Topic 4

Case Studies

Contents

Case Study No. 1

Collins Constructions have won the tender for the construction of a 40 km section of the Mt Barker highway. The site is about 100 km from the nearest township, Moreton. An old quarry adjoining the site is still operated by Mt Barker Quarries (MBQ), who hold current Main Roads certification. Because of their location and certification, Collins selected MBQ as a supplier.

A contract to supply 10 and 20 mm cover aggregate to the project was duly signed. Collins' CQR obtained a copy of the certificate and forwarded it to the project superintendent on a Monday; this was 10 days before the company was to start stockpiling material on site. On receiving the certificate, the superintendent advised that they still had not received the 40 kg samples for each aggregate, for testing, as required under specification.

The Collins CQR immediately contacted the quarry manager to find out why the samples had not been delivered as previously arranged. The quarry manager said that the person nominated for the task had been off sick and everybody thought he had delivered the samples. The manager immediately arranged for samples to be delivered to the superintendent.

The superintendent gave approval for use of the aggregates on the Friday and the CQR advised the project manager of this approval.

The 10 and 20 mm aggregates required for the project were delivered and stockpiled in suitable areas under the direction and supervision of the road foreman, to ensure they complied with the specification over the next two weeks. The foreman arranged for the stockpiles to be randomly sampled and tested after each delivery run to ensure compliance.

During the third week, unseasonable rains closed down construction over a three-day period; the next two days were spent removing excess water and restoring the site.

Deliveries from the quarry were resumed after a four-day period, as the quarry manager advised that the rain had caused flooding and the area had to be pumped. Due to the delay from the rain, the project manager requested additional deliveries. He intended to increase the works program by an additional two hours each day for the next 3 weeks. The quarry manager advised that this would not be a problem.

The increased activity meant additional stockpiles were created in preparation for the heavier demand on material, and the existing stockpiles were quickly run down first.

On the first two days of the new program, the quarry continued to deliver new material to the stockpiles, while existing stockpiles were run down. In that time, no sampling and testing were carried out, as the person allocated by the foreman for the task had injured himself during the site cleanup and was off work. This resulted in the road crew being short staffed and under pressure to comply with the new program schedule.

At this time, the superintendent carried out a random inspection of the new stockpiles to ensure they complied with specification. At the same time, the 20 mm aggregate was sampled and sent for testing. The sample was found not to comply with the grading curve as there were too many fines. Further sampling and testing of the stockpiles found the newer stockpiles did not comply and a non-conformance was issued to Collins Constructions. The CQR immediately advised the project manager and quarry manager and arranged a meeting that afternoon with the quarry manager.

After questions were asked at the meeting, it became apparent that the quarry had:

- not sampled and tested the new material, as all personnel were being used to achieve the increased delivery targets
- taken the material from the western face and not the northern face as previously used, due to the area still being partially flooded.

The CQR also noted that the quarry certification was only for materials taken from the northern face of the quarry and specifically stated that material on the western face was not suitable and could not be used on the job.

The CQR advised the project manager of the extent of the problem and the project manager initiated a site meeting with all parties to seek a resolution to the non- conformance.

It was agreed after extensive discussion that the material was non-conforming and could not be reprocessed to a conforming product. The material would have to be removed at the supplier's cost.

The quarry manager advised that the northern face was now available to process material. In response and as part of the corrective measures, the superintendent required the quarry to sample and test the material, and provide results, every day for the next two weeks. Collins were to provide the results of an independent testing program over the same period. These results would verify compliance. A review of the material would be undertaken at the end of this period with a more relaxed testing program possible thereafter.

The contractor immediately requested an extension of time of 5 days due to the delays; after considering the facts of the case, the superintendent reduced this to 3 days.

Case Study No. 2

Using a Frequency Diagram

Cement is used in the stabilisation of a sub-grade on which a concrete pavement for an airfield is to be constructed. The strength of the sub-grade when stabilised using 2% cement by weight achieves the specified unconfined compression strength of 0.75 MPa (as determined by test).

The following cement contents were obtained from 21 samples of the stabilised soil:

2.0, 2.1, 2.2, 1.9, 2.3, 2.1, 2.2, 2.1, 2.3, 2.0, 2.1, 1.8, 2.2, 1.9, 2.1, 2.0, 2.2, 2.1, 1.9, 2.0, 2.4.

The range of the results is from 1.8 to 2.4%. We therefore set up a table with increments of 0.1% within the limits of the range, and count the number of cement contents recorded under each value. (In this type of chart, count the number of occurrences of each value by placing a tick mark ✓ each time).

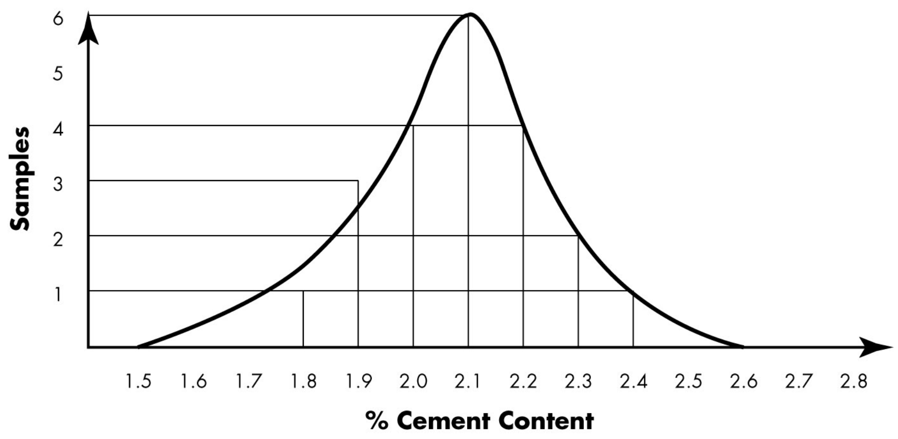
1.8	1.9	2.0	2.1	2.2	2.3	2.4	%
✓	✓	✓	✓	✓	✓	✓	
	✓	✓	✓	✓	✓		
	✓	✓	✓	✓			
		✓	✓	✓			
			✓				
			✓				
1	3	4	6	4	2	1	*No. of samples*

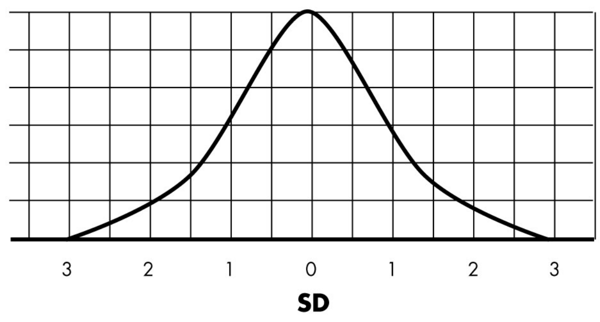
The next step is to draw a graph with cement content (%) as the horizontal or x-axis, and number of samples as the vertical or y-axis.

The graph has a bell shape and is called a normal curve. Graphs that show the number of measurements having a given property are often of this shape. For example, if we plot the height measurements of 1000 people against the number of people, the result is almost always a bell shape.

The second graph shows the mean in the centre with three standard deviations marked off on either side.

Although the curve extends (at least in theory) from minus to plus infinity, most of the area under it is within three standard deviations on either side of the mean.





Case Study No. 3

Calculating Standard Deviation

In the example shown in Case Study No. 2, the mean cement content is:

Show divisions below as formulas:

$$\frac{\text{Sum of cement content percentages}}{\text{Number of samples}} =$$

$$= \frac{2.0 + 2.1 + 2.2 + 1.9 + 2.3 + 2.1 + 2.2 + 2.1 + 2.3 + 2.0 + 2.1 + 1.8 + 2.2 + 1.9 + 2.1 + 2.0 + 2.2 + 2.1 + 1.9 + 2.0 + 2.4}{21}$$

$$= \frac{43.9}{21}$$

= 2.09%.

There are two ways to show how widely the results are spread around the mean:

- Use a range diagram (see next page)
- Calculate the standard deviation.

The calculation for standard deviation involves the following steps:

- List the individual measurements of cement content (see column 1 next page)
- Subtract the mean from each measurement (column 2)
- Square the figures in column 2 and list them (column 3)
- Add the figures in column 3.

The following table shows the calculation of SD using the individual measurements. Some of the differences between x and the mean (x–µ) are negative. When a negative number is multiplied by itself (i.e. squared), the result is a positive number.

x	x–µ	(x–µ)²
2.0	2.0 – 2.09 = –0.09	0.0081
2.1	2.1 – 2.09 = 0.01	0.0001
2.2	2.2 – 2.09 = 0.11	0.0121
1.9	1.9 – 2.09 = –0.19	0.0361
2.3	2.3 – 2.09 = 0.21	0.0441
2.1	2.1 – 2.09 = 0.01	0.0001
2.2	2.2 – 2.09 = 0.11	0.0121
2.1	2.1 – 2.09 = 0.01	0.0001
2.3	2.3 – 2.09 = 0.21	0.0441
2.0	2.0 – 2.09 = –0.09	0.0081
2.1	2.1 – 2.09 = 0.01	0.0001
1.8	1.8 – 2.09 = –0.29	0.0841
2.2	2.2 – 2.09 = 0.11	0.0121
1.9	1.9 – 2.09 = –0.19	0.0361
2.1	2.1 – 2.09 = 0.01	0.0001
2.0	2.0 – 2.09 = –0.09	0.0081
2.2	2.2 – 2.09 = 0.11	0.0121
2.1	2.1 – 2.09 = 0.01	0.0001
1.9	1.9 – 2.09 = –0.19	0.0361
2.0	2.0 – 2.09 = –0.09	0.0081
2.4	2.4 – 2.09 = 0.31	0.0961
21		0.4581

To find the standard deviation:

Divide the sum at the bottom of column 3 by the number of samples, less 1

Take the square root of this number.

$$SD= \sqrt{\frac{\sum(x - \mu)^2}{(n - 1)}}$$

$$SD= \sqrt{\frac{0.45}{(21 - 1)}}$$

SD= 0.15%

In the example (stabilising a sub-grade using 2% cement), the specification states that the cement content % shall not be more or less than 1.64 SD.

Cement content % = Design cement content % + or –1.64 SD

The standard deviation (0.15%) times the allowable variation (±1.64) is:

Allowable cement content % = 2.0% ± 1.64 x 0.15%

= 2.0% ± 0.246.

The acceptable range of cement contents (i.e. to remain within 1.64 SDs) is between:

2.0 + 0.246 = 2.246%

and

2.0 – 0.246 = 1.754%

In some cases, the specification may call for a cement content that is in a more restricted range, such as:

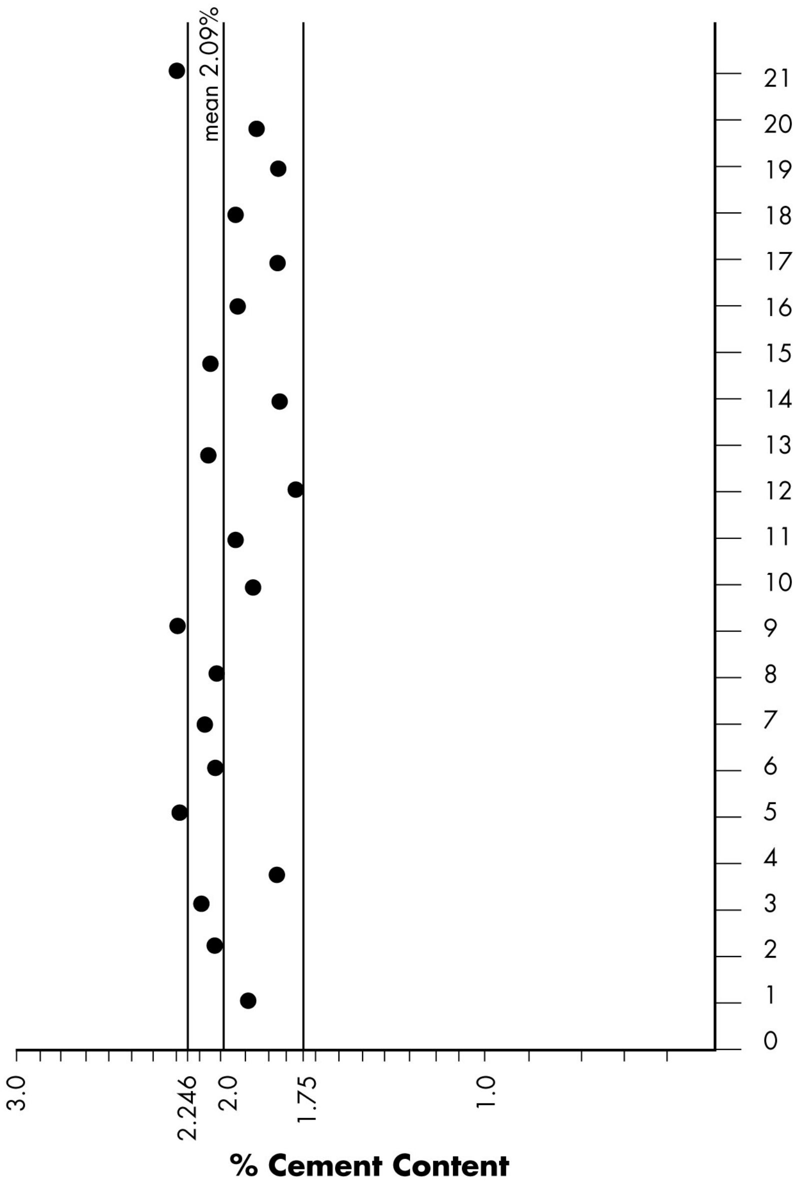
Cement content % = Design content % + 1.64 SD

Under this specification, the minimum cement content is 2% and the maximum cement

content is 2.246%.

Allowable cement content % = 2.0% ± 1.64 x 0.15%

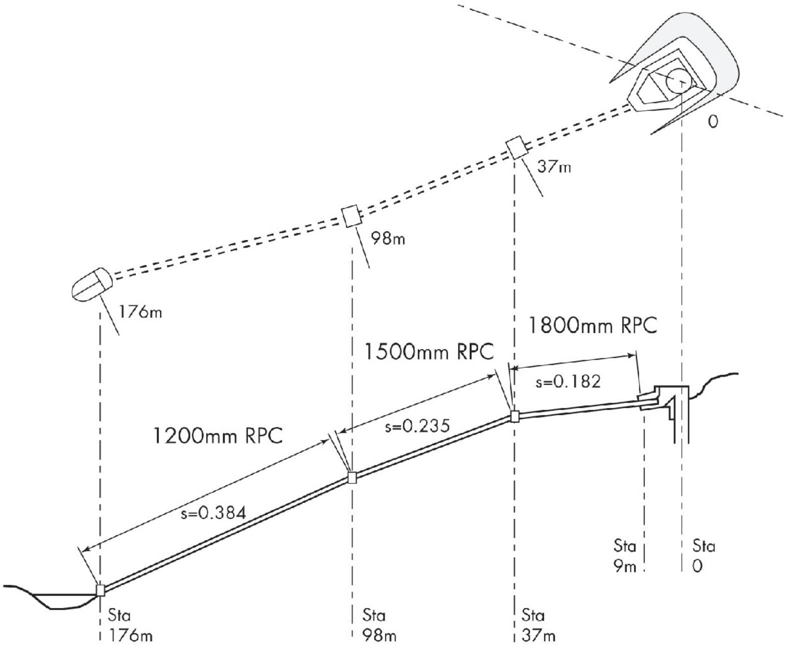
= 2.0% ± 0.246.


mean 2.09%
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
3.0
2.246
2.0
1.75
1.0
% Cement Content

Case Study No. 4

Amount of Pipe to be Paid for under a Schedule of Rates Contract

Contract documents often specify that payment be based on planned lengths indicated in the drawings. As shown below, the lengths in the drawings are generally shown in station intervals, which are always horizontal dimensions. These dimensions however, are not representative of the actual lengths supplied and placed by the contractor.



If the pipes are laid to specific grades, the contractor must supply and lay a greater length of pipe than that shown on the plan. The schedule rate must therefore reflect this difference.

The inspector has a choice: determine the amount of pipe to be paid for, by measuring the actual lengths, or by measuring the plan length. If the measurement is of the actual length, the inspector may be approving an overpayment of 7.00 m.

The lengths determined are as follows:

- Plan length minus the length of the upper structure (9m) = 167.00 m
- In-place length minus the length of the upper structure (9m) = 174 m.

The emphasis on in-place length is critical in a measure-up, because it has allowed for variations in the length to accommodate fittings from the original length of the pipe when delivered to site.

An inspector who measures delivered lengths, rather than in-place lengths, runs the risk of recommending an overpayment, unless of course the contract documents actually stipulated payment to be made based upon the length of pipe delivered to the site.

Note!

All staff engaged in measuring up for payments must read the contract documents very carefully before undertaking the measurements.

Case Study No. 5

Width of Pavement to be Paid For

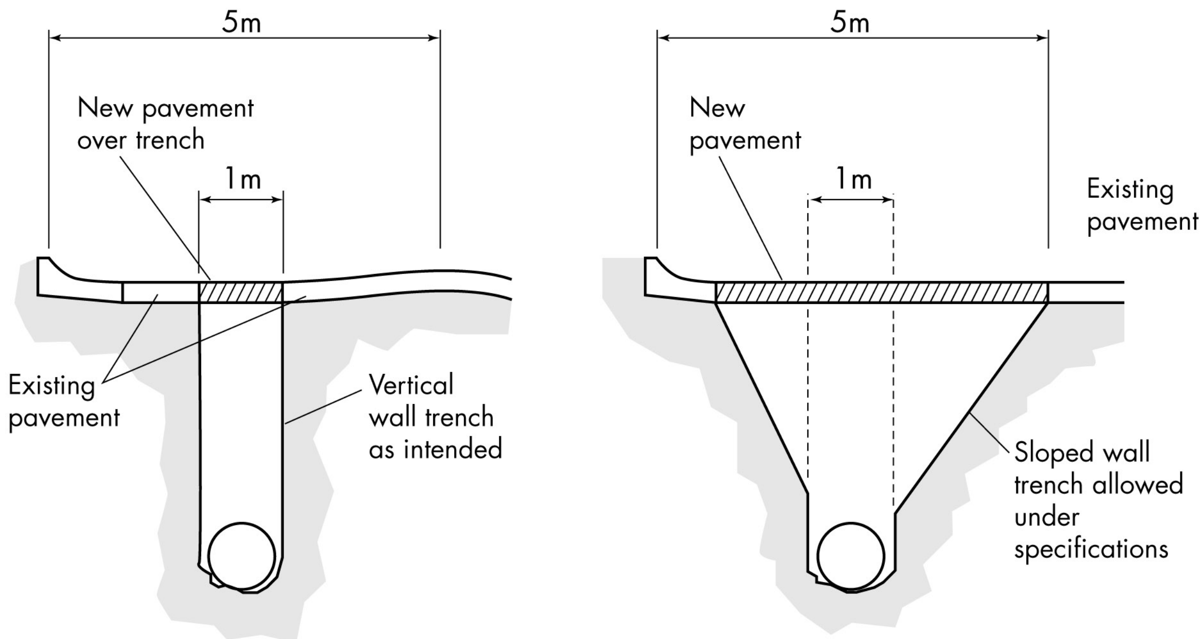
On one actual pipeline job in a city street, the unit price for repayment over trenches was quoted higher than that for roadway pavement, because it would have to be done using hand tools. The contractor for this project, being an enterprising person, carefully studied the specifications and noted that the earthwork provisions permitted:

A slope on that portion of the trench walls that are above a plane lying one foot (0.3m) above the pipe; provided that any excess excavation resulting from such methods is to be at the contractor's own expense.

The contractor sloped all of the trench walls in the city street area, opening up the entire width of one half of the city street, which he then repaved using a regular paving machine. The specifications for repayment of the area over the pipe trench were based upon the number of square metres of area to be actually paved, rather than upon the number of linear metres of pavement to be constructed over trenches. The result was that the contractor not only eliminated the added cost of trench shoring in deep trenches, but also 'bought' a street repaving job. Essentially, he repaved an entire half of the city street using a paving machine, but was able to perform the work at unit prices intended for hand excavation methods.

The only excess cost to the contractor was extra labour needed to slope the sides of the pipe trench and the removal of the additional, existing paving. The cost to the city was an additional $15 000. There was nothing in the contract that would provide legal relief.

This example shows how the method of measurement for payment purposes can mean significant differences in the cost of a project. In this case, it was the specifier's fault for not co-ordinating the paving specification with the earthworks specification. Under the terms of the contract specifications, the contractor was fully within his legal rights.



Effect of sloping trench walls on pavement width requirements