

LEVEL 1 INSPECTION AND TESTING: RELIABILITY OR LIABILITY?

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ABSTRACT

In 1990, when the earthworks Guidelines were first introduced, adoption of Level 1 Inspection and Testing in accordance with AS3798 was seen as the panacea for standard practice in the industry for the determination of compliance with specification requirements for compaction of fill. Since then, the use of Level 1 responsibility has become widespread on large earthworks contracts where an engineered fill is the required product. Reliability of the engineering performance of compacted fill was seen as the main selling point for justification to principals.

Experience has shown there are many limitations associated with implementation of the concept outlined in the Guidelines, so that the result is a liability for many stakeholders in an earthworks contract. This paper explores some of the challenges associated with implementation of Level 1 Inspection and Testing, as it is now known, which can reduce the goal of 'reliability' to a 'liability' for the stakeholders in the earthworks contract. These challenges include:

- physical limitations of workload for the Geotechnical Inspection and Testing Authority/Geotechnical Testing Authority;
- whether sufficient testing is completed to reliably identify problem "hot spots";
- whether sufficient data is recorded to enable audit of traceability of completed testing;
- the low relative cost of testing in relation to contract value;
- whether remuneration rates for Geotechnical Testing Authority staff are sufficient in relation to site operatives to resist temptations;
- what liabilities may arise for the stakeholders from defects or problems in the finished product;
- what remedies may be available to rectify the challenges;
- whether results of testing some time after completion are still representative;
- whether the GITA/GTA should be part of the contractors QA/QC system to enable better integration.

The authors do not intend to provide answers to these challenges, but to initiate some discussion.

1 INTRODUCTION

Adoption of **Level 1** responsibility in accordance with AS3798-1990 was seen at the time when the earthworks Guidelines were first introduced as the panacea for standard practice in the industry for the determination of compliance with specification requirements for compaction of fill. This document had been preceded by Guidelines prepared by a Sub-Committee of the Sydney Group of the Australian Geomechanics Society in 1988. By publication of the Guidelines as an Australian Standard, wider recognition was assured together with legal precedent as to the statement of good practice.

The aim of **Level 1** responsibility was that the Geotechnical Testing Authority (GTA) would have sufficient presence on site on a full time basis to enable meaningful observations of the quality of earthworks compaction being carried out, together with the quality of the material being used. In addition, sufficient testing would be carried out to give indicative test results as to the degree of compaction being achieved. The GTA was to decide the location and timing of sampling and testing. This aim continued in AS3798-1996.

Level 2 responsibility did not call for full time presence, but rather the GTA carried out sampling and testing at locations selected by the GTA as required or specified after being advised by the superintendent/contractor when site visits were required.

Level 3 responsibility was for testing where and when requested with the superintendent/contractor being responsible for calling for the tests, deciding the locations and recording the test location and level.

The publication of the AS3798 - 2007 Guidelines has made some revisions to the 1996 version. In relation to Inspection and Testing these have included:

- Clarification of the terminology by referring to **Level 1 Inspection and Testing**, not simply Level 1 as in 1990 and 1996;

- Clarification of the importance of inspection for completion of Level 1 Inspection and Testing by referring to the Geotechnical Inspection and Testing Authority (GITA) not merely the Geotechnical Testing Authority (GTA) as previously used and as appropriate for Level 2;
- Recognising that, except for very small projects, the inspector of the works would not be able to complete both the inspection, with associated *in situ* density testing and necessary laboratory reference compaction testing and
- Elimination of Level 3 as found in 1990 and 1996 Guidelines.

These changes address to some extent some of the deficiencies discussed below that the authors have identified by reviewing the results from a number of Level 1 earthworks commissions completed under AS3798-1996. Other deficiencies remain.

2 SITE WORKLOAD

There are many factors which affect the rate of fill placement and compaction. The following discussion is based on a nominal “average” rate for a large earthworks project to illustrate the time, and hence manpower, required to complete appropriate testing.

In accordance with AS3798 - 2007, the duties of the GITA for Level 1 may be summarised as including the following:

- a. Observation of materials being delivered to site;
- b. Observation of the spreading and compaction of the materials;
- c. Evaluation of the extent of fill being placed within each layer; this would be regarded as the “lot” for QA purposes provided the material quality is similar throughout;
- d. Completion of field density tests at locations selected by the GITA geotechnician to be representative of the materials placed and compacted within the lot;
- e. Documentation of each test location and level;
- f. Completion of laboratory compaction tests to achieve a reference density such that the relative compaction achieved can be calculated;
- g. Completion of necessary documentation.

These duties were also relevant for the GTA under Level 1 responsibility to AS3798-1996.

Duties (a) to (e) are field based and require presence on, or with consistent view of, the area of earthworks. Duties (f) and (g) are “office” based and would usually not allow the field based duties to be completed by a single geotechnician to the same degree as would be achieved by presence at the area of earthworks operation.

On large earthworks operations there may be fill placement and compaction happening on a number of lots at the same time. This further complicates execution of the field duties and may require more than one observational geotechnician to complete the inspection and *in situ* density testing satisfactorily.

The frequency for field density testing on a ‘not one to fail’ basis during Level 1 Inspection and Testing would be at least in accordance with frequencies given Table 8.1 of AS3798 - 2007. Often, Level 1 Inspection and Testing is completed on larger scale earthworks operations, such that the requirements of Table 8.1 would be:

- one test per layer per material type per 2,500 m² or
- one test per 500 m³ distributed reasonably evenly throughout the full depth and area or
- three tests per lot.

whichever is the greater.

For a moderate to large earthworks contract associated with residential subdivision or commercial/industrial development an indicative fill quantity could be about 3,000 - 5,000 cubic metres compacted in place per day. Such quantities can be compacted by a CAT 825 compactor provided the delivery is suitably coordinated and the material is uniform in fill quality. If moisture conditioning is required, then the quantity would be at the low end of this range, or less, unless additional plant is available.

An indicative lot area could be say 100 m by 250 m. Therefore, about 1.5 - 2 full layers would be placed and compacted per day, based on a compacted layer thickness of 0.3 m.

Thus the number of *in situ* density tests in accordance with Table 8.1 frequency would be 4 to 7 tests on an area basis, or 6 to 10 tests on a volume basis. An indicative field density test rate using a nuclear densometer would be about 10 minutes to 15 minutes per test depending on surface preparation requirements and the method of determining the test location and level. Therefore, using 8 tests, between about 1.5 hours to 2 hours of field density testing would be required every day.

During that time a substantial quantity of the fill would be delivered, spread and compacted, being typically about 15% to 20% of the day’s production. If the same geotechnician is carrying out the field density tests and inspection then it is most likely that the inspection during the field density testing operation will be substantially less thorough than during the period when testing is not being completed.

Unless the supplied material is very uniform, which is unusual, then a laboratory compaction test is required for each field density test. Even a one point compaction test is likely to require on average about 15 minutes to complete, assuming there is no moisture conditioning and over sized material. Thus there would be an additional 2 hours required to complete the laboratory compactions. Where materials are variable and four point compaction tests are required, the time required could be on average up to 1 hour per test. For most site laboratories, any meaningful inspection is not feasible whilst the geotechnician is in the laboratory carrying out the compaction tests. Additional time is also required in the site office processing the test results and documenting the inspections.

Based on the above, it is likely that a single field geotechnician will have at least 4 to 5 hours per day carrying out the field and laboratory tests and documentation in a diligent and reliable fashion. About half the day’s fill production would occur during that period and there would inevitably be questionable inspection of the compaction methodology and fill quality. If results, particularly the compaction test results, are being falsified, then clearly more time is available for the inspection component.

Under AS3798-1996 there was no guidance / requirement for personnel levels under Level 1. To the authors’ knowledge, it was most common for a GTA to only provide one field geotechnician to complete the Level 1 role. The inevitable conclusion would have to be that the degree of inspection carried out would be at best superficial for about half of the fill placed and compacted. The uniformity of the fill achieved would therefore be highly dependent on the reliability of the contractor. The GTA would have a liability with respect to the fill placed and compacted during the period of reduced or even non existent inspection.

There may be a tendency for the contractor’s production rate to increase during the periods of reduced inspection. This would further increase the liability since the final opinion in relation to the quality of the fill produced would not be based on uniform procedure and test results.

The 2007 Guidelines have addressed this deficiency by warning that both the inspection and testing roles could not be fulfilled by the inspector. The above example figures clearly demonstrate why.

The authors agree with this amendment and would expect increased staffing levels by GITA on medium to large scale earthworks contracts. If the fill production rates are less than above, then in theory it may be possible for one geotechnician to manage the GITA role under Level 1. However, to reliably fulfil the requirements of the 2007 Guidelines, there may have to be agreed work patterns/times with the contractor such that no fill is placed, or spread and compacted during the periods of field and laboratory testing if only one geotechnician is present on site.

3 IS SUFFICIENT TESTING COMPLETED?

The authors do not claim to be experts in the evaluation of statistical significance of testing carried out. However, it was considered useful to make some comparisons with other testing frequencies that might reasonably be completed. Limited research did not identify any papers which addressed this issue.

3.1 PROPORTION OF VOLUME TESTED

Assuming a sample size of 150 mm diameter by 150 mm depth as typical for a sand replacement test, or a similar volume for a nuclear densometer test, then the volume actually tested is about 0.00265 m³.

Using the testing frequencies in accordance with the Table 8.1 of AS3798-2007 the proportion of material actually tested is given below:

Type of Earthworks	Frequency of testing considered	Percentage of volume tested	Approximate ratio of volume tested
Type 1: Large scale operations	1 test per 500 m ³	0.0005%	1 in 189,000
Type 2: Small scale operations	1 test per 200 m ³	0.0013%	1 in 75,000
Type 3: Concentrated operations	1 test per 100 m ³	0.0026%	1 in 38,000

Even for testing of the Type 3 Concentrated Operations the actual proportion tested does not seem very large and for Type 1 Large scale earthworks the proportion appears to be miniscule.

It would be interesting if the above ratios could be compared with other civil engineering materials. However, with fairly limited research the authors have not been able to find comparable testing requirements. Concrete strength testing appears to be strongly related to statistical evaluation of production over a period of time. Consideration is given to the measures of mean, standard deviation, and coefficient of variation over a statistically large number of tests. Consideration is also given to setting a minimum value for acceptance, rather than having to accept outliers which fall within statistical variation that might otherwise be accepted. What is clear is that the factors controlling fill using variable natural soil sources are likely to be far more variable than manufactured components used in concrete. This should imply far more frequent testing for fill than for concrete.

By way of comparison, reference to an early reference, Troxell & Davis (1956), now a somewhat antiquated text, a typical sampling frequency at that time was "1 test (3 specimens) for each 250 cu yards" of concrete. Given that a standard test cylinder was 6 inches diameter by 12 inches high, the 3 specimens would represent a specimen ratio of about 1 in 34,000. If only 1 specimen was tested then the ratio of the tested volume to the lot would be about 1 in 100,000 which is comparable to the Type 2 earthworks ratio above. It would be a big concrete pour to achieve 250 cubic yards in a day, so this test frequency may apply over a number of days production.

Thus, this comparison indicates that the testing ratios required by AS3798 - 2007 are probably similar to a "manufactured product" for which quality control on the input factors is far more readily achieved than is likely to be the case for a fill derived from a number of sources. This should imply a far greater testing frequency would be required for fill to have appropriate confidence in the reliability of the result, i.e. the testing frequency should be higher than that given in Table 8.1.

3.2 INDICATIVE SIZE OF "HOT SPOTS"

Within the fill, there is always a possibility of some zones that are less well compacted than others. For example, the operator of the compaction plant may lose concentration so that the track of the roller does not remain parallel and adjacent to the previous track with the result that zones are missed between subsequent passes. These "omissions" may be worse with less experienced plant operators of compactors or water carts. Since it is known that the degree of compaction achieved is less with fewer roller passes, the zones that have been missed will have reduced compaction such that these zones may not achieve the specification target.

Similarly, the operator may lose count of the number of passes and miss out some passes, or have to curtail the number of passes in order to leave site on time. Again a reduced number of passes would result in less well compacted fill which may not achieve the specification target.

Alternatively, variation in material quality, such as type of soil or the moisture content can occur. Such variations also affect the degree of compaction achieved for a given number of passes of the compactor.

These zones of reduced compaction can be regarded as "hot spots". Location of the hot spots becomes one of the aims of the testing.

With inspection during Level 1, the geotechnician may form a view as to the likely location of hot spots and then target them with the testing. However, with Level 2 testing there is no prior inspection which can guide the selection of the test locations. Therefore the confidence levels that can be associated with a prescribed amount of testing can be considered on a statistical basis.

To illustrate this concept, comparison can be made with the sampling design guidelines for contaminated sites by the NSW Environment Protection Authority (EPA, 1995). In those EPA guidelines Table A details the minimum number of sampling points required for site characterisation based on detecting the circular hotspots by using a systematic sampling pattern. Further details are given in Procedure F which explains "*If a systematic sampling pattern is used and all sample measurements return concentrations below an acceptable limit, the result can be interpreted as indicating the sampling area is free of hotspots larger than the critical size.*"

If the same concept is applied to fill compaction test result, then, when all test results are more than the specification target, the hotspot will have results of less than the specification target.

Using the EPA procedure, for a site area of 2,500 m² (0.25 hectare), the EPA recommended number of testing points would be 8 giving an equivalent testing density of 32 testing points per hectare. The consequent diameter of a hotspot that can be detected with a 95% confidence limit would be about 21 m in diameter i.e., at this testing frequency, the site area would be reasonably "free of hotspots" larger than that critical size of about 21 m diameter. Conversely, hotspots of smaller than that size could be present. Inherent in this concept is that the "contaminated" stratum being tested is reasonably homogeneous with depth so that a sample selected at any depth within the relevant stratum is representative. If a number of different strata are present, then the testing frequency has to be applied to each stratum.

Using this same methodology for a compacted fill, with 8 tests per 2,500 m², all of which achieve the compaction specification, there would be a 95% confidence limit that areas of fill not complying would be smaller than about 21 m in diameter, which is about the plan size of a house.

3.3 WHAT CONFIDENCE LEVEL IS APPROPRIATE?

If only one test is completed per 2,500 m² on a fill layer (in accordance with Table 8.1 of AS3798 - 2007) on a grid pattern within a much larger area, then the resulting hotspot diameter for 95% confidence limit would be about 59 m. The confidence limit for a 40 m diameter hot spot would be 50%. This is the limit of the data given in Table D (Procedure F of EPA, 1995). By extrapolation, the confidence limit for a 20 m diameter hotspot at this test frequency would probably be less than 10%.

Is this an appropriate confidence level for earthworks testing to determine whether a house is to be located over a poorly compacted zone within a layer, or not?

Does the placement of a number of layers alter the statistics involved with the finding of a hotspot? Can “randomly selected” locations in each one layer within a number of layers be summated to be equivalent to a systematic sampling pattern of the whole?

The authors are not sure. If it is reasonable to regard the total fill as being homogeneous, then yes, it may well be reasonable to consider that the total testing becomes indicative of the resultant grid spacing and the size of the hot spot would be smaller.

However, it seems far more likely that the fill will not be homogeneous and that hot spots will be present on a layer by layer basis. The chances of the hot spot for each layer being in the same area of the fill should be very small so that the effect of poorly compacted zones within any one layer is very much reduced. On some sites there may be an operational constraint that influences the location of the hot spot and makes a poorly compacted zone likely in each fill layer at about the same location. For example, the problem of achieving good compaction right to the edge of a fill batter with consequent adverse effect on batter stability or on a structure located adjacent to the edge of the fill batter.

On face value the above shows the amount of testing per fill layer is very low in comparison with that required by a contamination investigation to show that hotspots of a notional size of about 20 m to 30 m in diameter are not present. Practitioners responsible for the investigation of contaminated sites have found that to achieve reasonable confidence of identifying hot spots that are larger than can be easily accommodated during site contract works, significantly greater amounts of testing are required than the EPA Guidelines due to lack of homogeneity in fill materials with depth.

It could be argued that the approach for investigation of a contaminated site is to search for a hot spot of unknown location on a “random” site. A well constructed fill should not be random. With the inspection component of Level 1, the confidence level should be boosted by the appraisal of the uniformity of the procedures adopted and the uniformity of the material quality. The test locations can be targeted to areas of suspected poor compaction based on the inspection completed.

However, for Level 2 Testing, the lack of inspection (since the GTA is not on site during the compaction process) means that there is no prior assessment as to where the hot spot of poor compaction may be located. This gives a strong argument that the frequency of testing for Level 2 should be substantially higher than for Level 1, if the same overall confidence level is to be achieved.

For residential subdivisions the authors consider there is a strong case on liability grounds to increase the testing frequency so as to reduce the likely size of hot spots to less than the size of house. This would require at least about 4 times the Table 8.1 frequency to make any significant reduction in the size of hot spot to about 10 m at a 95 % confidence limit.

4 AUDIT OF TESTING DATA

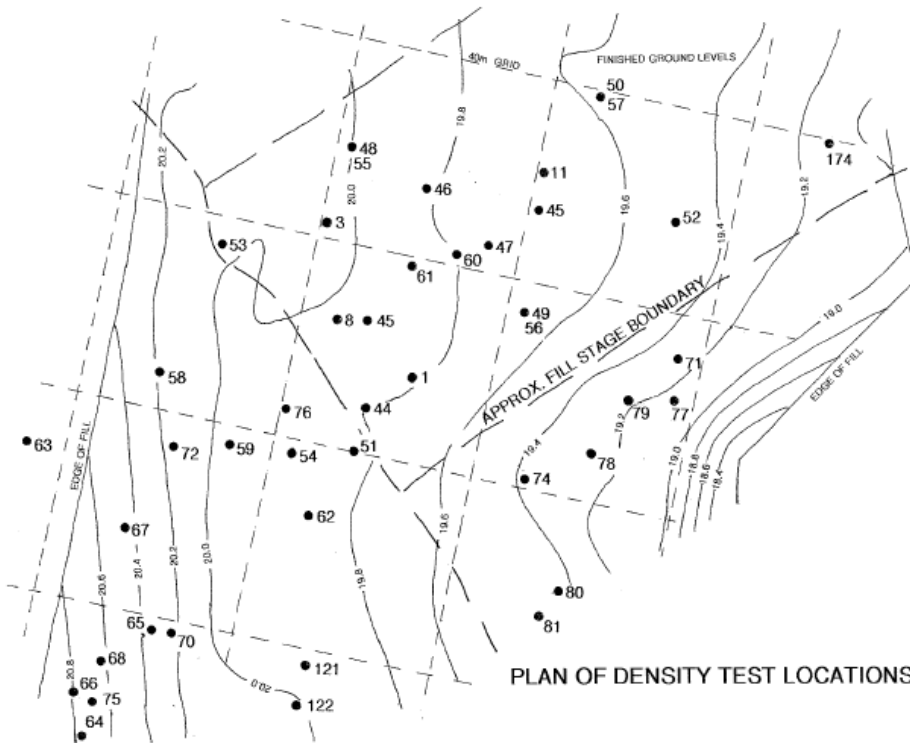
Often, as a matter of ‘due diligence’, principals may require that compaction test data be subject to an audit.

The usual data presented will be tables of test results giving the test location and level, test date and the results achieved in the field and laboratory giving the compaction test result. Usually the test locations will be shown on a plan. There may be some plans showing either stripped levels prior to fill placement or thickness of fill placed. Daily diaries, if included, are usually only descriptive and often very brief. Figure 1 shows some typical data that would be included in a final report.

So what can be done by way of an audit of such data?

Often there will be a surveyor’s calculated volume of fill placed, or it can be calculated from the level/contour plans before and after. From this volume, the expected number of tests according to Table 8.1 can be determined and compared with the total number completed. Similarly, the average layer area and number of layers may be determined

from the plans and an expected number of tests determined on this basis. It would be foolhardy for the GTA not to achieve these numbers of tests since they are relatively easily checked, even if only approximately.



SUMMARY OF DENSITY TEST RESULTS

Date Tested	Test Number	Test RL	Compaction Ratio %	Moisture Variation %	Comment	Date Tested	Test Number	Test RL	Compaction Ratio %	Moisture Variation %	Comment
19/05/2007	1	15.410	98.0	0		22/08/2007	63	19.040	98.0	1.0 dry	
20/05/2007	2	15.780	99.5	0.5 wet		22/08/2007	64	19.650	99.0	1.5 dry	
21/05/2007	3	16.320	98.5	1.0 wet		23/08/2007	65	17.140	99.0	2.0 dry	
1/06/2007	11	15.770	98.5	1.0 wet		23/08/2007	66	18.660	99.0	0	
4/07/2007	44	15.760	99.5	1.5 dry		25/08/2007	67	18.360	100.5	1.5 dry	
4/07/2007	45	15.470	98.0	1.0 dry	Two locations on plan	25/08/2007	68	20.300	100.0	1.5 dry	
4/07/2007	46	15.980	99.5	1.5 dry		26/08/2007	69	20.540	107.0	2.0 dry	Located beyond plan shown
8/08/2007	47	17.800	103.0	2.0 dry		26/08/2007	70	20.180	100.0	2.0 dry	
16/08/2007	48	17.910	97.0	2.0 dry		27/08/2007	71	16.850	99.0	0.5 wet	
18/08/2007	49	17.880	93.5	4.0 dry		27/08/2007	72	19.980	99.0	0.5 wet	
18/08/2007	50	18.110	97.5	2.0 dry		28/08/2007	73	17.200	99.0	1.0 dry	Located beyond plan shown
15/08/2007	51	17.900	103.5	2.0 dry	Date out of order	28/08/2007	74	16.760	99.0	1.0 wet	
15/08/2007	52	18.000	105.0	1.5 dry	Date out of order	28/08/2007	75	20.240	98.5	2.0 dry	
18/08/2007	53	17.800	99.5	2.0 dry		29/08/2007	76	18.910	99.5	1.0 dry	
19/08/2007	54	18.710	99.5	2.0 dry		29/08/2007	77	17.890	100.0	1.0 wet	
19/08/2007	55	17.590	99.0	2.0 dry	retest No 46	2/09/2007	78	18.170	100.5	1.5 dry	
19/08/2007	56	16.730	100.0	2.0 dry	retest No 49	2/09/2007	79	19.380	99.5	1.5 dry	
19/08/2007	57	16.920	98.0	2.0 dry	retest No 50	3/09/2007	80	19.270	98.5	0.5 dry	
19/08/2007	58	16.580	98.0	1.0 dry		30/09/2007	81	19.690	100.5	2.0 dry	
20/08/2007	59	19.590	99.5	1.0 dry		30/09/2007	121	18.100	98.0	2.0 dry	
20/08/2007	60	18.650	98.5	0.5 dry		30/09/2007	122	18.990	103.5	0.5 dry	
21/08/2007	61	19.580	100.0	0		4/10/2007	174	19.600	99.5	2.0 dry	
21/08/2007	62	18.090	103.0	2.0 dry							

Figure 1: Example final earthworks report summary

Is such a check sufficient? The authors believe it is not sufficient.

Examination of the total number of tests does not indicate whether the tests were “distributed reasonably evenly throughout the full depth and area” as assumed or required by Table 8.1 for the indicative frequency. A visual check can be made for distribution across a plan area, but this may not make any allowance for variation in number of layers or extent of each layer across the fill area, nor whether the fill in each layer is sufficiently uniform to be regarded as a lot. If the fill area is particularly large, then each fill lot may not comprise a layer over the entire fill area.

Analysis of the data presented is usually unrewarding in this regard and does not enable evaluation of the number of layers and, more importantly, the extent of each layer. Laying the fill with a surface crossfall makes determination of whether every layer has been tested difficult unless the crossfall is defined/known.

The missing factor on the daily reports is the extent of fill placed on each day or within each lot as shown on a plan with the test locations. If the fill is being derived from a number of sources, then the origin of the fill (as an indicator of the fill quality) should also be tracked on a similar basis. Now that GPS units are relatively cheap and plan coordinates for way points can be readily measured and stored onsite and then down loaded onto plans, the preparation of a daily fill plan and/or daily lot plan should become standard practice. Such a plan would also include the test locations and any variations in material types etc. Analysis of such plans would give a much better picture as to the adequacy of the testing completed.

AS3798-2007 defines a lot as “an area of work that is essentially homogeneous in relation to material type and moisture condition, rolling response and compaction technique, and which has been used for the assessment of the relative compaction of an area of work.” (Paragraph 1.2.8) If the material type varies, for example because it is derived from a number of different sites, then strictly speaking each change in material type would define a lot and Table 8.1 would require 3 tests to be completed.

The extent of each lot needs to be known at the time of testing and be recorded. Then if a failure result is measured it is known as to what area needs to be reworked and retested. Usually the report data will merely refer to a retest of a failure without any comment in relation to the extent / location of the area reworked etc. If a failure is encountered, then in accordance with paragraph 8.7 of AS3798-2007, the entire lot should be reworked and retested. Thus, more than one test should be completed for the retest, not just the localised rework and retest in the area of the failure.

Thus, design of the quality plan for the inspection and testing should require the following to enable audit of the results:

- Site Plans prepared on a daily basis to define the layer/lot being placed and tested and indicative levels or cross falls.
- The basis for assessing uniformity of the materials within a layer/area and hence how lot areas are being defined.
- Daily diaries to record site activity and progress.
- Location (plan coordinates and reduced level) of *in situ* density tests within each lot.
- Results of each *in situ* density test.
- Corrective action taken when a failure is reported, including the date and time of notification of the failure, details of the corrective action including a plan of the area reworked and levels at that time.
- Results of all retests, as above and
- Full survey plans to define stripped levels prior to fill placement and final levels.

5 INDICATIVE TESTING COSTS

Some Level 1 commissions are being paid for on a unit rate for the volume of fill placed and compacted. Typical rates in Sydney for 2006 are about \$0.40/m³ to \$0.60/m³. If the testing is carried out at the recommended rate of 1 test per 500m³, then the payment for testing is about \$200 to \$300 per test. Given that the unit rate has to include the inspection component as well as the laboratory compaction test, then clearly large volumes are required to be placed on average on a daily basis to cover all costs, and allow for variation in fill placement rates.

Limited enquiries of earthworks contractors has given an indicative compacted fill rate for a large earthworks fill contract in Sydney of \$3.50/m³ excluding testing, though clearly the earthworks cost will depend on many project specific variables. Then for large earthworks contracts the testing cost is about 10% of the total fill placement cost.

For smaller Type 2 earthworks jobs, the rate for fill may be more like \$8/m³ to \$10/m³. The testing cost would be more like \$150/test to \$180/test on a Level 2 basis using schedule of rates basis. Then assuming a Type 2 earthworks testing frequency of 1 test per 200 m³, the relative testing cost would be about 8% to 11% of the fill cost.

For either of the above, the relative cost of the testing is only a small component of the total, say about 10%, but is still a cost some clients may not wish to pay. If implementation of testing results in improved confidence in the quality of the fill, then the cost benefit seems undeniable.

6 PAY SCALES FOR GITA/GTA STAFF

Are the geotechnicians adequately paid for the work completed for the responsibility they take and for the liability to the employer as a result of their work?

The ECLA/AWU Soil, Concrete Testing and Analysis Award 2000 pay rates for full time staff applicable from 1 December 2006 are given in the table below for some of the Classification/Skill levels. The hourly rate has been multiplied up to give an annual package on the basis of a 45 hour week with overtime at time and half after 38 hours and including the 9% Superannuation Guarantee Levy.

Classification/Skill Level	\$ per hour	Annual package
Adult - First year	15.39	\$42,421
Tester (min 2 years)	16.56	\$45,646
Tester	17.82	\$49,119
Supervising Tester	18.45	\$50,855
Junior – 18 years of age	10.84	\$29,879

In addition to the package, benefits such as site allowances, provision and use of a vehicle may also be paid. Most employers find that payments of at least about 10% to 20% over the award are appropriate to experienced staff.

In comparison with these packages, limited enquiries with earthworks contractors have indicated the following salary packages would be indicative of the current employment market:

Labourer	\$60,000 to \$70,000 per annum
Plant Operator (truck, dozer, compactor)	\$70,000 to \$90,000 per annum
Site Foreman	\$100,000 to \$140,000 per annum

Thus, even allowing for over award payments, it is clear that experienced geotechnicians are unlikely to earn as much as plant operators whose work they are, in effect, checking.

Is this conducive to honest, ethical behaviour?

Given the disparity, and considering the cost ramifications of reduced production arising from test results being failures, there must be a lot of pressure, whether of a financial nature or otherwise, on some geotechnicians to falsify results. The consequence of such behaviour is significant in terms of liability to most of the stakeholders arising from unsatisfactory performance of the fill once structures are constructed on the fill.

To overcome most of the temptations, significant increases in pay rates for geotechnicians would be required. There would have to be commensurate increases in the charges for testing to match.

7 LIABILITIES ARISING

AS3798-2007 states that for Level 1 inspection and testing the client will usually require the GITA *“to provide a report setting out the inspections, sampling and testing that is carried out, and the locations and results thereof”*, on completion of the earthworks. *“Unless very unusual conditions apply, the GITA should also be able to express an opinion that the works (as far as it has been able to determine) comply with the specification and drawings.”* (Clause 8.2)

To understand the liabilities one must first understand the defects or problems in the finished product – an engineered fill. The fill could form the substrate of a road, or support structures and floor slabs. Other uses such as dam embankments are too specialised to consider here. The most common ‘failure’ would comprise settlement or excessive deflection due to under-compaction or heave due to over compaction of reactive clay placed well dry of optimum.

The client considers they have not been provided with a product they specified and paid for. Losses inevitably arise and so they seek redress.

Liability for the losses is aimed at all parties involved. The contractor may be seen to have a major liability since he had the contractual relationship with the client and the obligation to comply with the contract specification. He had responsibility for execution of the work and may be seen by some as the only party having real control. However, the GITA may also be seen to have a major liability also due to a responsibility for “checking” the product being produced by the contractor. Involvement at Level 1 may substantially increase the exposure above that associated with Level 2. A project manager may also be seen to have a liability if contract administration was lax.

Let us suppose, for example, the GITA carried out their inspection and testing reasonably diligently and the test results are all in accordance with the specification requirement. Post incident investigations have failed to reveal over-size or unsuitable materials. Then, assuming the design specification for the fill was reasonable, the only obvious issue would be the degree of observation of the filling process by the geotechnician (GITA). If this was satisfactory (e.g. two technicians on site throughout, one in the field and supported by other staff), what could be the cause of the problem?

Far more likely, however, is a combination of possible causes – a contractor whose attitude to specifications and testing was ‘cavalier’ – inexperienced geotechnicians who may not appreciate all the issues – over worked geotechnicians who spend too much time in the laboratory doing compactions, while poor practices occur elsewhere on site.

So who is liable when the floor slabs of the warehouse settle and crack?

- The contractor for not doing the work properly, or the GITA for signing off?

In this situation, probably both – but proportionate liability or joint and several liability?

What would determine the proportion – the ratios of the GITA’s fee to the Contractor’s claim? If not, why not?

The claims of which the authors are aware that have gone to court, were even more complex. In one case failure of a container pavement arose as a consequence of the contractor(s) placing asphalt over a base course which was full of water due to recent rain. It was claimed that the testing was faulty and that the GTA should be responsible, i.e. the GTA was responsible for a multi-million dollar claim. Subsequent investigations revealed deficiencies in the design and specification of the materials used in the fill and pavement layers. Thus the dispute over a relatively simple issue became increasingly complex. In the end it was concluded that the design, specification and project management were to blame, not the testing. Although the GTA was not found liable in any way, the cost of defence far exceeded the value of the original commission.

Other examples could be quoted where problems have arisen as much from a lack of overall project co-ordination as from specific technical deficiencies. In such cases, the authors opine that project managers need to be given a big

wake-up call that they cannot sit on the sidelines pointing fingers at consultants and contractors who are working on a limited brief and an even more limited budget. Many of the problems would not have occurred if there were better co-ordination and technical input at all stages of a project. The old adage applies: “you get what you pay for”.

Experience shows that involvement in any litigation arising from a problem is very costly to all involved, in monetary terms, in the time and effort required in mounting a defence and in the emotional strain. A lot of the financial costs may not be covered by insurance. Therefore any litigation is unprofitable.

Are the rates charged for testing sufficient to cover the costs when a job does go wrong?

8 WHAT ARE THE REMEDIES?

Realistic expectations – given the nature of earthworks, is it reasonable to expect 100% performance?

Most engineers first reaction is ‘no’! So we need to make clear that whilst 100% apparent performance is often achieved, this may be due to an element of ‘statistical luck’ and a combination of other favourable factors (e.g. pavements being conservatively designed, design loads not being realised in practice, etc.).

How can we go about this? What is an acceptable failure? One pothole per 100 m? Two cracks less than 5 mm wide per floor slab?? It is very hard to define but perhaps we have to try. This approach has been used for a long time now with AS2870 with regard to performance expectations of domestic dwellings.

If no failures are acceptable we have to decide how to achieve such standards – by higher quality, more rigorous testing, by better forms of contractors’ insurances or by more conservative (and hence costly) designs. We have the same problem with AS2870 – it is all very well saying that 95% of houses should not have significant damage, but what if you are one of the unlucky ones? Is it acceptable to you? Can you blame designers for being conservative? Is it in the client’s ‘best’ interest?

In effect, the remedy becomes clear – clients must understand better what they are buying – what performance can they expect? This should be part of the designer’s job. It is very hard to convince clients that they should expect less than perfection, and therefore we need a ‘standard’ expectation.

With regard to forming an insurance pool to cover the 1% (or is it the 5%?) of clients who suffer a degree of failure or under-performance, there is an obvious problem – the insurance becomes a honey pot attraction for everybody who has a crack in their driveway. It would be essential to define ‘acceptable damage’. There would need to be an agreed assessment authority – independent and clearly so. Problems arose with the Builders’ Licensing Board when they were policing the early AS2870 scheme, because they were not seen to be independent and, indeed, perhaps were not.

9 POST-COMPLETION TESTING

There is some evidence, largely anecdotal, that testing of fill some time after completion rarely gives good results.

The authors have first hand experience of several sites where post-completion testing of fill has given surprisingly low density results, quite inconsistent with earlier testing. This is most evident with clay fill, particularly fills where dispersive and reactive clays are involved.

The *in situ* density of natural clay soils in the Sydney area is generally well below the density we try to achieve in compacted fills – figures in the order of 92% of SMDD are typical. Therefore, the mechanical properties of *in situ* natural soils, such as stiff residual clays are related to properties other than density, perhaps minor cementation or secondary bonding of clay minerals. If this is the state the soils naturally tend towards over time, we may have to accept that it is an unnatural condition to achieve by compaction the mechanical properties we want as engineers and special precautions are needed to maintain this condition – perhaps avoiding moisture infiltration and maintaining some sort of static surcharge condition to avoid ‘natural rebound’. Except where very low compaction occurs at depth in substantial fills, the majority of problems tend to occur in the upper 1 m or so of the fills where the opportunity for shrinkage, swelling and rebound are greatest. These measures are things we do tend to do already. But perhaps we need to be more watchful of the details and also be wary of unrealistic performance expectations of highly reactive and/or dispersive clay fills. We should actively warn our clients of such behaviour being possible, or even likely.

10 THE LIMITATIONS OF AS3798

The outline of the final report that GITA are expected to provide at the completion of a project seems reasonable at first glance. However, clients need to consider some of the underlying issues. If land is sold after the completion of earthworks, often the only comfort offered to the purchaser is the report from the GITA. There is no offer of warranty from the contractor who carried out the works that they comply with the specification – the only direct relationship with the contractor may be between the vendor/developer and the contractor; any attempts by purchasers to pursue remedy with the contractor may only be possible through complex legal suits. There needs to be an assignment of responsibility

from the contractor to the purchaser, as if the purchaser had entered into the original contract. This would place more onus on the contractor to achieve the necessary Standards.

Clients often request GITA/GTAs to 'certify' compaction. This is not the report described in AS3798-2007 clause 8.2, but in effect may be taken as a guarantee, which clearly places the GITA in a position of untenable risk and must be resisted.

The situation is exacerbated to some degree where contracts call for the GITA to be retained by the contractor as part of the contract price – this is very neat for the project manager as a way to define and control costs, but often results in unscrupulous contractors using GITAS who are totally dependent on one or two contractors for all or most of their income and who may be bullied into working under conditions well below the standard necessary (see comments earlier in this paper regarding the number of staff required for Level 1 testing).

The issue of performance expectations has been outlined previously but it should be recognised at all stages that achievement of a compacted fill with zero risk of areas with sub-standard properties is an unachievable goal and it would be helpful if this was explicit in AS3798-2007 as it is in AS2870-1996.

11 QUALITY ASSURANCE

The testing (Level 1 and 2) and observation (Level 1) of fills by a GTA/GITA forms part of a Quality Assurance/Quality Control program and should not be seen as the only part of the process which delivers the required product.

In this regard, the engagement of the GTA/GITA by the Contractor is positive as it becomes clear that the GTA/GITA is not an independent "certifying" authority, but part of the Contractors QA/QC process. The Contractor takes out the appropriate insurances to cover defects in the product they produce. The only liability that should attach to the GTA/GITA is if their own work is negligent, such as falsification of results or inaccurate testing, though the latter is often hard to prove as noted above.

This brings us to our final and perhaps most alarming point. The authors are aware of strong anecdotal evidence that laboratory compaction tests, which are necessary for and are reported as part of the relative compaction calculations, are often not completed. The time, cost and hard labour involved in carrying out the tests and the fact that on a large commercial or residential subdivision project the tests can accumulate at rates of 10 to 20 per field geotechnician per day, is a massive incentive to falsify results. Once the laboratory falls behind the daily output from the field geotechnician, it becomes a huge cost if under-compaction were to be reported at a later date as much additional fill will have been placed over the failed area.

The way of the future seems to lie towards real time monitoring of compaction and location. Substantial work has been completed in the USA known as Intelligent Vibratory Compaction. In this process the performance of vibratory rollers is monitored by a variety of rebound responses which are directly related to the modulus of the compacted soil. The operator has read-outs in the cab to show how the soils are behaving and the whole process is recorded against GPS data such that there is a permanent record of performance. The density and moisture content testing of the fills thus form a much lesser (though important) part of the quality control process. Bring it on!

12 DISCLAIMER

The opinions expressed in this paper do not represent any company policy by the authors' employer and may vary subject to the particular circumstances relevant to a commission.

13 REFERENCES

- Australian Standard AS2870-1996 Residential Slabs and Footings
- Australian Standard AS3798-1990 Guidelines on Earthworks for Commercial and Residential Developments. Standards Australia.
- Australian Standard AS3798-1996 Guidelines on Earthworks for Commercial and Residential Developments. Standards Australia.
- Australian Standard AS3798-2007 Guidelines on Earthworks for Commercial and Residential Developments. Standards Australia.
- Troxell, G.E. and Davis, H.E. (1956). Composition and Properties of Concrete. McGraw-Hill Book Company.
- Environment Protection Agency, NSW (1995). Contaminated Sites – Sampling Design Guidelines.