QUANTUM

GROUND STABILISATION

Quantum Ground Stabilisation System

Presented by:

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The Quantum Ground Stabilisation (QGS) System is a two part system that beneficiates the load bearing capacity of natural gravels and soils for road making purposes:

- One part lubricates the particles enabling greater compaction
- The other, a powder, fills capillary voids mitigating against soil moisture movement
- The nett result is significantly improved shear strength of the natural material

The QGS System is not a cementing agent:

- Is therefore not prone to the shrinkage problems associated with cement
- It can be reworked in service without loss of integrity
- For repair use, treated material can be stockpiled for unlimited time prior to compaction

The QGS System improves the bearing capacity of natural gravels and soils by:

- Enhancing compaction through reduction in the capillaries between soil particles
- Mitigating soil moisture increase thus maintaining the integrity of the natural cohesion and inter-particle friction

The QGS System demonstrates these benefits through:

- Increased unconfined compressive strength
- Improved shear strength
- Virtual elimination of permeability to ground water and rainfall

The QGS System is a chemical substance which breaks up the adhering water film leading to an irreversible agglomeration of fines thus substantially reducing the capillary rise of water and allowing better compaction of the treated soil and increases required density under traffic.

In comparison with untreated soil, QGS has the following characteristics:

- Better compactibility through changing the water characteristic in the soil
- Strong reduction of water absorption through reducing the capillary activity
- Reduced water permeability
- The Proctor Density Optimum Moisture Content of treated soil is lower and the density is higher
- Malleability reduced, shrink and swell behaviour

QGS inorganic powder prevents the treated soil from water ingression by closing the capillary. Water absorption is drastically reduced, preventing swelling of the soil.

Advantages of QGS System in relation to cement and lime stabilization:

- Mixed soil can be stored for unlimited time and remain fully effective
- Environmentally safe and compatible
- Easy to apply in the field, no curing time, use as soon as dressed and rolled
- Large tolerance in soil varieties for treatment
- Given correct material ratios, suitable application is made easier due to the constant rate of application per cubic metre

The QGS System works the same with any type of soil as it activates the cohesive forces of the soil and substantially and lastingly reduces the influence of water. The QGS System modifies the soil permanently and thus is used in-situ or in a factory premixing procedure.

The bearing values of the treated soil allow for a notably higher bridge function in the bearing layers and thus a risk free reduction of the wearing course where applied, which may reduce the cover from 60 mm to 20 – 25 mm.

Suitability of Natural Materials:

- Generally, 33% gravel, 33% sand and silt, 33% clay
- Free from deleterious substances
- Free from excess organic matter
- Free from high concentrations of sulphate ions

For grading characteristics, see laboratory reports.

Primary Questions and Answers

1. How to define SOIL STABILISATION?

"Soil stabilisation" is achieved if an in-situ Soil has been rendered usable for risk free application in any earthwork.

2. How to achieve SOIL STABILISATION?

In the past 50 years many attempts at improving the behaviour of soils have been undertaken with the aim to avoid the substitution of conventional construction material for unsuitable in-situ soil, i.e. soil of lower quality. The products chosen for this purpose can be divided into the following groups:

– Products gluing together the soil particles, such as binding agents, and

– Products gluing at a change of the chemical composition of the soil, thus reacting with the soil, and improving its properties.

Some products out of these two groups show both effects, e.g. hydraulic binders.

What all these products have in common is the fact that they can be used only under certain conditions, i.e. with certain soil types and certain granulations of the soil. They often fail to yield satisfactory results because soils rarely have a homogeneous composition, and this makes it impossible to anticipate the effect.

3. What are the advantages of the Quantum Ground Stabilization System?

The Quantum Ground Stabilization System (QGS), comprising the combinations a liquid formulation and powder formulation, was developed and devised specifically for the purpose of soil stabilisation, avoiding the paths other products (binders and chemical reactants) had gone with questionable outcomes.

Any cohesive soil has a tendency to petrify again; all it needs to achieve this goal is a very, very long time span and very high pressure. It is possible, however, to accelerate this procedure by catalytic processes. If the soil can be activated by catalysts or pseudo-catalysts and influenced in complex processes in its undesired behaviour, a considerable improvement can be achieved with nearly all kinds of soil and with the same quantities of additives.

This is what QGS does:

The use of the liquid formulation results in an irreversible agglomeration of the fine particles of the clay and in this way, a reduction of the active soil surface. The adhering water film is destroyed to a very high extent, thus activating the inherent binding power of the soil and the water content in the soil, especially its capillary saturation, is virtually diminished. An additional treatment of the soil with the powder formulation enables a 'tailored' degree of stabilisation in accordance with the requirements of each particular construction site.

4. How to apply QGS products?

The liquid product has to be diluted with water to obtain the working solutions. This is done on the construction site, taking into account the actual moisture content of the soil, i.e., is the soil moist, less water has to be added; is it dry, more water is necessary. Yet the quantities of additives, determined in the laboratory, always remain the same.

If the powder product is used in addition with the liquid product, this product is applied in dry state and mixed into the soil at the upper level. This is an advantage particularly on sites where due to an already high moisture content in the soil the addition of aqueous solutions might cause problems in terms of compaction.

5. What types of soil can be treated with QGS?

Principally all types of cohesive or semi-cohesive soils can be influenced to the required extent. The degree of stabilisation is determined by the requirements of the construction.

Supposition: the soil must be mechanically mixable. Very heavy sticky clays (such as some organic clays, e.g. black cotton soil) may cause problems and have to be adapted by adding sandy material, see references to our successful Stabilisation with the Swiss Laboratories.

6. Where is the soil to be treated - on the construction site?

The mixing-in of the liquid formulation and powder formulation into the in-situ soil available on site is the preferred application practice. The soil can however, also be mixed with the products in any kind of mixing plant, stored for unlimited time and on demand be built-in from this material stock. The Quantum Ground Stabilization System is, to our knowledge, the only process that allows both possibilities.

7. What is the depth of a treated layer?

Generally the liquid product is mixed with the soil to a depth of 25 cm, and a standard quantity of 0.2 litres per m2 is recommended in 95 to 98 out of 100 cases. The upper 10 cm of this layer already treated with the liquid product receives an additional treatment with the powder formulation. The standard quantities for the powder are between 2 and 4 kg per m2.

The actual depth as well as the horizon where the treatment shall start is determined by the soil properties, the tasks a road has to perform and the load the road has to bear, in accordance with the static aspects. It must however be taken into consideration that the bearing capacity of a treated soil layer is much higher than that of an untreated one, which may result in considerable cost savings.

8. Are any temporal limitations to be considered when using QGS?

None - provided the soil in question is workable. If rainfall is expected, the work can be interrupted at any time and continued at the same stage after an improvement of the weather occurs. The powder product is incorporated immediately after the liquid product.

9. Does the QGS System reduce the permeability of soil?

Yes - on the one hand by better compactibility of the soil and on the other by rendering the soil water-resistant up to any required extent, even to full impermeability.

10. How to calculate the quantities of QGS additives to be applied?

Has the specific weight of the soil and its moisture content to be considered?

No; products used in soil stabilisation should not be delicate or problematic in their application. Natural soils keep changing in their granulation, and a correspondingly changing application rate of the additives on the site would hardly be possible. We recommend working with the following values:

1 m3 of soil 2000 kg (2 tons)
1 m2, 25 cm deep; therefore 500 kg liquid formulation
1 m2, 10 cm deep; therefore 200 kg powder formulation

As standard quantities of the additives, empirical tests have revealed the following amounts for the overwhelming majority of existing soils:
for the liquid product: 0.2 litre per m2
for the powder product: l% to 2% of soil weight= 2 to 4 kg per m2

The liquid product is diluted on the construction site with as much water as the soil will accept for optimal compaction, OMC.

11. Do roads built with the QGS additives turn slippery in rainy periods?

Yes, they might. Since owing to the treatment the clayey fines are kept within the soil and not washed out, a treated soil surface may turn slippery in wet stage. Yet this fact is of no importance, as the treated soil layers are not normally used as a wearing course. For this latter purpose we strongly recommend to apply a thin surface coating, e.g. with asphalt, which realises a durable coating on the stable soil layer and keeps the road dust free.

12. What are the advantages of the QGS System over cement stabilisation?

Cement can be used as a drying aid for over moist soils and as a compacting aid. It is also suitable as a stabilising agent with certain non-cohesive soils. With cohesive soils, however, whose clay content differs and which may even contain organic pollutions, one may run into trouble with cement. On the other hand, by incorporating too large amounts of cement, a brittle layer of weak concrete may build up which tends to break into lumps, caused by the dynamic load of the traffic (by vibration). This can lead to a very unpleasant situation in the sub grade, since such cracks do not heal any more and frequently force their way up to the wearing course.

With the QGS System these objections can be completely neglected. The additives change the soil permanently and provide it with properties, which it did not have before and which it will not lose any more.

13. How do treated soils behave with regard to swelling and shrinkage?

The QGS additives have an enormous impact on the water sensitivity of a soil material and reduce it to a minimum. Thus the soil loses its natural conductivity to a high degree, i.e. shrinkage when drying out and swelling through the incorporation of moisture. Once compacted and subsequently slowly drying out, a permanent moisture content can be attained, which is around Proctor optimum (OMC) or slightly below. This means that the bearing capacity of a treated layer can also be maintained in wet periods.

14. In what cases is the QGS System of benefit?

In all cases where soil is used as the basic construction material or where soil causes stability problems, particularly in soil road/railroad construction and maintenance (subgrade, subbase and base layers).

15. What kind of tests shall be conducted?

As the first step the soil is to be classified, its granulation and dry density evaluated, and its special properties such as content of salt or organic matter determined.

Subsequently, a series of test blocks are produced, which comprise an untreated block and blocks treated with the standard quantities of additives. The blocks are then dried and tested regarding the following points:

- Dry pressure resistance;
- Capillary rise of water (by putting them on a water-saturated sand bed or by partly immersing them in water and observing their behaviour under water);
- Remaining pressure resistance after capillarity test;
- CBR test: for this purpose the blocks have to be dried first and then immersed in water (in deviation from the usual specifications for CBR testing).

Secondary Questions and Answers

16. Is there an optimal soil composition existing for QGS?

Normal physical conditions may be taken into account: the better the granular composition, i.e. the sieve curve, the higher the mechanical stability of the soil. An unfavourable granulation or an overrate of a certain fraction can be improved by mixing other soil available nearby in order to reach the starting point for a high mechanical stability, because the better the starting point with regard to the bearing capacity, the greater the effect of the treatment with the QGS additives.

17. How to treat non-cohesive soils (sand) with QGS?

Since the QGS products interact with the fine particles that thanks to the treatment can be used as natural binders, sand has to be mixed with cohesive soil prior to the treatment with the QGS additives in order to obtain a content of fines of approx. 20 to 30%. The soil mix prepared in this way can then be treated just as any other soil.

18. Is it beneficial to incorporate a sand layer beneath the treated layers in order to facilitate the water drainage?

A treatment of soil with the QGS System renders the soil to a high extent water-resistant, i.e. reduces its water content substantially. Nevertheless, adequate drainage must be provided for the whole construction prior to building up the single layers.

19. What consistency does the soil need before treatment?

Here the normal standards for earth constructions apply: soil should always be worked with at its Proctor optimum or slightly above, but never at too low a moisture content. The QGS System frees the bound water, which increases the compaction process enormously, especially with gravel and rock-containing material that can be wedged.

The treated soil loses its ability to take up water. This results in a constantly increasing compaction by the traffic, even if the initial compaction has taken place at too high moisture content. This continuous compacting effect can no longer be disturbed by the destructive impact of swelling soil when taking up water, the density increases constantly and the effect of the QGS System remains a permanent one.

20. Can any increase of bearing strength be expected?

A soil loses its bearing strength by taking up water. Therefore any diminution of such water absorption will yield increased bearing capacities. If the CBR value (California Bearing Ratio) is taken as an indicator for the bearing capacity of a soil, a CBR value of three to five times that of an untreated soil can be expected by the QGS treatment.

21. Can such increase in bearing strength be achieved with any soil?

Experience gathered throughout the globe with many different soil types confirm that improvements can be expected with all kinds of soil, from low-class types up to good soils. With the latter the CBR value generally exceeds a value of 230, which is the usual measuring range. Such treated soil can already be called a high-quality mineral concrete.

22. Can the QGS System be of assistance on swamps?

Yes, to a considerable extent. Since such soil frequently contains high amounts of silt, they are extremely water-sensitive and highly suitable for a treatment with QGS. It is understood, however, that despite this ideal situation a correct planning must be elaborated, including drainage, construction of the embankment (at least one metre above water level), compaction of the sub grade, etc.

23. At what point does compaction to take place?

Also here the rules applicable in conventional earth constructions hold true, i.e. the compaction should be performed with a moisture content at Proctor optimum or slightly above (or, e.g. in cases of imminent rain showers, immediately after construction). If for whatever reasons the compaction cannot take place immediately so that the soil dries too much, the missing moisture has to be incorporated by means of a tank car and the soil subsequently compacted.

24. Can the effect of the liquid formulation be observed on the soil?

Yes; if a mix of water with fine soil particles is prepared and the liquid product is added, the irreversible agglomeration of the fines can clearly be observed. The mineral phase immediately separates from the water phase; the coarsening of the fines is visually and physically measurable.

25. Are certain significant values of the soil changed by the treatment (such as dry density, Proctor optimum, etc.)?

This depends on the soil. Normally the optimum moisture content will shift to a lower figure, while the dry density increases by 5% to 10%. With certain soils these values do not change, the voids, however, increase.

26. Are the QGS additives dangerous to the environment?

No. Already in the development stage high priority was given to this issue and secured that no harm would be caused either to human beings or to the environment, provided the products are correctly used. Due to the fact that a treated soil is rendered highly impermeable, the transportation medium for the distribution of any polluting agents - the water - is even eliminated.

27. Do the Attenberg limits change by the treatment?

Yes. Normally these limits (plasticity and liquidity) are no longer visible, since a treated soil can only be brought into these ranges by forced mixing with water. Wherever measurements have been performed, no significant changes could be observed.

28. In which layers of a soil construction are the additives to be built in?

Their use is of benefit in all cases where local soil is to be used and where costs should be saved by avoiding pricey soil exchanges. It must be called to mind that most road damages result from the soil material beneath the surface - damages that can only be repaired by removing this soil, and for this purpose the entire road must be destroyed. Thus an in-situ soil is often the most expensive part of a road body, a fact that unfortunately becomes visible only when it is too late. This is why any sub grade, sub base, and base course layer should advantageously be treated with the QGS additives.

29. Are the QGS additives only effective with fine particles?

The major effect of the QGS System aims at a high influence on the fines in a soil, because it is these fines which are chiefly responsible for any instability; the coarse parts do not cause problems.

30. How to determine the correct dosage of the QGS additives?

In 95 to 98% of all cases the standard quantities of the liquid product and the powder product will yield the desired effect. Only in very few and rare cases it may be necessary and advisable to adapt the dosage. For this purpose, simple laboratory tests are conducted, a point which is being discussed below.

31. What effects can be expected from such laboratory tests?

In most cases already the standard quantities yield a better compactibility of the soil, a diminished capillary rise of water and a reduced destruction under water. The soaked CBR value is three to five times higher than that of a comparable untreated soil, provided, however, that the CBR test blocks had been dried before testing.

32. Do these improved values affect the planning and the cost of a project?

Yes. The improved behaviour of the soil allows not only its use but avoids the import of borrowed material for exchange. Depending on their quality before treatment, it is therefore possible to upgrade in-situ soils for use in the sub grade, sub base, and base layers.

If e.g. for a road body three layers of different materials are projected to reach the required bearing strength (representing together a layer of 600 mm depth), a reduction of this depth to a total of 350 mm can be achieved with the QGS System. The cost savings obtained only by this usability and improvement of the in-situ soil and the reduced layer depth are in the range of 20 to 50% of conventional constructions involving soil exchange.

33. What content of fines does a soil need in order to be suitable for a treatment with the QGS additives?

Since we aim at a very dense soil material, the content of fines (clay/silt) should not be lower than 20 to 30%. This yields a satisfactory mechanical stability.

The maximum content of fine particles, especially clayey soil, is exceeded, if the material can no longer be mixed mechanically. In this case the addition of sandy and coarse material is required to render the soil better workable.

34. What is to be done with heavy-traffic roads?

The consulter knows the condition of the existing sub base, the construction material, the required bearing strength, the traffic to be expected, and makes his calculations on this basis. Since every soil can be significantly improved by the QGS additives (see CBR value), the consulter can take advantage of this fact by using material available on the site, which otherwise he would have to replace.

35. Is an application on low-traffic roads advisable?

Yes; especially on such roads it is important to maintain the degree of compaction once reached and to prevent re-destruction of the road by the take-up of water or traffic volume, since for cost reasons it is usually necessary to work with in-situ soils on secondary roads.

36. Are the additives effective only against the impact of water on soils?

No. Water sensitivity is only one of the properties of soils that can be influenced. As complex as a soil itself is in its behaviour, as complex has to be any method influencing this behaviour, e.g. by better compactibility, coarsening of the grain size, or activation of the inherent binding power of the soil.

37. What is the effect of each particular additive?

The liquid formulation does the essential work in consolidating the soil, particularly by irreversibly agglomerating the fine particles and thus reducing the specifically effective soil surface and by effectively diminishing the rise of capillary water.

The powder formulation is however a dry product and therefore of advantage in cases of high moisture content in the soil to be treated and also in areas of high flood occurrences or with soils of higher salt content.

38. Is it recommendable to work with moisture contents above optimum?

A moisture content slightly above the optimum is of no harm and preferable to one below optimum. With more moisture the liquid solution can be better distributed and can penetrate the clay lumps more easily. Of special importance is a thorough pulverisation of the soil since the liquid product is effective only on the soil surface it can reach. The better the distribution, the higher is the effect.
Sometimes it may be advantageous (e.g. with heavy, lumpy clays) to add 1% to 2% of cement or lime hydrate to support this effect.

39. Is it advisable to test a soil in the laboratory ahead of a treatment in the field?

Yes. Although in 95 to 98 out of 100 cases the same low quantities of QGS additives will yield the desired effect, it is recommendable to examine each soil with regard to its inclination to be influenced. Visually very similar soils may show very different properties and may also react very differently.

40. What are the application fields apart from road and railroad construction?

In all cases where stable soil material is required, it is recommendable to make use of the QGS additives, such as in:

- the production of high-quality heavy duty work stations, wind and solar farms
- the protection of slopes from soil erosion
- the protection of pond and lakes from seepage

41. Protection from soil erosion: how to use the additives for this purpose?

Especially the fine particles of a soil can be blown and carried away very fast by wind and water, leading to soil erosion and the loss of substantial quantities of fertile land. The best protection from soil erosion is vegetation, i.e. an area in danger of erosion should be covered with plants as fast as possible.

The QGS additives enable the production of a soil mortar, which, applied on the earth, dries to a water-resistant crust, thus protecting the soil underneath from being carried away. However, in order to ensure a successful re-cultivation, the dead soil must be covered with a layer of fertile soil (a few centimetres may already suffice). In this fertile layer seed and fertilizers will be incorporated and subsequently covered with treated soil mortar, of which two layers of each 5 to 10 cm thickness should preferably be applied with a mortar spray gun.

42. In- what size containers are the QGS products available?

Usually the products are shipped m 200 litre drums (liquid product) or in jumbo paper bags with 1000 kg of powder product, if the size of the site is not asking for a delivery in bulk by tank trailer.

43. Is it possible if we only apply the liquid product in road construction?

No. The QGS System is a total system, not only compaction aid or something else - it allows to change the behaviour of the treated soil completely. Water is the most effective enemy of stability; QGS fights against the capillary rise of water and agglomerated the fines irreversible. Due to the fact that the capillaries still exist, surface water could penetrate into the treated layer and reduce mechanically the effectiveness of the treatment with the liquid product; therefore to prevent this, we add in the top layer of the powder product to avoid this filling up of the voids with seeping in water. The liquid product is used alone only in the deeper layers; in the top we need the combination of both additives to get the full protection besides other effects due to the complexity of the stability problems.

44. If we have to use the powder product, can we apply it together (as a mixed blend material) with the liquid product instead of applying it after we apply the liquid product first?

The separate application of the additives is for economic reasons only, because when we treat a 250 mm layer with the liquid product, usually only the top 100 mm of the treated soil will be additionally treated with the powder product. Due to the perfect performance more and more customers are using both additives in full depth and in this case both additives can be mixed into the soil together at once. If a good professional mixer is available (like Wirtgen, Bomag, CMI, Caterpillar, Bitelli, etc.) it is often possible to reduce the added additives to 50% only because we need only their presence and not the quantity but less additives needs better mixing quality which can be achieved with these equipment.

45. Has the liquid product the ability to penetrate after the application?

Aqueous liquids have the natural ability to penetrate into soil; the liquid product is spreading very wide because 1 It of the liquid formulation can theoretically, diluted in sufficient water coat monomoleculary a surface up to 25 Mio m2 Anyway we do not need further penetration because by proper mixing into the soil

we get a spontaneous agglomeration with the soil particles which makes the treatment impossible for being leached out by water. The soaked CBR values of a treated soil are usually improving 3 to 5 times, with more than 50% more than 5 times; preparing the in-situ soil by adding missing fractions ahead of the same treatment allows to get at higher mechanical stability further substantial improvements. See in this respect our documentation.

46. Is the QGS treated surface slippery when wet?

When not used as it should be used, YES. Any clayey soil, stable or unstable, becomes slippery when wet. Therefore it is necessary to, prepare for the base course a soil mix where the clay content is not dominant (you need a real Macadam) mix of clay, silt, sand and stones. To prevent slippery condition as well as mechanical abrasion (dusting) treated soil roads should always be paved with a thin layer of asphalt to serve and preserve the investments in the betterment and avoid also dusting. Due to the fact that the properly treated soil layer will become the "bridge" of the road, the wearing course can be dramatically reduced and the savings are outperforming the QGS costs in a way that the total calculation gives savings in the range of 20% to 50% of the construction costs.

47. Can the QGS System be applied during wet weather (in the rain)?

Contractors will be very careful in ripping-off a soil road when rain may occur, because over moistened soil needs weeks to become workable and compactable again; therefore, when you are working with the QGS System you will have to interrupt the work quickly and close the open road with all rolling equipment as fast as possible to avoid this over moistening of the soil. After the rain you can continue the application; there will be no leaching out or run away of material.

During long rainy seasons, when work at roads will be not possible, you will have the alternative to premix the soil mix you need later on the road, stockpile it and import it when, the conditions allow to work at the site.

48. How soon after application can a surface (road surface) withstand the traffic? IMMEDIATELY!

Due to the fact that the QGS treatment has no "potlife" the application can be interrupted any time, not only when it rains but also when you have to open the road temporarily for the traffic because there is no diversion (detour) existing. You can even prosper from such traffic, it is compacting your layers like a tire roller. Supposition is that the soil is compactable and not over moistened.

49. How long will the QGS System last? Will applications be required regularly?

The QGS treatment is a permanent one. This means, a soil once treated remains treated, which makes it possible to use treated material several times e.g. when used as a temporary road. In a road the density increases over time far more than 100% mod. AASHO density - we have impressive examples of roads, which have existed for more than 25 years and are still in perfect condition. See in this respect our documentation. Therefore treated sub-grade, sub base and base courses will need no repeated treatment. The only requirement will be to take care of the wearing course, but also there the maintenance will be strongly reduced due to the fact that the treated embankment will protect the wearing course against destruction from the ground.

50. Does the QGS System perform well in conditions affected by salt water (sea water)?

Salty soils usually do not cause great problems regarding stability as long as the salt content is not too high - laboratory tests show very easily and impressively the limits and also the way how to improve it by preparing mixes with other types of soil. We have plenty of excellent results with the QGS System in the neighbourhood of the sea like the Container Terminal in Manila/Philippines or a plant and container yard in Holland, to name a few only. The possibility of treating a soil completely to impervious conditions will avoid that sea (salty) water can penetrate like fresh water. All these features can easily be demonstrated on soil samples already in the laboratory before you start any application in the field. Therefore field application will never be a failure if you follow your lab-findings.

51. What is the difference between the QGS System and stabilisation with binders (cement, lime, asphalt)?

Any artificial binding system is heavily dependent on the quality of the soil and will show only under specific conditions with limited numbers of soils satisfying results; the QGS System activates the soil itself towards petrification and can improve 100% of all kinds of soil, as long as the content of fines is large enough or increased to 20% to 30%

52. Stabilisation with Cement - disadvantages:

For certain non-cohesive soils and in arid areas cement can be a suitable stabiliser provided the treated layer is thick enough and the underlying sub grade does not move under the dynamic forces of the traffic. Otherwise the weak cementation of the treated soil will lead to cracks and slabs, which "swim" on the subgrade and will cause deformation / heavy deflection with no chance of self-healing of the treatment. Once broken it remains broken.

With the QGS System we use, in such cases clay material as a natural binder and the treatment controls the water sensitivity of the soil mix, if necessary up to full impermeability. Once treated the soil remains treated, can be relevelled and even re-used on other places without loss of the improved behaviour.

53. Where is the QGS System the right choice?

In any earthwork where the water sensitivity of the soil causes stability problems and where the soil should be improved permanently with the capability to further increase stability, the QGS System is indicated. Due to the fact that treated soil will get an increased CBR which is 3 to 5 times higher than the soaked value of the same untreated soil, this opens up the opportunity to replace lots of borrowed material with in-situ soil, change the design completely and save in this way 20% to 50% of the construction costs compared with the same quality of a conventionally built road.

Any soil can be brought to any desired behaviours; it can be 'tailored' to the requirement on the site, and the QGS System offers the unique advantage that it can be used 'in place' as well as 'in-plant' where pre-mixed soils can be stockpiled even for years before being used on the site without losing any of the improving effects of the treatment.

54. Can the QGS System prevent seepage?

The most spectacular visual effect of the QGS System is the substantial reduction of the influence of water to the treated soil. The capillary rise can be reduced close to zero, the soil gets fully impervious when properly treated and the soil mix contains sufficient fines to allow a dense packing of the soil to avoid voids in the soil as far as possible. K-values in the range of 1.10-6 to -7 can be brought to fully impervious behaviour with values of 1.10-9 to –11.

Due to this advantage, the QGS System is very successfully used in avoiding seepage in artificial lakes, ponds, and in constructing impervious soil layers in the bottom of disposal areas to avoid the seepage of effluents from the waste into the ground water.

55. Can the QGS System avoid or reduce deformation and deflection, measured with the Benkelmann Beam?

Deflection and following deformation in the formation of a road is mainly caused by the behaviour of the base, sub-base and sub-grade; the more sensitive to moisture, the more deformation, and this becomes visible in the deflection tests. When properly designed, the deflection can be reduced substantially and the level of the road remains close to the value at the time of construction. The treated soil will not be saturated with moisture and change density by swelling and shrinking; the stable conditions in the treated formation will allow to put a lighter wearing course on top, which also will contribute to less deflection and deformation.

56. How to calculate properly the use of the QGS System?

Any earthwork must be seen as a complete project - not the single layer cost is important; important is, what change in the design is possible with the QGS System to make full use of the advantages of this unique system.

Cost effective single steps are:

a) Using as much as possible in-situ soil instead of borrowed material;
b) Avoiding excavation of in-situ soil and replacing with borrowed material and both importation costs;
c) Possibility of pre-mixing material and save construction time;
d) Due to higher loading capacity of the treated formation the wearing course can be substantially reduced in size, which contributes to better performance in avoiding the deformation caused by the accumulation of heat.

If all aspects are respected, substantial savings compared with conventional construction methods can be realised already during construction, irrespective of the further savings due to greater durability and lower costs for maintenance.

57. Why should an in-situ soil be improved by adding missing fractions ahead of a treatment with the QGS System?

Usually in situ soils cannot be used for any layer in a formation because certain parameters are required for each layer and need to be respected. E.g. pure fine sand cannot be used in a formation; it will never develop the desired loading capacity, and it will be the weak link in a formation. But if such find sand is bound with clayey fines, you will get higher density and compressive strength and with the treatment you will keep the soil mix stable even in moist periods.

This means that with any in-situ soil it is of advantage to look around the site, for materials available that can improve the sieve curve of the in-situ soil to better mechanical stability. Such improvement of the mechanical stability will pay substantially, because the QGS System works in most cases with the same quantities and costs - the better the starting point the more you get from the treatment. E.g. a soil with CBR 7% can be brought with the treatment to CBR 20% to 35%; but if the same soil is ahead of the treatment improved by adding clayey soil and/or coarse material to a CBR 15% the same, treatment will lead to soaked CBR values of 50% to 75% and even more.

58. How can the effectiveness of the QGS System be proved?

The QGS System offers the unique possibility of checking in simple laboratory tests the full effectiveness of the treatment ahead of any use in the field - therefore a failure in the field becomes impossible. You know in advance what you will get and already in the laboratory you can develop the proper soil mix, which satisfies all your requirements.

All standard soil tests as specified can be used. The only modification we recommend is that all samples, untreated as well as treated, have to be dried back from OMC to approximately 50% OMC to show realistic behaviour in the tests, comparable with the performance in the field. Especially samples with clay content, as is always the case with treated soil samples, perform with misleading results if tested at OMC; such samples become sensitive to water only after they have been dried back, which is always the case in the field, where it is impossible to keep the OMC as standard.

59. Is Erosion control possible with the QGS System?

A treated, clayey slurry on be applied with a plastering pump on slopes and protect them with a crust against wind and water erosion. Usually ahead of this plastering a fertile soil layer is applied and seed spread before the application of the clay slurry is done, in two applications of each 5 - 7 mm, where the second application closes the shrinkage cracks of the first application. The formed crust helps to keep the fertile soil moist and

speeds up germination; the plants have no problem to grow through the crust and take over in the following the erosion control. There where a recultivation is not possible, the protection layer may have to be repeated, according to the requirements, from time to time.

60. How to get A4 soils (silt) under control with the QGS System?

Silty soils are most difficult for construction because they are very sensitive to moisture, show swelling and shrinkage, and are difficult to work with. Especially these types of soil work excellently with the QGS System and can become fully impervious when properly treated. These soils can also be used as a natural binder for sands and coarse material. Some silt with single corn size may require the addition of clay for better compressive strength and density but altogether cause no problems in getting them fully under control and upgrade them to risk-free construction material

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Atterberg Limits Report

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 5/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Name :	**SOIL STABILISATION**	Order Number :	**-**
Project Number :	**BNS227**	Test Method :	**Q104A, Q105 & Q106**
Location:	**Laboratory Testing , Banyo**		**Page 1 of 1**

Sample Number :	BN11544	BN11546		
Test Number :	1	2		
Date Sampled :	30/11/2016	30/11/2016		
Date Tested :	12/12/2016	12/12/2016		
Sampled By :	Matthew Rheinberger	Matthew Rheinberger		
Sampling Method :	AS1289.1.2.1 - Clause 6.2	AS1289.1.2.1 - Clause 6.2		
Material Source :	Hanson - Ferny Grove Quarry	Hanson - Ferny Grove Quarry		
Material Type :	Type 2.5 Roadbase	Type 2.5 Roadbase		
Sample Location :	**Comparative Testing** **No Additive** **Type 2.5 Roadbase**	**Comparative Testing** **CONSOILD 2%** **Type 2.5 Roadbase**		
Lot Number :	-	-		
Moisture Method :	Q102A	Q102A		
Sample History :	Oven Dried	Oven Dried		
Sample Preparation :	Dry	Dry		
Notes :	No Cracking or Crumbling	No Cracking or Crumbling		
Mould Length (mm) :	149.98	150.10		
Liquid Limit (%) :	24.8	35.0		
Plastic Limit (%) :	16.6	31.2		
Plasticity Index (%) :	8.2	3.8		
Linear Shrinkage (%) :	3.6	2.2		
SPECIFICATION DETAILS				
Specification Number :				
Liquid Limit - Max :				
Plasticity Index - Max :				
Linear Shrinkage - Max :				
Remarks :	-			

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APPROVED SIGNATORY

Paul Shaw - Senior Technician
NATA Accreditation Number :
19460

Newstead Brisbane Laboratory

Coffey Services Australia Pty Ltd
ABN 55 139 460 521
47 Dogget Street
Newstead QLD, 4006

FALLING HEAD PERMEABILITY TEST REPORT

Approved Signature: Joseph Langley

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Report No.: PERM: BRIS16S-04536

NATA Accredited laboratory Number: 431
Date of Issue: 23/12/2016
Tested by: GM Checked By: JEL

PROJECT

Client	Soil Engineering Services	**Location:**	Banyo
Principal:	NA	**Issue No.:**	1
Job No.:	754-BRIS00011AA	**Project:**	QC Testing
Work Order No.:	BRIS16W-02036	**TRN:**	As per client

SAMPLE

Sample ID:	BRIS16S-04536	**Material Description:**	As per client
Client Sample ID:	BN11345	**Sampling Method:**	As per client
Date Sample:	As per client	**Source:**	Stabilsed Type 2.5

TEST RESULTS

Test Type	**A.S 1289 6.7.2**		**Temperature at Test**	**°C**	**22**
Compactive effort specified	**% of MDD**	**100**	**Surcharge applied**	**kPa**	**3.0**
Specimen MDD	**t/m3**	**2.168**	**Specimen Dry Density**	**t/m3**	**2.18**
Specimen OMC	**%**	**8**	**Specimen Wet Density**	**t/m3**	**2.34**

LABORATORY DENSITY RATIO	**%**	**100.3**
LABORATORY MOISTURE RATIO	**%**	**95.5**
COEFFICIENT OF PERMEABILITY $k_{22\,°C}$	**m/s**	**$1.7x10^{-10}$**
COEFFICIENT OF PERMEABILITY $k_{20\,°C}$	m/s	**2×10^{-10}**

COMMENTS

Coefficient of permeability **k (m/s)** is determined by using: (AS 1289 6.7.2-2001, Clause 8(a) Page 5)

Newstead Brisbane Laboratory

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FALLING HEAD PERMEABILITY TEST REPORT

Approved Signature: Joseph Langley

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The results of the tests, calibrations and/or measurements included in this document are traceable to Australian / International standards.

Report No.: PERM: BRIS16S-04537

NATA Accredited laboratory Number: 431
Date of Issue: 23/12/2016
Tested by: GM Checked By: JEL

PROJECT

Client	Soil Engineering Services	**Location:**	Banyo
Principal:	NA	**Issue No.:**	1
Job No.:	754-BRIS00011AA	**Project:**	QC Testing
Work Order No.:	BRIS16W-02036	**TRN:**	As per client

SAMPLE

Sample ID:	BRIS16S-04537	**Material Description:**	As per client
Client Sample ID:	BN11544	**Sampling Method:**	As per client
Date Sample:	As per client	**Source:**	Type 2.5

TEST RESULTS

Test Type	**A.S 1289 6.7.2**		**Temperature at Test**	**°C**	**22**
Compactive effort specified	**% of MDD**	**100**	**Surcharge applied**	**kPa**	**3.0**
Specimen MDD	**t/m3**	**2.218**	**Specimen Dry Density**	**t/m3**	**2.22**
Specimen OMC	**%**	**7.8**	**Specimen Wet Density**	**t/m3**	**2.39**

LABORATORY DENSITY RATIO	**%**	**100.2**
LABORATORY MOISTURE RATIO	**%**	**97.4**
COEFFICIENT OF PERMEABILITY $k_{22\,°C}$	**m/s**	**$3.4x10^{-9}$**
COEFFICIENT OF PERMEABILITY $k_{20\,°C}$	m/s	**3×10^{-9}**

COMMENTS

Coefficient of permeability **k (m/s)** is determined by using: (AS 1289 6.7.2-2001, Clause 8(a) Page 5)

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Unconfined Compressive Strength Report

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 4/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Name :	**SOIL STABILISATION**	Order Number :	**-**
Project Number :	**BNS227**	Test Method :	**Q115 (1978)**
Location:	**Laboratory Testing , Banyo**	**Page 1 of 1**	

Sample Number :	BN11544	BN11546		
Test Number :	1	2		
Sampling Method :	AS1289.1.2.1 - Clause 6.2	AS1289.1.2.1 - Clause 6.2		
Date Sampled :	30/11/2016	30/11/2016		
Date Tested :	7/12/2016	7/12/2016		
Material Type :	Type 2.5 Roadbase	Type 2.5 Roadbase		
Material Source :	Hanson - Ferny Grove Quarry	Hanson - Ferny Grove Quarry		
Lot Number :	-	-		
Sample Location :	**Comparative Testing** **No Additive** **Type 2.5 Roadbase**	**Comparative Testing** **CONSOILD 2%** **Type 2.5 Roadbase**		
Sample Type :	Laboratory	Laboratory		
Curing Details :	Temperature Controlled Room	Temperture Controlled Room		
Details of Replacement :				
Elapsed Time :	7 Days	7 Days		
Additive Type :	No Additive	CONSOLID		
Compactive Effort :	Standard	Standard		
Additive Content (%) :	0	2		
Oversize (%) :	-	-		
Moisture Content 1 | 2 | 3 (%) :	7.7 | 7.7 | 7.7	7.3 | 7.3 | 7.3		
Dry Density 1 | 2 | 3 (t/m³) :	2.234 | 2.224 | 2.227	2.191 | 2.18 | 2.165		
Moisture Ratio 1 (%) :	98.9	90.7		
Moisture Ratio 2 (%) :	98.9	90.7		
Moisture Ratio 3 (%) :	98.9	90.7		
Relative Compaction 1 (%) :	100.8	101		
Relative Compaction 2 (%) :	100.3	100.6		
Relative Compaction 3 (%) :	100.5	99.8		
Target Moisture Content (%) :	7.8	8.0		
Target Dry Density (t/m³) :	**2.217**	**2.168**		
UCS Cylinder 1 | 2 | 3 (MPa) :	**0.2 | 0.2 | 0.2**	**1.8 | 1.8 | 1.8**		
UCS (MPa) :	**0.2**	**1.8**		
Remarks :	-			

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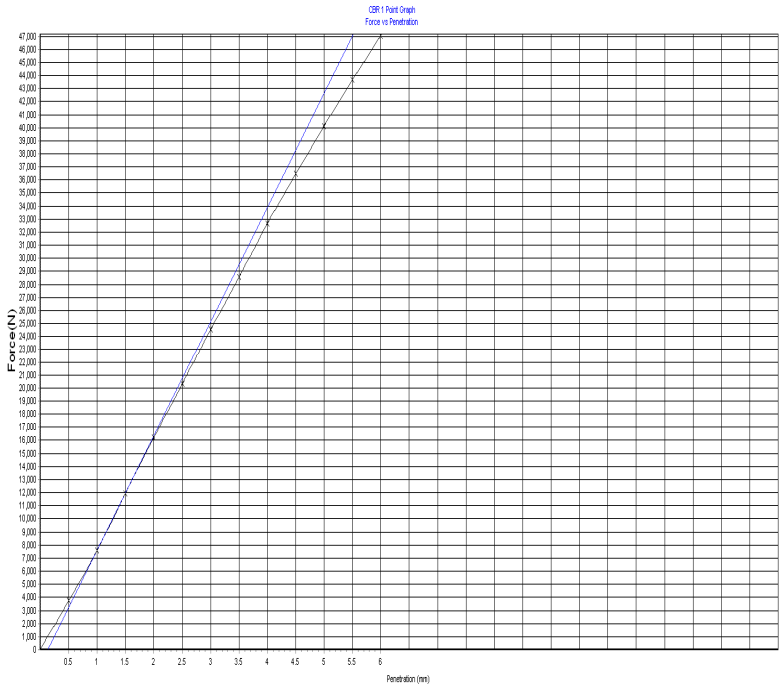
California Bearing Ratio Report (1 Point)

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 3/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Number :	**BNS227**	Order Number :	**-**
Project Name :	**SOIL STABILISATION**	Test Method :	**Q113C**
Location:	**Laboratory Testing , Banyo**	**Page 1 of 2**	

Sample Number :	**BN11546**	SAMPLE LOCATION
Date Sampled :	**30/11/2016**	**Comparative Testing**
Date Tested :	**30/11/2016**	**CONSOILD 2%**
Sampled By :	**Matthew Rheinberger**	**Type 2.5 Roadbase**
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	
Material Source :	**Hanson - Ferny Grove Quarry**	Lot Number :
Material Type :	**Type 2.5 Roadbase**	Test Number :
Remarks :		

Moisture Method :	Q102A
Maximum Dry Density (t/m³) :	2.168
Optimum Moisture Content (%) :	8.0
Compactive Effort :	Standard
Nominated Percentage of MDD :	100
Nominated Percentage of OMC :	100
Achieved Percentage of MDD :	100
Achieved Percentage of OMC :	94.0
Dry Density Before Soak (t/m³) :	2.176
Dry Density After Soak (t/m³) :	2.178
Moisture Content Before Soak (%) :	7.5
Moisture Content After Soak (%) :	7.5
Density Ratio After Soak (%) :	100
Field Moisture Content (%) :	3.7
Top Moisture Content - After Penetration (%) :	8.0
Total Moisture Content - After Penetration (%) :	7.8
Soak Condition :	**Soaked**
Soak Period (days) :	4
Swell (%) :	0.0



CBR Surcharge (kg) :	4.5	Bearing Ratio 2.5mm (%) :	160
Oversize (%) :	-	Bearing Ratio 5.0mm (%) :	**210**
Oversize Material Replaced (%) :	No	**CBR Value (%) :**	**210**

Site Selection :	-
Soil Description :	Type 2.5 Roadbase

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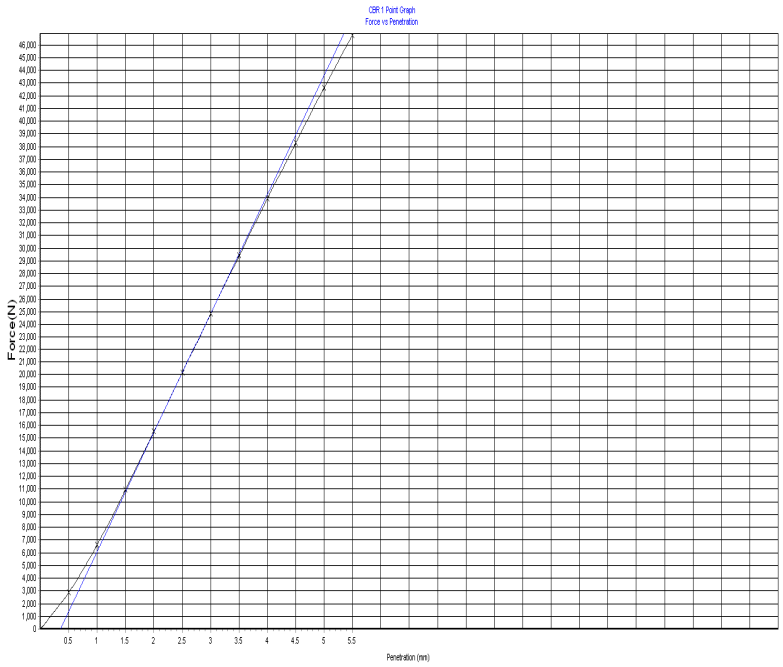
California Bearing Ratio Report (1 Point)

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 3/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Number :	**BNS227**	Order Number :	**-**
Project Name :	**SOIL STABILISATION**	Test Method :	**Q113C**
Location:	**Laboratory Testing , Banyo**	**Page 2 of 2**	

Sample Number :	**BN11547**	SAMPLE LOCATION
Date Sampled :	**30/11/2016**	**Comparative Testing**
Date Tested :	**30/11/2016**	**CONSOILD 2%**
Sampled By :	**Matthew Rheinberger**	**Type 2.5 Roadbase**
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	
Material Source :	**Hanson - Ferny Grove Quarry**	Lot Number :
Material Type :	**Type 2.5 Roadbase**	Test Number :
Remarks :	**The unsoaked CBR was left to cure in a sealed container for the 4 day period before penetration.**	

Moisture Method :	Q102A
Maximum Dry Density (t/m³) :	2.167
Optimum Moisture Content (%) :	8.0
Compactive Effort :	Standard
Nominated Percentage of MDD :	100
Nominated Percentage of OMC :	100
Achieved Percentage of MDD :	101
Achieved Percentage of OMC :	90.0
Dry Density Before Soak (t/m³) :	2.181
Dry Density After Soak (t/m³) :	2.184
Moisture Content Before Soak (%) :	7.2
Moisture Content After Soak (%) :	11.9
Density Ratio After Soak (%) :	101
Field Moisture Content (%) :	3.6
Top Moisture Content - After Penetration (%) :	7.0
Total Moisture Content - After Penetration (%) :	7.2
Soak Condition :	**Unsoaked**
Soak Period (days) :	4
Swell (%) :	0.0



CBR Surcharge (kg) :	4.5	Bearing Ratio 2.5mm (%) :	180
Oversize (%) :	-	Bearing Ratio 5.0mm (%) :	**230**
Oversize Material Replaced (%) :	No	**CBR Value (%) :**	**230**

Site Selection :	-
Soil Description :	Type 2.5 Roadbase

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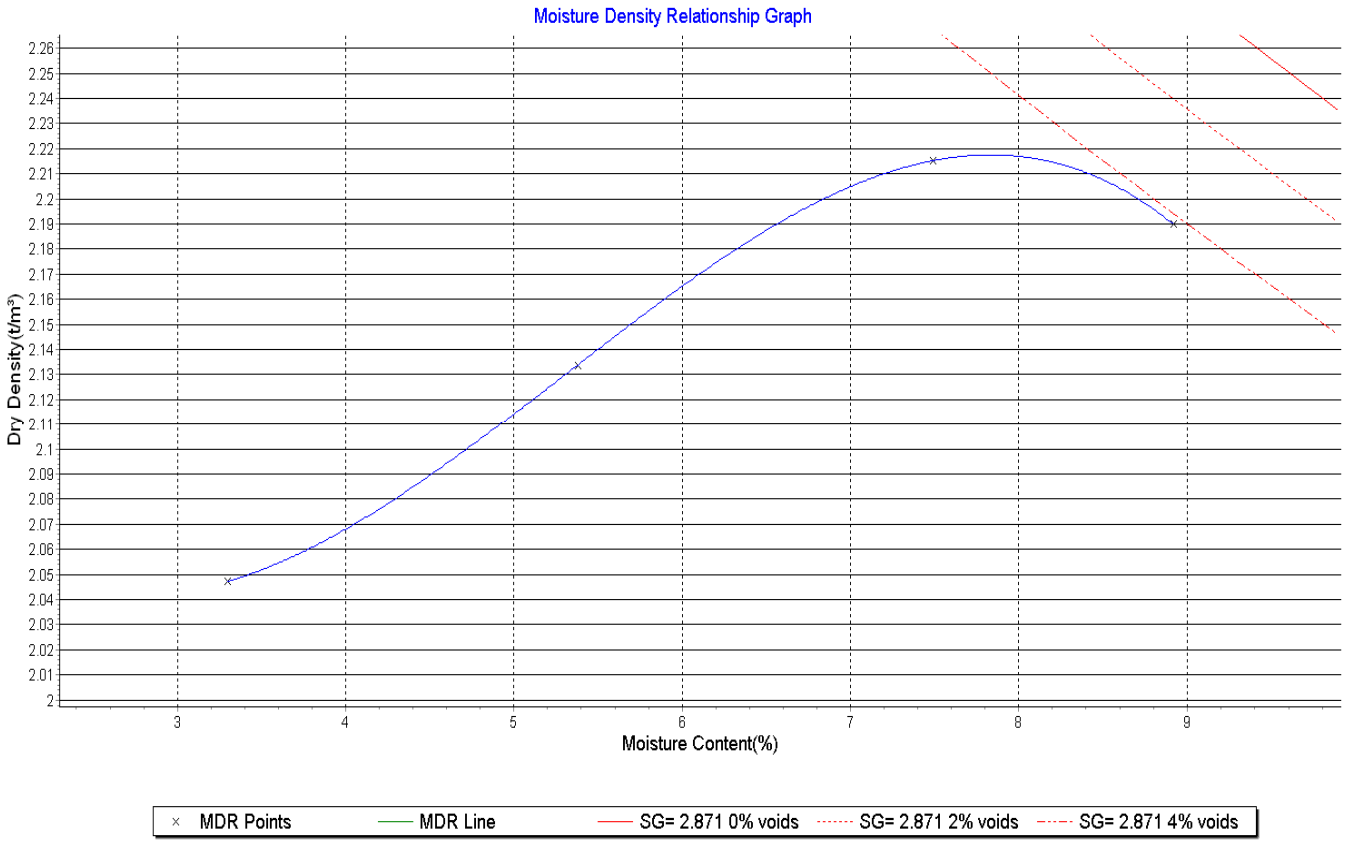
Moisture Density Relationship Report

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 1/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**12/12/2016**
Project Name :	**SOIL STABILISATION**	Order Number :	**-**
Project Number :	**BNS227**	Test Method :	**Q142A**
Location:	**Laboratory Testing , Banyo**	**Page 1 of 2**	

Sample Number :	**BN11544**	SAMPLE LOCATION	
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	**Insitu Material**	
Sampled By :	**Matthew Rheinberger**	**No Additive**	
Date Sampled :	**30/11/2016**		
Date Tested :	**6/12/2016**		
Material Type :	**Type 2.5 Roadbase**	Test Number :	
Material Source :	**Hanson - Ferny Grove**	Lot Number :	
Remarks :		Moisture Method :	Q102A

Maximum Size (mm) :	19.0	**Maximum Dry Density (t/m) :**	**2.218**
Oversize Dry (%) :		**Optimum Moisture Content (%) :**	**7.8**
Oversize Density (t/m³) :			



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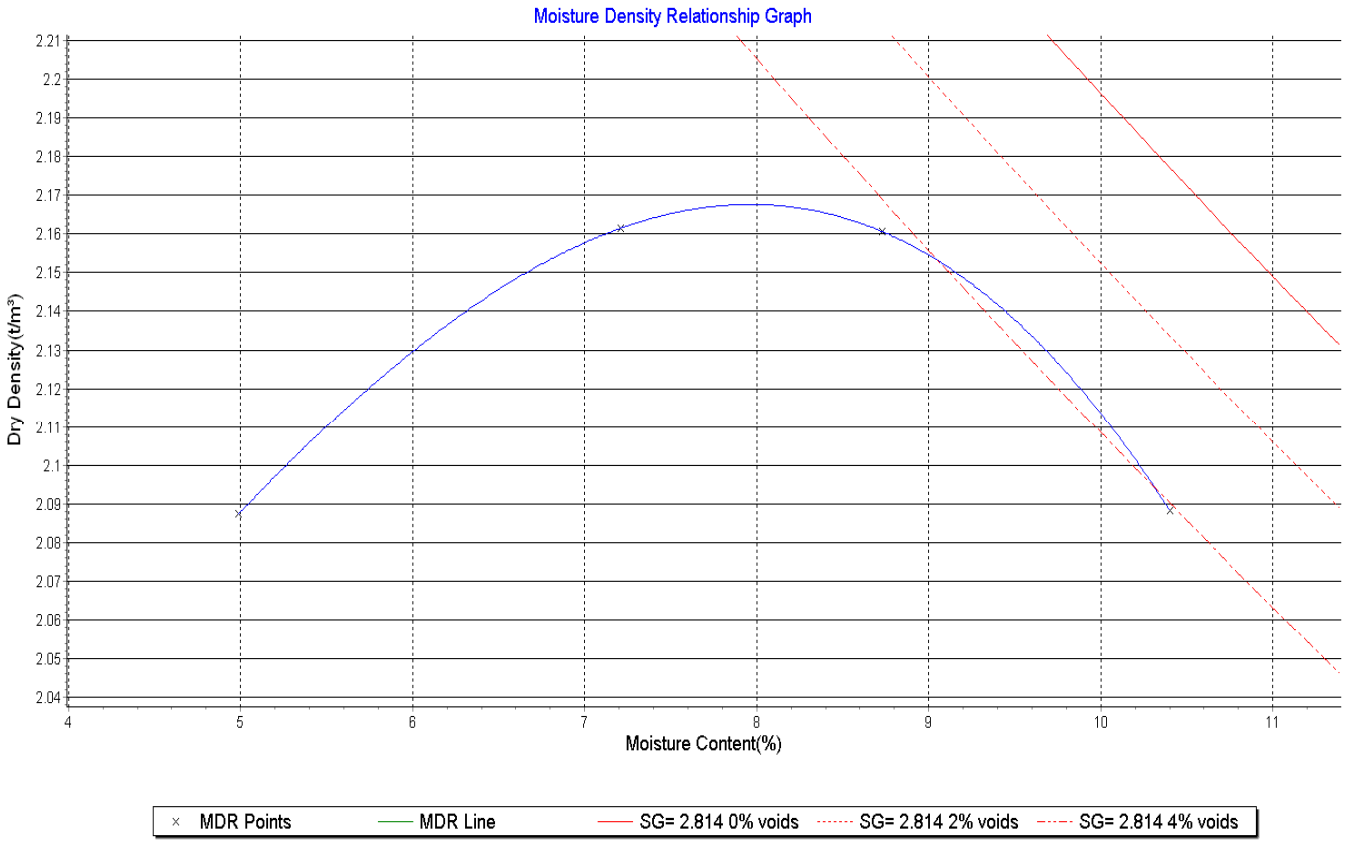
Moisture Density Relationship Report

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 1/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**12/12/2016**
Project Name :	**SOIL STABILISATION**	Order Number :	**-**
Project Number :	**BNS227**	Test Method :	**Q142A**
Location:	**Laboratory Testing , Banyo**	**Page 2 of 2**	

Sample Number :	**BN11546**	SAMPLE LOCATION	
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	**CONSOILD 2%**	
Sampled By :	**Matthew Rheinberger**	**With Additive**	
Date Sampled :	**30/11/2016**		
Date Tested :	**6/12/2016**		
Material Type :	**Type 2.5 Roadbase**	Test Number :	
Material Source :	**Hanson - Ferny Grove**	Lot Number :	
Remarks :		Moisture Method :	Q102A

Maximum Size (mm) :	19.0	**Maximum Dry Density (t/m) :**	**2.168**
Oversize Dry (%) :		**Optimum Moisture Content (%) :**	**8**
Oversize Density (t/m³) :			



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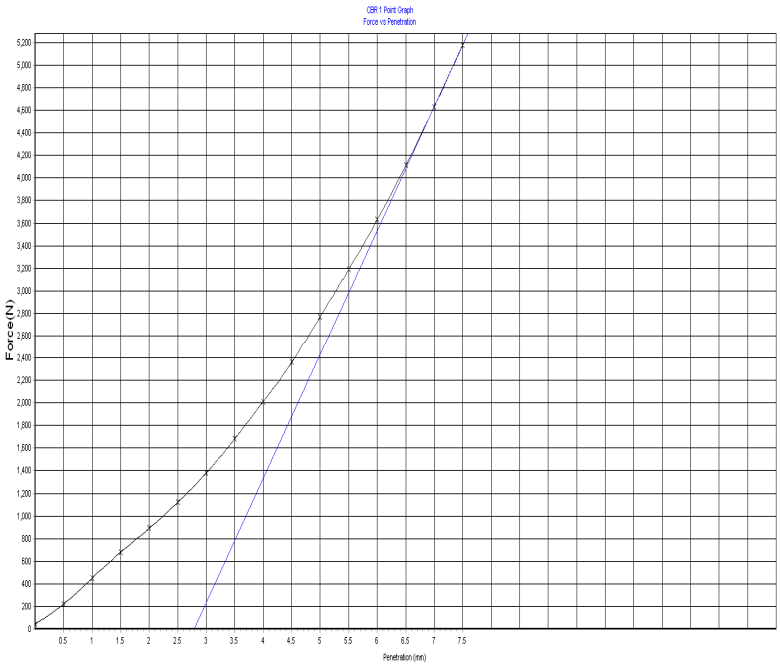
California Bearing Ratio Report (1 Point)

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 2/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Number :	**BNS227**	Order Number :	**-**
Project Name :	**SOIL STABILISATION**	Test Method :	**Q113C**
Location:	**Laboratory Testing , Banyo**	**Page 1 of 2**	

Sample Number :	**BN11544**	SAMPLE LOCATION
Date Sampled :	**30/11/2016**	**Comparative Testing**
Date Tested :	**30/11/2016**	**Type 2.5 Roadbase**
Sampled By :	**Matthew Rheinberger**	**No Additive**
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	
Material Source :	**Hanson - Ferny Grove Quarry**	Lot Number :
Material Type :	**Type 2.5 Roadbase**	Test Number :
Remarks :		

Moisture Method :	Q102A
Maximum Dry Density (t/m³) :	2.218
Optimum Moisture Content (%) :	7.8
Compactive Effort :	Standard
Nominated Percentage of MDD :	100
Nominated Percentage of OMC :	100
Achieved Percentage of MDD :	100
Achieved Percentage of OMC :	95.0
Dry Density Before Soak (t/m³) :	2.227
Dry Density After Soak (t/m³) :	2.236
Moisture Content Before Soak (%) :	7.4
Moisture Content After Soak (%) :	7.5
Density Ratio After Soak (%) :	101
Field Moisture Content (%) :	3.7
Top Moisture Content - After Penetration (%) :	7.8
Total Moisture Content - After Penetration (%) :	7.5
Soak Condition :	**Soaked**
Soak Period (days) :	4
Swell (%) :	-0.5



CBR Surcharge (kg) :	4.5	Bearing Ratio 2.5mm (%) :	10
Oversize (%) :	-	Bearing Ratio 5.0mm (%) :	**16**
Oversize Material Replaced (%) :	No	**CBR Value (%) :**	**16**

Site Selection :	-
Soil Description :	Type 2.5 Roadbase

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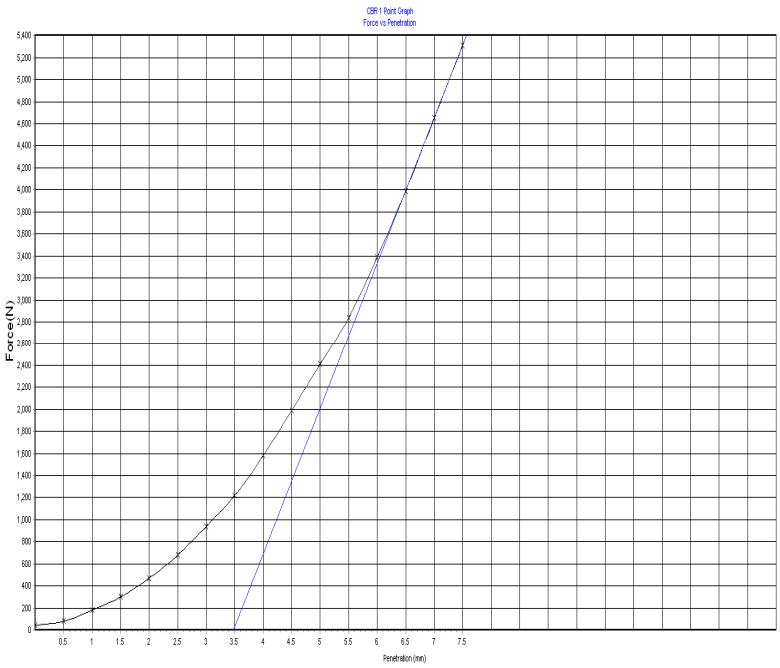
California Bearing Ratio Report (1 Point)

Client :	**CONSOLID (COD)**	Report Number:	**BNS227 - 2/1**
Address :	**PO Box 595, Cleveland, QLD, 4163**	Report Date :	**14/12/2016**
Project Number :	**BNS227**	Order Number :	**-**
Project Name :	**SOIL STABILISATION**	Test Method :	**Q113C**
Location:	**Laboratory Testing , Banyo**	**Page 2 of 2**	

Sample Number :	**BN11545**	SAMPLE LOCATION
Date Sampled :	**30/11/2016**	**Comparative Testing**
Date Tested :	**30/11/2016**	**Type 2.5 Roadbase**
Sampled By :	**Matthew Rheinberger**	**No Additive**
Sampling Method :	**AS1289.1.2.1 - Clause 6.2**	
Material Source :	**Hanson - Ferny Grove Quarry**	Lot Number :
Material Type :	**Type 2.5 Roadbase**	Test Number :
Remarks :	**The unsoaked CBR was left to cure in a sealed container for the 4 day period before penetration.**	

Moisture Method :	Q102A
Maximum Dry Density (t/m³) :	2.218
Optimum Moisture Content (%) :	7.8
Compactive Effort :	Standard
Nominated Percentage of MDD :	100
Nominated Percentage of OMC :	100
Achieved Percentage of MDD :	100
Achieved Percentage of OMC :	100.0
Dry Density Before Soak (t/m³) :	2.22
Dry Density After Soak (t/m³) :	2.23
Moisture Content Before Soak (%) :	7.8
Moisture Content After Soak (%) :	7.7
Density Ratio After Soak (%) :	101
Field Moisture Content (%) :	3.7
Top Moisture Content - After Penetration (%) :	7.5
Total Moisture Content - After Penetration (%) :	7.4
Soak Condition :	**Unsoaked**
Soak Period (days) :	4
Swell (%) :	-0.5



CBR Surcharge (kg) :	4.5	Bearing Ratio 2.5mm (%) :	7
Oversize (%) :	-	Bearing Ratio 5.0mm (%) :	**14**
Oversize Material Replaced (%) :	No	**CBR Value (%) :**	**14**

Site Selection :	-
Soil Description :	Type 2.5 Roadbase

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025.

APPROVED SIGNATORY

Paul Shaw - Senior Technician
NATA Accreditation Number :
19460

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CONSOLID AG – SOIL TEST REPORT

Date	**2016-06-16 - 96 hours (4 DAYS) – 2 cm Water Bath**	
Location	**INTERNATION SOIL LABORATORY** **CONSOLID AG / Switzerland**	
Client	**Consolid System (Aust) Pty Ltd** **Environmental Soil Stabilisation**	PO BOX 595 CLEVELAND Q 4163 **AUSTRALIA** Ph: **61 7 3821 0745** Fax: **61 7 3821 0746**
Person	**Mr. Mike FARRAR - mfarrar@austrahort.com.au**	
Testing	**Capillarity**	
Responsibility	**Bernhard EGEL**	

1. Soil Sample

Sample 1: **LT 16-01** **AUSTRALIA**	**QUEENSLAND** **BLACK SOIL** **Colour: "dark gray"** **Soil Type: Silty Clay with little organic material**	
Sample 2: **LT 16-02M:** **AUSTRALIA**	**BARACALBA** **DECO SUBSTRATE** **Colour:"brownish"** **Soil Type: Granulated Stony Sand** 	

2. CONSOLID System - Treatment

CONSOLID 444 (C444)	**0.8 l CONSOLID 444/m³**			**B**
	1 m³ soil = approx.. 2'000 kg			
	CONSOLID 444 Additives added:			**800 ml**
	Soil:	2'000 kg		800 ml
		20 kg		8 ml
		10 kg		4 ml
		1 kg		0.4 ml
	CONSOLID 444 Soil Laboratory Working Solution (WS):			
	2 % CONSOLID 444 Working Solution (C444 WS): **1:50 with water (H_2O) in the soil laboratory are equal to 800 ml CONSOLID 444 per m³ in the field:**			
	CONSOLID 444 WS		**1:50**	**B**
	Soil:	1'000 g	20 ml	C444 WS
		600 g	12 ml	C444 WS
		500 g	10 ml	C444 WS
		400 g	8 ml	C444 WS
SOLIDRY (SD)	**1% SOLIDRY**		**20 kg SOLIDRY/m3**	**S**
	Soil:	2'000 kg	20 kg	SOLIDRY/m³
		1'000 g	10 g	SOLIDRY
		500 g	5 g	SOLIDRY
	2% SOLIDRY		**40 kg SOLIDRY/m3**	**SS**
	Soil:	2'000 kg	40 kg	SOLIDRY/m3
		1'000 g	20 g	SOLIDRY
		500 g	10 g	SOLIDRY

The effect of the unique CONSOLID System:

CONSOLID 444	SOLIDRY
	
AGGLOMERATION EFFECT **After compaction properly!**	**WATER RESISTANCE EFFECT**

Testing Results:

Sample	0	BS	BSS	BSSM2	BSSM4
LT-16-01	500 g	500 g	500 g	400 g	300 g
LT-16-02				100 g	200 g
C444 WS		2%	2%	2%	2%
SD		1%	2%	2%	2%
N.W.C..	10%	10%	10%	9%	8%
Comp. Wat.	12%	10%	14%	13%	12%
Water Cont.	22%	20%	24%	22%	20%
Wet Weight	541 g	554 g	568 g	561 g	553 g
Wet Density	2'006 kg/m^3	2'028 kg/m^3	1'979 kg/m^3	2'019 kg/m^3	2'064 kg/m^3

Capillary Testing – Start:

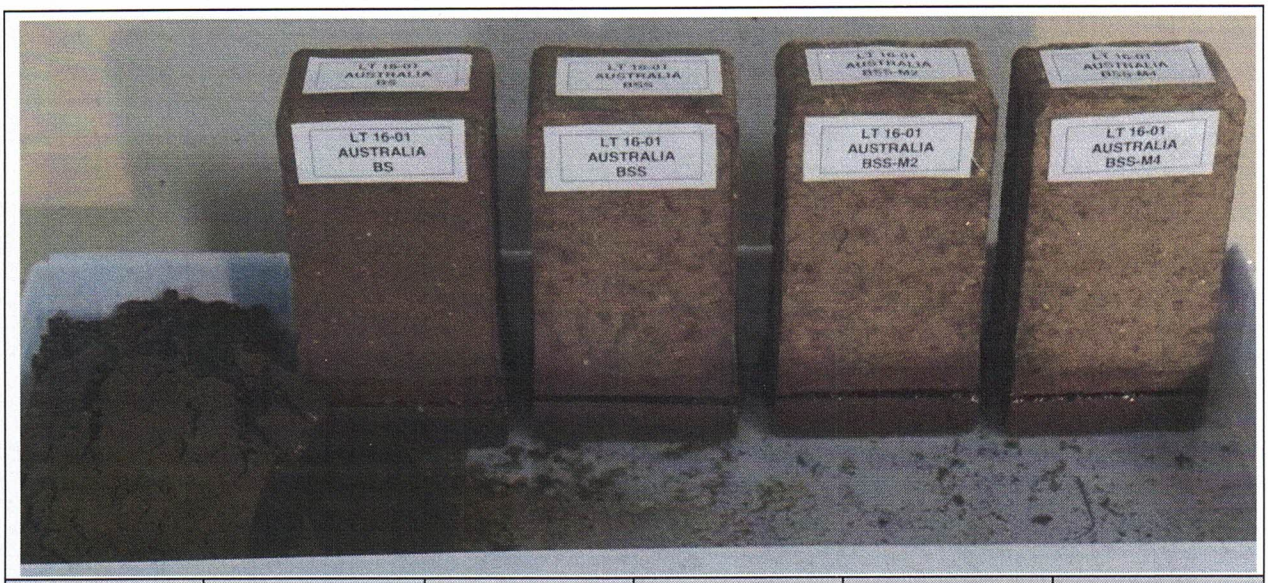
Start	0	BS	BSS	BSSM2	BSSM4
Dry Weight	541 g	554 g	568 g	561 g	553 g
Dry Density	2'064 kg/m^3	2'021 kg/m^3	1'956 kg/m^3	1'956 kg/m^3	1'960 kg/m^3

3 hours	0	BS	BSS	BSSM2	BSSM4
Weight			518 g	513 g	508 g
Cap. mm	50	0	0	0	0
Cap. Water			4 g	5 g	5 g
%			0.8 %	1.0 %	1.0%
Effect		Very little swelling			

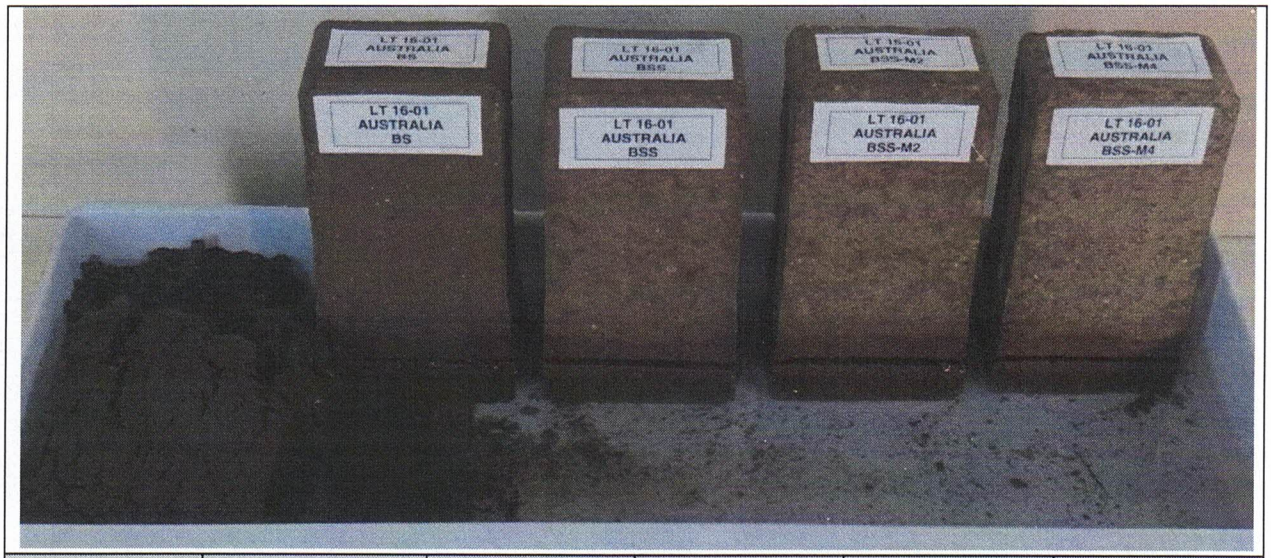
9 hours	0	BS	BSS	BSSM2	BSSM4
Weight			522 g	516 g	511 g
Cap. mm	100	2	1	1	1
Cap. Water			8 g	8 g	8 g
%			1.6 %	1.6%	1.6%
Effect	Soil collapsed	very little swelling			

24 hours	0	BS	BSS	BSSM2	BSSM4
Weight			527 g	520 g	514 g
Cap. mm		10	10	10	10
Cap. Water			13 g	12 g	11 g
%			2.5 %	2.4 %	2.2 %
Effect	collapsed	little swelling	very little swelling		

48 hours	0	BS	BSS	BSSM2	BSSM4
Weight			530 g	522 g	516 g
Cap. mm		10	10	10	10
Cap. Water			16 g	14 g	13 g
%			3.1 %	2.8 %	2.6 %
Effect	collapsed	little swelling	very little swelling		



72 hours	0	BS	BSS	BSSM2	BSSM4
Weight			530 g	522 g	516 g
Cap. mm		10	10	10	10
Cap. Water			16 g	15 g	14 g
%			3.1 %	2.8 %	2.6 %
Effect	collapsed	little swelling	very little swelling		

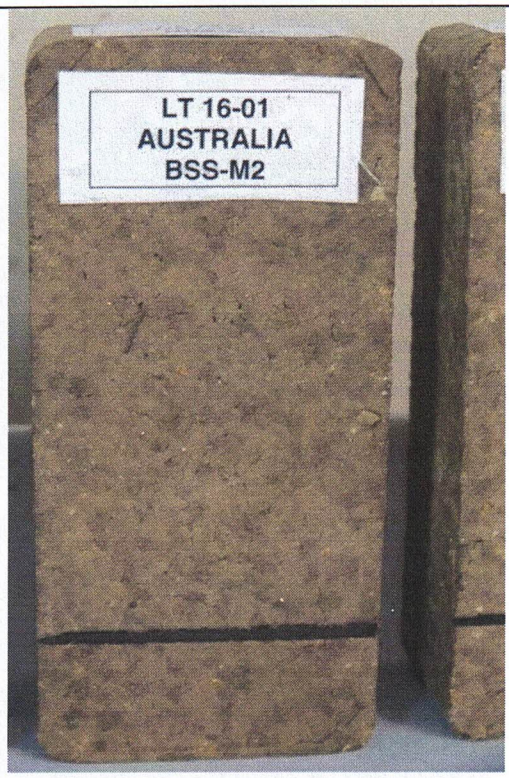


96 hours	0	BS	BSS	BSSM2	BSSM4
Weight		532	532	524	518
Cap. mm		10	10	10	10
Cap. Water		28g	18g	16g	15g
%		5.6%	3.5%	3.1%	3.0%
Effect	collapsed	little swelling	very little swelling		


LT 16-01
AUSTRALIA
BS
LT 16-01
AUSTRALIA
BSS
LT 16-01
AUSTRALIA
BSS-M2
LT 16-01
AUSTRALIA
BSS-M4

Untreated: 0

Remark: Soil surface difference after compaction:

Untreated / Treaded "BS"	Treaded "BSS-M2"
	
In the field the treaded soil might be not as sticky as the untreated soil regarding the "Compaction Roller". Treated soil: Improved compaction result possible!	**Treated soil with 20% sand should give improved compaction result and will be easily to process.**

This soil needs very professional Stabiliser Equipment in the field "Mixing Process"!

CAPILLARY TEST

Testing method:

CAPILLARITY of:	**Untreated Soil Sample** 500 g Soil Sample Compaction Water	**Treated Soil Sample** 500 g Soil Sample CONSOLID 444 C444 WS SOLIDRY SD Compaction Water
Compaction	Soil Press (50 kg/cm^2)	Soil Press (50 kg/cm^2)

Very important:

The better / professional / homogeneously you mix the soil with the CONSOLID Additives and the compaction water the better will be the result!
This is very important when you work in the field therefore you need very professionally construction equipment/machinery!

The soil samples should always be compacted at O.M.C. (Optimum Moisture Content)

LABELING:

O	=	**UNTREATED**
B	=	**CONSOLID 444 (0,8 lt/ m3)**
S	=	**1% SOLIDRY**
SS	=	**2% SOLIDRY**
M	=	**adding of missing soil fractions (Sand, Clay, Gravel, ...)**

Capillary test = 20 mm = **2 cm in water bath.**

If the soil is **"Heavy Clay"** you might add **20% - 60% "Sand"** to get the soil **shrinkage down!**
If the soil is **"Sand"** you might add **20% - 60% "Clay"** to get the **needed cohesion!**

For example: In the beginning you should make different tests to get the right experience:

Untreated	**Treated 1% SD**	**Treated 2% SD**
Clay 100 %	BS	BSS
Clay 80 % + 20 % sand	BSM2	BSSM2
Clay 70 % + 30 % sand	BSM3	BSSM3
Clay 60 % + 40 % sand	BSM4	BSSM4
Clay 50 % + 50 % sand	BSM5	BSSM5
Clay 40 % + 60 % sand	BSM6	BSSM6
Clay 30 % + 70 % sand	BSM7	BSSM7
Clay 20 % + 80 % sand	BSM8	BSSM8

If you do this series you get a very good experience for the soil stabilization (treatment) with the unique **CONSOLID System**. You are getting the experience for adding sand or clay to the soil. Therefore you get the shrinkage and swelling under control – you can design it.

Black Soil Brick Tests - Queensland Solar Farm

QUANTUM
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Testing completed on 19 July 2021.

Each brick was immersed in 20 mm of water within a 2-litre pail and over 72 hours imbibed as follows;

Sample A – Black soil alone, no treatment, collapsed and failed.

Sample B - Black soil 100% treated with Quantum liquid and powder imbibed 21 grs or 6.02%

Sample C - Black soil and 2.5 aggregate under 19mm, ratio 50/50% imbibed .05 grs or 111%

Sample D – Black soil and 2.5 aggregate under 19mm, ratio 65/35% imbibed 8 grs or 1.88%

Gross weights at commencement respectively 350 grs, 348.50, 448.50 and 424.50 grs

A conclusion may be drawn that neither A nor B are suitable whereas the 50/50 blend is near to perfect and the 65/35 could be very commercially acceptable in this troublesome soil.

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Honours Students Theses, Students 1 - 6, University of Sunshine Coast

1. Hayden Curran, *Waterproofing of natural materials to improve bearing capacity*, University of Sunshine Coast, 2016: Results, Conclusion, Recommendations.

2. Shaun Callanan, *Further Investigations into the Efficacy of a Soil Stabilisation Product for use within Australian Pavement Design*, University of Sunshine Coast, 2018: Summary and Conclusion.

3. Riley Brooks, *Investigation into the improvement of shear soil properties using a soil stabilisation method*, University of Sunshine Coast, October 2019: Methodology, Results, Discussion and Conclusion.

4. James Barr, *Alternative to lime stabilisation. How Quantum Ground Stabilisation could be the answer*, University of Sunshine Coast, February 2021.

5. Josh Stanley, *Bearing strength of road base materials stabilised with the QGS System for use in road and railway construction,* University of Sunshine Coast, February 2021.

6. Jake O'Neill, *Investigating the Performance of Quantum Ground Stabilisation Products with Combinations of Blacksoil and 2.5 Gravel to Stabilise for Various Pavement Applications*, University of Sunshine Coast, November 2020