrt{\frac{\Sigma d^2}{4n}}$$

n = number of pairs.

$S_{\overline{\Delta h}}$ = st. dev. of a height difference, being the mean of BI-FI and BII-FII.

4.3 Correct all ΔH for the effect of a non-horizontal bottom face of staff. Derive first a correction table from measurements (3.5).

4.4 List ΔH forward and backward and $\overline{\Delta H}$ (mean) and compute the differences d and:

$$S_{\overline{\Delta H}} = \pm\sqrt{\frac{\Sigma d^2}{4n}}$$

where n = number of legs
$S_{\overline{\Delta H}}$ = st. dev. of mean height diff. (forward and backward).

4.5 Comment on the difference of $S_{\overline{\Delta h}}$ and $S_{\overline{\Delta H}}$. What is the theoretical relationship between the two st. dev.?

4.6 Derive the standard deviation of the total height difference BM10 and BM25 (double run levelling). Using the total length of the levelling run (from plan), derive the standard deviation of a 1km double run levelling corresponding to your measurement precision.

Compute a second standard deviation of a 1km double levelling run on the basis of $S_{\overline{\Delta H}}$ (see 4.4), assuming all sighting distances to be 25m long (viz. 20 height differences to the km).

Compare the above km precisions with the manufacturer's specifications:

Zeiss NI1 ±0.2mm
Zeiss NI2 ±0.3mm (with plane plate micrometer)

Comment on your results and the differences to the expected precisions.

4.7 Starting with the "Epoch 00" value for BM10, compute all elevations of your levelling run benchmarks. Compute the differences "01" minus "00" for all bench marks (in millimetre). Plot the differences "01" minus "00" against height differences from BM10, using different symbols for BMs with two and three digit numbers.

Considering only BMs with two digit numbers (likely stable BM), compute an average value of the differences "01 minus 00" and add the negative value to all heights (datum shift). (If the difference "01-00" versus height difference plot exhibits a strong linear trend, you may consider using a linear regression instead of the simple datum shift).

4.8 With the datum shifted (and possibly scaled) new heights, compute the new differences "01 minus 00". From the new differences "01-00" of the two digit BMS, compute an average value of the discrepancies S_o as follows:

$$S_o = \pm\sqrt{\frac{\Sigma d^2}{n-u}}$$

where d = "01" minus "00" (in mm).

n = number of differences considered (~ 10).

u = 1 in the case of a simple datum shift.

u = 2 in the case of an applied linear regression.

Compare now the (new) differences "01-00" of <u>all</u> BM- with S_o. Points with differences "01-00" > 3 S_o can be considered to have moved. Should the diff. of two digit BM exceed the 3 S_o limit, compute a new S_o without these points and make a new analysis.

Three digit BMs found to be stable may be included in a subsequent computation of S_o and final analysis.

4.9 Transfer the heights of the epoch measured by you in the attached table and mark the significant differences "01 minus 00" with an asterisk.

4.10 Inspect unstable marks in the field and comment on the possible reasons of their instability. Discuss settlement patterns, if such are emerging. Consult also with a group who did run the other level of BM to establish profile patterns (viz. 101 →201, e.g.).

4.11 Consult 29.005 report writing instructions for overall presentation of report. (NO report to client).

NOTE: In paragraphs 4.7, 4.8, 4.9 replace epoch "01" by the number of the epoch actually measured by your group, viz. 1982 = "02", 1983 = "03".....
In paragraphs 4.7, 4.8, 4.9 replace epoch "00" by epoch "03", if your group measured one of the following epochs: '04','05','06'.

J.M. RÜEGER.
(9 October, 1984).

APPENDIX: ADJUSTMENT OF INVAR STAFF BUBBLE

Set the rod up vertically in relation to horizontal plane (surface of the earth) using a plumbob.

Eliminate any displacement of the level bubble with the aid of the outer adjusting screws. Do not disturb the central retaining screw.

APPENDIX: THREE INSTRUMENT METHOD FOR THE ADJUSTMENT OF LINE OF SIGHT TO HORIZONTAL

Text from Zeiss NI1 Handbook. Use three NI2 and replace the term "NI1" in the text by NI2. The method is based on the so-called Gauss-collimation-technique. Set telescope focus to ∞ by sighting to a point as far away as possible.

1. Three-instrument Method:

   If another two levels (e.g. ZEISS Ni2) are available, the line of sight can be levelled in a minimum of space.

2. Set the instruments up on the circumference of a circle, spaced a few decimetres apart, and adjust the centres of their objectives so that they are roughly at a common level. It is advisable to number the instruments (J_1, J_2, J_3). In the adjustment procedure explained below, the Ni1 precision level will be designated as J_1 and the other two levels as J_2 and J_3 respectively.

3. Centre the circular level. Loosen the clamp on the adjusting wedge of the ZEISS Ni1. With the other two instruments (if not ZEISS Ni1) make reticule adjusting screws accessible by removing the corresponding covers.

4. Set telescope of J_1 approximately to ∞. Turn the focussing knobs of ZEISS Ni1 and Ni2 fully counterclockwise, then turn them back through a quarter revolution.

5. The Ni1 plane-parallel plate need not be in a special position.

6. Focus the instrument J_2 on the crosshairs of instrument J_1 (Ni1), taking care that the setting is made against a bright background, e.g. a sheet of light paper. Use the adjusting screw of instrument J_2 to bring the horizontal lines of the two reticules into coincidence.

7. Focus instrument J_3 on instrument J_1 in the same manner as instrument J_2, as described under 6, and obtain coincidence with crosshairs of J_3.

8. Point the objective of instrument J_2 at that of J_3. Focus instrument J_3 on the crosshairs of J_2 and eliminate one half of any level difference between the horizontal lines as well as focus differences in each of the instruments.

9. Point instrument J_1 at J_3 and obtain coincidence between its horizontal lines and those of J_3 by turning the adjusting wedge.

10. After this operation, the collimation lines of the three instruments are horizontal.

    Next, check the vertical position of the crosshairs of J_1 and J_2. Should a difference exceeding one line width be noted, then the procedure described under 6. to 10. must be repeated.

S E T T L E M E N T S U R V E Y

RETAINING WALL, LIBRARY ROAD, U.N.S.W.

DATUM: APPROX. A.H.D. BASED ON U50 = 45.42 m

MEASURED BY STUDENTS OF SUBJECT 29.032, PRECISE SURVEYS IN INDUSTRY AND ENGINEERING, SCHOOL OF SURVEYING, UNIVERSITY OF NEW SOUTH WALES.

$S\Delta h$ = standard deviation (average) of the height difference between two BM's.
$S\Delta H$ = standard deviation of the height difference between BM10 and BM25.

	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
10	37.3258	±0.0	37.3258	+0.4	37.3262	+0.3	37.3261
11	37.3005	+0.1	37.3006	+0.1	37.3006	+0.1	37.3006
12	37.2817	+0. 4	37.2821	+0.5	37.2822	+0.5	37.2822
13	37.2924	+0.4	37.2928	+0.5	37.2929	+0.4	37.2928
16	---		37.6345	(±0.0)	37.6345	+9.6	37.6441
14	39.4949	+0.1	39.4950	+0.1	39.4950	+0.1	39.4950
101	40.4199	±0.0	40.4199	+0.1	40.4200	±0.0	40.4199
15	41.5283	-0.2	41.5281	±0.0	41.5283	±0.0	41.5283
102	41.9718	±0.0	41.9718	-0.1	41.9717	-0.3	41.9715
103	43.5289	±0.0	43.5289	±0.0	43.5289	-0.2	43.5287
104	45.0436	-0.2	45.0434	-0.2	45.0434	-0.4	45.0432
301	39.3811	+0.1	39.3812	+0.1	39.3812	+0.1	39.3812
302	41.8686	-1.0	41.8676	-2.3	41.8665	-2.4	41.8664
201	44.3397	±0.0	44.3397	-0.1	44.3396	+0.1	44.3398
202	45.5753	+0.1	45.5754	±0.0	45.5753	+0.3	45.5756
203	46.2153	-0.2	46.2151	-0.1	46.2152	+0.1	46.2154
204	46.8166	-0.1	46.8165	-0.1	46.8165	+0.2	46.8168
105	46.8977	-0.1	46.8976	-0.2	46.8975	±0.0	46.8977
21	49.1320	±0.0	49.1320	±0.0	49.1320	+0.1	49.1321
22	51.2691	±0.0	51.2691	+0.1	51.2692	+0.1	51.2692
23	50.1204	+0.1	50.1205	+0.1	50.1205	+0.1	50.1205
24	52.0513	±0.0	52.0513	±0.0	52.0513	±0.0	52.0513
25	52.4009	+0.1	54.4010	+0.1	52.4010	±0.0	52.4009
	(mm)		(mm)		(mm)		(mm)
$S\Delta h$	±0.07		±0.06		±0.04		±0.04
$S\Delta H$	±0.31		±0.26		±0.15		±0.14
BM	EPOCH 00 24.9-28.10.80	01-00	EPOCH 01 14.8-3.9.81	02-00	EPOCH 02 11.8-7.9.82	03-00	EPOCH 03 12.5-1.6.83

S E T T L E M E N T S U R V E Y

RETAINING WALL, LIBRARY ROAD, U.N.S.W.

DATUM: APPROX. A.H.D. BASED ON U50 = 45.42 m

MEASURED BY STUDENTS OF SUBJECT 29.032, PRECISE SURVEYS IN INDUSTRY AND ENGINEERING, SCHOOL OF SURVEYING, UNIVERSITY OF NEW SOUTH WALES.

$S\Delta h$ = standard deviation (average) of the height difference between two BM's.
$S\Delta H$ = standard deviation of the height difference between BM10 and BM25.

	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
10	37.3261	±0.0	37.3261	±0.0	37.3261		
11	37.3006	±0.0	37.3006	+0.1	37.3007		
12	37.2822	-0.2	37.2820	+0.2	37.2822		
13	37.2928	-0.1	37.2927	+0.1	37.2928		
16	37.6441	-16.1	37.6280	+0.2	37.6282		
14	39.4950	±0.0	39.4950	-0.1	39.4949		
101	40.4199	-0.5	40.4194	+0.8	40.4202		
15	41.5283	-0.1	41.5282	+0.2	41.5284		
102	41.9715	+0.3	41.9718	-0.1	41.9717		
103	43.5287	+0.3	43.5290	±0.0	43.5290		
104	45.0432	+0.4	45.0436	-0.2	45.0534		
301	39.3812	-0.7	39.3805				
302	41.8664	-1.3	41.8651				
201	44.3398	-0.7	44.3391				
202	45.5756	-0.3	45.5753				
203	46.2154	-0.3	46.2151				
204	46.8168	-0.2	46.8166				
105	46.8977	±0.0	46.8977	±0.0	46.8977		
21	49.1321	±0.0	49.1321	+0.1	49.1322		
22	51.2692	±0.0	51.2692	±0.0	51.2692		
23	50.1205	+0.3	50.1208	±0.0	50.1208		
24	52.0513	±0.0	52.0513	-0.1	52.0512		
25	52.4009	-0.1	52.4008	+0.1	52.4009		
	(mm)		(mm)		(mm)		(mm)
$S\Delta h$	±0.04		± 0.06		±0.05		
$S\Delta H$	±0.14		± 0.25		±0.21		
BM	EPOCH 03 12.5-1.6.83	04-03	EPOCH 04 18.-20.9.84	05-04	EPOCH 05 12.9.86		