“For stabilisation, upgrading, and recycling of low-quality soil material and construction rubble in road constructions and rehabilitation, earth work in railway construction, dam construction, sealing of irrigation facilities and ponds, airfields, runways and parking lots, industrial areas and much more.”

CONSOLID Ltd UK

The need for more cost-effective pavements led to the development and promotion of a number of chemical stabilising agents or treatments, which can be used in both roads and airports. These products attempt to improve the properties of the local or readily available marginal materials and by being able to use local materials large cost savings can be achieved.

With the proper use of the appropriate product, the performance (and service life) can also be improved. This is of particular importance in many parts of the world where roads and streets are required on a large scale in the development of rural and residential areas. The effectiveness (or performance) of the overwhelming majority of these products to date has been poor.

The CONSOLID System was developed because none of the existing chemical stabilising agents yielded satisfactory results and the main reason for their poor performance was not improper application, but most of the products available could not solve the problems for which they were offered.

It is therefore essential to understand both the effect of the treatment on the soil properties and the pavement behaviour to ensure proper application.

The products developed for use in pavements are CONSOLID 444 and SOLIDRY. They are normally used in combination (the CONSOLID System) by applying CONSOLID 444 to the total layer thickness (150 to 300mm) and SOLIDRY only additionally in the top 50 to 100mm.

CONSOLID 444 was developed in the late 1960’s and SOLIDRY completed the system in the early 1980’s.
The use of the CONSOLID System had to be started with demonstration roads all over the world to show the apparent major contribution the products can make in the provision of cost-effective pavements, and, more importantly, the fact that scarce conventional material can be replaced by inferior in-situ soils when properly treated.

Long time performance had to be shown to the potential customers for which the bad reputation of chemical stabilisation due to failures of other products had influence in the fast acceptance of the CONSOLID System. So far, several thousand kilometers of roads have been built and have given evidence of the unique character of the CONSOLID System in solving stability problems permanently.
Components of the CONSOLID System

CONSOLID 444
This is a chemical product which reduces the surface tension of water around soil particles so that the barrier film surrounding them is dispersed in order for the surfaces to associate with each other. This causes an agglomeration of fines (mainly the minus 0.06mm fraction). CONSOLID 444 is not a binding compound, but improves certain soil characteristics through the waterproofing effect. CONSOLID 444 is moderately acidic (pH = 6), has an ammonia odour and is inflammable at high temperatures. The process is permanent and irreversible once dried. The material (soil) treated with CONSOLID 444 has the following properties compared to untreated material:-

- Reduced resistance to compaction due to the loss of pore water
- Reduced rising of capillary water
- Reduced permeability
- The optimum moisture content is lower and the density is higher for treated material. In such cases where density and optimum moisture content are the same as in the untreated material it has shown that the voids in the treated material have increased due to the agglomerating effect of CONSOLID 444
- Continued process of the agglomeration of fines with time
- Reduced water sensitivity (higher water resistance)
- Larger increase in dry density by after-compaction, even if compacted at a high moisture content
- Lower water penetration (better waterproofing)
- Reduced plasticity and swell

CONSOLID 444 is mixed with water (in the ratio of 20 to 50 parts of water to 1 part of CONSOLID 444) and applied at a rate of 0.4 to 0.8 L/m² (0.25 to / 1% by weight). The pavement layer is normally mixed to a depth of 150 to 300mm. Larger quantities of CONSOLID 444 are not harmful. The mechanism of stabilisation is basically the formation of cations during evaporation. Higher strengths are achieved by keeping the soil dry.
SOLIDRY

This has similar active ingredients as CONSOLID 444. The ingredients have a synergetic effect. SOLIDRY is applied to the top 50-100mm of the pavement that has been pre-treated with CONSOLID 444. SOLIDRY is a dry powdered product and is applied at a rate of 0.5 to 1% by weight of soil.

The CONSOLID SYSTEM

The CONSOLID System encompasses the use of CONSOLID 444 and SOLIDRY. CONSOLID 444 is normally best for dry silly/sandy soil and non-flooded areas, while CONSOLID 444 and SOLIDRY are best for wet clayey/silty soil and flooded areas. CONSOLID 444 is mixed and applied separately in water carts, while SOLIDRY is mixed with the dry or wet soil. The quantity of water used for the dilution or dispersion depends upon the moisture conditions of the soil (more water with dry soil and less water with moist soils) but always the same quantities of CONSOLID 444 or SOLIDRY as determined by prior laboratory testing. Proper mixing is essential to ensure good distribution of the products to the soil particle surface. Compaction should take place at Proctor Optimum/OMC or slightly above OMC. In case of too high moisture content, compaction must be avoided to prevent entrapped moisture leading to deflection and cracking under traffic.

Where the moisture content is high, SOLIDRY should be used with conventional construction equipment. None of the products are poisonous. CONSOLID 444 is supplied in Southern Africa in 200L drums or in bulk, while SOLIDRY is supplied in 20kg bags or in bulk quantities.

The cost of the CONSOLID System depends on the application rates. In respect of cost comparison it is in our opinion misleading to compare the costs of the CONSOLID System with treatments of cement/lime or bitumen, since the latter treatments do not permanently change the soil and therefore comparisons are not the same.

Our findings state that the costs of a treated soil with CONSOLID additives provides substantial savings (as opposed to a conventional construction of the same road) due to the fact that a much higher portion of in-situ soil can be used and that the wearing course can be reduced, contributing to major overall savings. These savings using the CONSOLID Road System have shown cost savings over 35%. The construction costs are similar to those of conventional treatments (eg cement, bitumen) except that curing is normally not required.
Areas that the CONSOLID System can be applied

PAVEMENTS
- Any type of heavy-duty roads including major highways
- Any type of low-volume road viz. agricultural, forest, rural, conventional urban roads and township developments
- Road shoulders
- Railroad embankments
- Parking lots
- Residential streets
- Road rehabilitation: worn roads, worn asphalt pavement into base course
- Airports

MANUFACTURING OF AIR-DRIED SOIL BRICKS
- Affordable housing
- Sub-base for problematic soils

EROSION CONTROL
- Embankments
- Channels
- Dumps

OTHERS
- Playgrounds
- Sports fields
- Dams
- Refuse dumps

MINING
- Underground roadways
Advantages and Disadvantages of the CONSOLID system

**IMPROVEMENTS OF MATERIAL PROPERTIES**

- Reduces permeability and capillary rise
- Reduces plasticity index (Pl)
- Reduces optimum moisture content
- Increases California Bearing Ratio (CBR) as well as unconfined compressive strength and stiffness
- Increases maximum dry density
- Reduces swell and linear shrinkage
- Prevents water from softening the soil (after curing). The moisture content remains low during soaking and the dry strength is retained
- Strength is gained by the evaporation of moisture. The CONSOLID System works in and as well as in areas with high humidity. The general conditions regarding compaction have to be respected under all circumstances, which means compaction at PO/OMC or slightly above

**COMPACTION**

- Enhances compaction
- Remarkable increase of density by compaction after construction under traffic
- Reduces drying period

**CONSTRUCTION**

- Simple application
- Robust in that application rates do not have to be exact
- Can be stockpiled/ premixed
- Construction can be interrupted by rain without negative consequences

**GENERAL**

- Improves frost resistance
- The CONSOLID System is not recommended as a dust repellant as there are less expensive solutions for this problem
- Upgrades inferior soils
- Prevents softening of clayey material during wet seasons
DISADVANTAGES

- A surfacing is normally required as it is required for any other type of treated or untreated base course/top layer to prevent mechanical abrasion.

Based on the listed advantages and disadvantages, the following uses are foreseen:-

- To provide a non-erodible base course or sub-base with high bridging effect under any type of wearing course with the possibility of reducing the wearing course substantially, because the treated layers will take over most of the required bridging effect for the road.

To improve marginal material by doing one or more of the following:-

- Increase bearing capacity (CBR)
- Reduce Pl
- Reduce permeability
- Reduce capillary action (cg on wet areas)
- To improve compaction and workability
- Use where the re-use of the materials is a strong possibility (as opposed to a cementitious product)
- Use where shrinkage cracking is a problem (versus cementitious but not bituminous stabilisation)
- Use where treated material has to be stored (as opposed to cementitious) or hauled long distances
- Limited use as a dust repellant or to prevent abrasion loss.
- Where proper mixing is a problem
- On road shoulders to protect moisture from ingressing into the outside metre of the pavement
- Underground mining roadways in collieries, gold, diamond and other mineral mining activity
- Affordable housing - air-dried soil bricks/in-situ casting into some type of formwork
Pavement Design

The procedure used in the design of most pavements with CONSOLID 444 and SOLIDRY treated layers has been limited to either no formal design or the CBR design method. There exists in most countries, typical pavement design for all types of roads (cross sections) respecting the specific requirements (thickness of wearing course, base course and sub-base layer) under different traffic conditions.

METHODS OF DESIGN

- **Catalogues of design** - this is a very widely used procedure - required layer thickness, layer type, CBR’s or unconfined compressive strengths (UCS), plasticity index (PI) and grading modulus (GM) are specified for pavements with different required bearing capacities, depending on the expected traffic and the climate. Most countries in the world follow this guideline.

- **AASHTO Road Test Equations** - Statistical equations relating to the expected life (load application) to the bearing capacity (strength) of the pavement were developed from full scale road test done in the USA during 1959 to 1961 and subsequent experience. The strengths of the pavement layers are expressed as structural coefficients. The structural coefficients are determined from CBR values or elastic moduli. The AASHTO design method is widely used in the USA. This method has the advantage that the strength of the layers (expressed as structural coefficients) need not be based on soaked strength values. However, certain minimum requirements will have to be incorporated to prevent shear failure due to high loads or tyre pressures. This design method lends itself well to the design of pavements using the CONSOLID system.

- **CBR design method** - This is the oldest documented pavement design method and is widely used all over the world. The strength of the pavement is expressed as a CBR value. In the original method this was the soaked value and the procedure is not used for stabilised layers, traffic has only been incorporated later. This method has potential to be used in the design of pavements using the CONSOLID system, but need some additional requirements regarding material properties and minimum strengths.

- **Mechanistic design** - This is based on the calculation of stresses at various critical points in the pavement. This is normally done by the elastic multi-layer theory of finite element methods. The material is characterised in terms of E values and Poissons ratios, the calculated stresses and strains are then related to expectant pavement life by means of fatigue relationships. This method can be used in the design of pavements with CONSOLID 444 and SOLIDRY, if fatigue relationships for these materials have been developed. Fatigue relationships for soils treated with the CONSOLID system can be significantly differently from conventional untreated soils.
PROPOSED DESIGN PROCEDURE

The philosophy behind the design of a pavement utilising the CONSOLID System is to make optimum use of the soil strength in the dry state by keeping water out of the pavement layers by improved consolidation, repelling of water and lower permeability of treated layers. The following steps should be followed in the pavement design:

- Decide on the design life - this can vary between 5 and 30 years and depends on the intended use, future extension, also the fact that in most cases CONSOLID is used in existing roads which must be built with the existing pavement and therefore any improvement of this type of pavement will improve the road itself.
- Calculate the design traffic in terms of the number of equivalent E80 axle loads (E80’s)
- Determine the load bearing capacity (strength) of the in-situ material. This load bearing capacity can be expressed in terms of CBR, elastic modulus or shear strength. CBR and E can be converted to structural coefficients.
- Determine the required pavement composition using any of the procedures mentioned above taking into consideration the availability (and costs) of materials and their untreated and treated properties. Future maintenance requirements must also be considered. Cognition must be taken of the fact that these design procedures have some limitations in accommodating soils treated with the CONSOLID System.
- Take factors such as cost-effectiveness, ease of construction, reuse of layers, drainage, geometric alignment into consideration, before finalising the pavement design.

MATERIAL DESIGN

This pertains to the design of the specific layer and includes the type of treatment used, the application rate, the compaction and the curing. Any of a number of treatments can be used, one of which is the CONSOLID system.

The CONSOLID System works with the overwhelming majority of soils at the same rates in the same way and one of the great benefits of the system is that you will achieve an improvement on ANY type of road.

Conventional treatments such as cement or bituminous stabilisation have well documented design procedures, on the other hand design procedures for the CONSOLID System are scarce. One of the reasons for this is that conventional testing procedures do not necessarily apply, the following general guidelines:

- All cohesive or semi cohesive materials can be treated. All other soils can be easily prepared and made treatable (sands by incorporating clayey material, heavy clays and sandy or coarse material).
• Add fines (particles less than 0.66mm in size), if fines content is less than 10% to obtain at least 20% before treatment.
• Application rates of CONSOLID 444 and SOLIDRY and 0.4 to 0.8L/m³, 0.5 to 1% by weight, respectively.
• SOLIDRY is very effective with moist soil or soils with high salt contents.

The exact quantities must be determined by laboratory testing.

• The hydrophobic behaviour of the CONSOLID System preserves the dry strength of materials and therefore questions the need to have specifications for grading and Atterberg Limits together with strength parameters. The effect the CONSOLID system has on soils can, however, change standard design procedures currently applied.
• One of the shortcomings in the available literature is the lack of formal pavement designs to draw up specifications or requirements before testing commences. In most cases the in-situ or available material was evaluated, untreated and treated, and then used.
• An optimum application of the CONSOLID System exists in most cases after little or even less density/strength can be achieved, similar to a bituminous mixture.
• In material design, the optimum application is therefore to be determined for a specific soil sample. The CONSOLID System was developed from the field for the field by going on an entirely different approach in upgrading in-situ soil than any other system.
• Regarding material design, the cost of treatment, haulage, quality, etc. should always be analysed to prove the most cost-effective alternative.
• The optimum application can differ with different gradings, compaction efforts and also particle form (material type).
• Practice has shown that the optimum application of the CONSOLID System will not differ with different gradings so far that it could not be respected in easily found application rates. The same applies to compaction efforts or particle form.
• The variability of material in one borrow pit and the sensitivity thereof with the usage of the CONSOLID System should be tested to minimise the risk of failure.
Construction Methods

Conventional construction equipment is used, namely:

- Motor grader with ripper
- Water tanker, with a spray bar for equal distribution of chemicals
- Disc plough or rotovator or both
- A small pump for pumping chemicals from 200L drums into tanker is desirable
- Bulk tanker (if SOLIDRY is used in bulk)
- A suitable compactor

Alternatives for Soil Mixing

- **The mix in place treatment** - This alternative is recommended when in-place soils are to be used or if the use of a mixing plant is not justified. This method reduces material handling and transportation costs. Mixing the soil with the correct quantity of compaction water containing CONSOLID 444 or SOLIDRY as additives is performed on the site. The water tanker must be tested to determine a spray rate and driving speed to ensure an even and correct distribution of the solution. Even if CONSOLID 444 is diluted only 1:10 with water, it needs several passes before the entire quantity has been applied.

- **The mix in plant treatment (fixed or mobile)** - This alternative is recommended when the required construction material has to be transported from deposits or when material handling is inevitable. This method reduces mixing costs, eliminates the loss of fines and allows storage of treated soil without loss of effectiveness of the treatment. The change in soil characteristics after treatment with CONSOLID 444 or SOLIDRY is irreversible thus offering opportunities of pre-mixing of the soil for later use. Concrete mixers are normally used to mix the required proportion of chemical and soil before stockpiling it for use as and when required. When the soil is pre-treated the minimum amount of water must be used for complete distribution of the solution. Such pre-treated material is ready for use when needed and modifications of the gradation for higher mechanical stability can be incorporated in the mixing process. Construction methods with pre-treated materials do not deviate from the conventional process. This method is utilised for underground roadways as it eliminates in-situ mixing. Underground conditions have restricted the in-situ method in some applications.
Construction with CONSOLID 444

The area to be treated is prepared as follows:

- Break up the layer thoroughly by running the disc plough and/or rotovator through the layer to be treated. The depth is between 0.15 and 0.30m. Layers can be windrowed aside.

- From the laboratory results and determined start values, calculate the following:
  - The quantity of water for optimum compaction.
  - The minimum quantity of water in order to secure a sufficient distribution of CONSOLID 444 in the soil.
  - The mixing proportion of the CONSOLID 444 solution.
  - The entire quantity of CONSOLID 444 for the area to be treated.
  - The entire quantity of water for the area to be treated.

- Place approximately two thirds of the calculated amount of water in the tanker or fill the tanker two thirds of its capacity. Add the required quantity of Consolid 444 according to the mixing proportion calculated while the water is being circulated. Care should be taken not to circulate the bottom layers of the water only. After this, the other third of water can be introduced while the mixture is being circulated.

- The mixture is sprayed uniformly onto the chosen surface.

- The CONSOLID 444 is mixed into the soil to the required depth with a disc plough and/or rotovator. CONSOLID 444 is surface active, therefore the solution must obtain the best possible contact with the soil particles. It is very important to break the soil down to its finest possible state for good results. Proper mixing is of the utmost importance.

- The treated layer with CONSOLID 444 is compacted with an appropriate compactor to the specified density, preferably a sheep-foot roller. It is used until the feet come out to the remaining 50-60mm.
Construction with SOLIDRY

• The SOLIDRY is mixed with the soil either in the stockpile or in-situ to a depth of 50-100mm.

General

• All drums which have been stationary for a period of time must be shaken by rolling around before use.
• Always store drums, especially the CONSOLID 444 in a shady place.
• Once CONSOLID 444 has been mixed into a water tanker, the dispersion will stay uniform for long period.
• CONSOLID 444 is mixed in first.
• Open the road to traffic as soon after completion as possible to obtain better densities. No waiting (curing) period is normally required. However, this depends on the strength of the material.
• Conventional density tests should be carried out to ensure adequate densities.

The construction process is simple and utilises conventional and readily available equipment. Construction can therefore easily be carried out by large or small construction or even maintenance units. The materials are mixed in separately at moisture contents slightly below optimum Proctor (or at Modified AASHTO) compaction. The amount and type (SOLIDRY) of treatment in addition to the CONSOLID 444 depend on the required strength and material type. This can and must be determined from laboratory tests. Proper mixing is important and proper compaction before opening to traffic may be important depending on the evaporation rate, the initial strength, the strength gain and loading.
Laboratory and In-Situ Testing

The effectiveness of the CONSOLID System had to be confirmed by testing any kind of in-situ soil all over the world, because it was the aim of the CONSOLID System to enable an improvement of any kind of soil anywhere in the world with more or less the same quantity of additives.

After testing more than 4000 different kinds of soil from all continents it can be asserted that CONSOLID 444 + SOLIDRY, allow the upgrading of any kind of cohesive soil and that the overwhelming majority of soil types can be treated within the standard application range.

The following main characteristics have to be respected:

- The soil should have a minimum of fines content of 20% and should be pulverised for the treatment.

- Avoid gap sized material or add the missing fractions to obtain the best possible mechanical stability (strength) prior to the treatment. The treatment with the additives of the CONSOLID System costs the same but yields much better effects if you respect this recommendation.

- Any standard test specified for soils can be carried out with the only modification that testing of the sample blocks should not take place before these blocks have had the possibility of curing (drying back) to at least 50% of the OMC.

- When test blocks will remain in their moulds for testing (CS, CBR), be sure that the test blocks will be sealed with wax after drying back because the test blocks might have shown shrinkage in the moulds and loosened from the mould, which would lead to wrong measurement figures.

Please note that the loading capacity of soil is metered differently in all states of the world.
Recommended Tests

Any kind of soil test specified for laboratory testing of soils can be carried out, as long as you respect the modification of curing (drying back) the test blocks to at least 50% OMC before testing is started.

Due to the fact that water is the greatest enemy for stability and any laboratory test showing improvements in behaviour with water will be an impressive way to see the high effectiveness of the CONSOLID System.

Such tests are:
- Capillary rise of water
- CS and UCS
- Penetration tests
- Soaked CBR
- Linear shrinkage
- Atterberg Limits*

* The fact that the CONSOLID treatment renders soils highly resistant against water, makes it necessary to moisten treated soil by mechanical mixing in, because there will be no other way for saturation or over-saturation of a treated soil. Therefore the change in the AL will be of only academic value.

COMPARATIVE TESTS

Adequate tests to the soaked CBR would be:
- Penetrometer tests as well as
- Elasticity modulus

The improvements are shown in the same way - conversion tables available in the CONSOLID Manual.

FIELD TESTS

In the field any standard test can be carried out and will show the improvement in remarkable figures.

To name a few:
- Field CBR
- Plate Bearing Pressure
- Penetrometer Test
These will show the fact that in most cases the values obtained in the field outperform the test results in the laboratory.

Very impressive is the fact that under traffic, the treated road is further improved to increased density.

The high stability against deformation is shown impressively in using the Benkelmann Beam / Deflection Test.
Environment

During the development of the CONSOLID System, great care was taken to avoid any pollution of the environment with the additives, provided they are applied correctly. The CONSOLID additives are used in extremely low quantities and do not contain any chemical which could cause pollution of water or air - see ELUAT test for details, available on request.

Safety

FIRE PROCEDURES

CONSOLID 444 - This material does not set free flammable vapours and no precautions are therefore necessary in the storage and handling of the compounds. SOLIDRY - This is non-combustible - see CSIR report for details, available on request.

SAFE HANDLING

The CONSOLID additives are technically chemicals and usual care should be taken in handling these materials. They cause no problems or harms when used properly. Avoid contact with the skin, inhalation of dust, vapours or spray mist. Contact with eyes may cause severe damages if not treated at once.

**Skin contact:** Wipe off the product, wash with 3% acetic acid followed by plenty of water and soap. Get medical attention if irritating symptoms arise.

**Eye contact:** Wash immediately with 0.5% acetic acid and irrigate with a soft stream of water for 15-20 minutes and then seek medical attention.

**Ingestion:** Do not induce vomiting because of the risk of burns in the gullet. Drink milk if available, otherwise water. Get medical attention.

**Wear suitable protective clothing, plastic gloves and eye/face protection.**
The CONSOLID System Summary

The CONSOLID System comprising CONSOLID 444 and CONSERVEX has been used since the late 1960s in various countries throughout the world. The alternative of using CONSOLID 444 with SOLIDRY instead of CONSERVEX was introduced in 1985. Information on the usage throughout the world has been well documented.

The CONSOLID System consists in mixing CONSOLID 444 into the soil to a depth of 150 to 300mm and after that SOLIDRY additionally to a depth of 50 to 100mm. Conventional construction equipment is used. Proper mixing, preferably at a moisture content slightly above the Proctor Optimum (OMC), is essential. The treated layer is preferably covered with a surfacing treatment (sand seal). The products are chemical additives and change the soil properties irreversibly.

The literature clearly shows that the treatment of a soil with the CONSOLID Additives does improve the properties of the soil. The strength (expressed as CBR, UCS, bearing capacity or E modules), is increased if the treated material is allowed to cure (dry out). The increase in strength occurs in unsoaked and soaked samples (after curing). Once the treated soil has been cured, water ingress into the soil is prevented at a high degree. The moisture content thus remains low and the strength high. The Atterberg limits (plasticity index, liquid and plastic limits are therefore not relevant. Apart from the evaporation of moisture from the treated soil during curing, the small quantities of lime/cement filler used in SOLIDRY will not contribute to the strength of the treatment. But the combination of the active ingredients of SOLIDRY with this filler, increases the effectiveness in a synergetic way. Further important benefits are the reduced capillary action, erosion and permeability. The amount in reduction in each of these again depends on the soil type and application rates.

Although recommendations are given on the application rates of CONSOLID 444, SOLIDRY, laboratory tests should be carried out to determine the appropriate application rates and the effect on the material properties. Testing in the laboratory and in the field can follow the conventional tests without limitations as long as the special performance of the CONSOLID System is respected.

Tests normally conducted at OMC or in wet stage should take place only after the treated (and untreated) material has had a possibility of drying to approximately 50% of OMC before soaking is started.

Pavement design methods currently used are based on soil strengths in soaked condition with no dry curing. This method will have to be adjusted to incorporate soils treated with the CONSOLID System.
Attention should also further be given to the determination of the soil strength in terms of elastic modulus and shearing strength parameters instead of CBR, as well as failure mechanisms and fatigue relationships. Any type of on-site testing, viz. elastic modulus or shearing strength parameters can be used to show the effectiveness of the CONSOLID System. Failure mechanisms do not exist. Once stability has been reached, it can only be destroyed again by mechanical means. To date, the CONSOLID System has had no fatigue relationships experienced. The permanence of the treatment results in an improvement of the treatment with time and under traffic.
FAQ’s

1. SOIL STABILISATION

"Soil stabilisation" is achieved if an in-situ Soil has been rendered usable for risk free application in any earthwork. However, we have to distinguish between "soil improvement" (a not very significant increase in quality, particularly of the workability of a soil) and the real "soil stabilisation" (an actual change of the soil properties to a considerable degree).

2. Soil Stabilisation - how is it achieved?

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. Consolid’s soil stabilisation system is different.

3. Are there any of these products still on the market?

Cement and lime are in use for soil improvement, mainly as curing aid, as well as for soil stabilisation. The great bulk of these products, however - approx. 200 are known to us - disappeared as fast as they turned up. A number of them had not been developed for soil stabilisation anyway, but were mere industrial waste products to be 'buried' on such sites of application. Some others were limited in their effectiveness to certain soil types only and of insignificant or short term effect, and thus of little or no value.

4. What are the advantages of the CONSOLID Soil Stabilisation System?

This soil stabilisation system, comprising the combinations CONSOLID 444/CONSERVEX and CONSOLID 444 / SOLIDRY, was developed and devised specifically for the purpose of soil stabilisation, avoiding the paths other products (binders and chemical reactants) had gone and which had prevented a success.

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.
And this is what the CONSOLID Soil Stabilisation System does: The use of CONSOLID 444 results in an irreversible agglomeration of the fine particles and in this way a reduction of the active soil surface. The adhering water film is destroyed to a high extent, thus activating the inherent binding power of the soil. The water content in the soil, especially its capillary saturation, is highly diminished and slowed down. An additional treatment of the soil with CONSERVEX or SOLIDRY enables a ‘tailored’ degree of soil stabilisation in accordance with the requirements of each particular construction site.

5. What types of soil can be treated with the CONSOLID soil stabilisation system?

Principally all types of cohesive or semi-cohesive soils can be influenced to the required extent. The degree of soil 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.

6. Is there an optimal soil composition existing for CONSOLID?

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 in other soil available nearly 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 CONSOLID soil stabilisation additives.

7. How to treat non-cohesive soils (sand) with CONSOLID Soil Stabilisation Products?

Since the CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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.

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

The mixing-in of CONSOLID 444 and CONSERVEX / SOLIDRY into the soil available on the site is one of the application possibilities. 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 CONSOLID soil stabilisation system is, to our knowledge, the only soil stabilisation or consolidation process that allows both possibilities.

9. What is the depth of a treated layer?

Generally CONSOLID 444 is mixed with the soil in a depth of 20 to 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 CONSOLID 444 receives an additional treatment with CONSERVEX or SOLIDRY. The standard quantities for CONSERVEX lie between 1 and 2 litres per m², for SOLIDRY 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.
10. 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 CONSOLID soil stabilisation 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.

11. 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 CONSOLID soil stabilisation system frees the bound water, which eases 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 to a high extent. 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 CONSOLID soil stabilisation system remains a permanent one.

12. Are any temporal limitations to be considered when using CONSOLID for soil stabilisation?

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. CONSERVEX or SOLIDRY can be incorporated immediately after CONSOLID 444.

13. 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. Is the CBR value (California Bearing Ratio) 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 CONSOLID soil stabilisation treatment.

14. 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.

15. How to apply the CONSOLID products?

CONSOLID 444 and CONSERVEX are liquid soil stabilisation products, which have 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 SOLIDRY is used in addition with CONSOLID 444, this product is applied in dry state and mixed into the soil. 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.
16. Can CONSOLID 444, CONSERVEX, and SOLIDRY also be injected?

No! Since a thorough mixing of the products with the soil is indispensable, it is not possible to work with injections.

17. Does the CONSOLID Soil Stabilisation 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.

18. Can the CONSOLID Soil Stabilisation 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 CONSOLID soil stabilisation products. 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.

19. 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.

20. How to calculate the quantities of CONSOLID 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 2000kg (2 tons)

1 m², 25 cm deep; therefore 500 kg

1 m², 10 cm deep; therefore 200 kg

As standard quantities of the additives, empirical tests have revealed the following amounts for the overwhelming majority of existing soils:

for CONSOLID 444: 0.2 litre per m²

for CONSERVEX: 0.5 to 1% of soil weight = 1 to 2 litres per m²

for SOLIDRY: 1 to 2% of soil weight = 2 to 4 kg per m².
CONSOLID 444 and CONSERVEX are diluted on the construction site with as much water as the soil will accept for optimal compaction.

21. Can the effect of CONSOLID 444 be observed on the soil?

Yes; if a mix of water with fine soil particles is prepared and CONSOLID 444 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.

22. 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.

23. Are the CONSOLID 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.

24. Do roads built with the CONSOLID 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 split, which realises a durable coating on the stable soil layer and keeps the road dust free.

25. What are the advantages of the 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 troubles 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 anymore and frequently force their way up to the wearing course.

With the CONSOLID Soil Stabilisation / Consolidation System these objections can be completely neglected. The soil stabilisation products additives change the soil permanently and provide it with properties, which it did not have before and which it will not lose any more.

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

The CONSOLID soil stabilisation 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 conduct 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 or slightly below. This means that the bearing capacity of a treated layer can also be maintained in wet periods.

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 what cases is the CONSOLID Soil Stabilisation 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 construction and maintenance (subgrade, sub-base and base layers); rail embankment construction or maintenance; in any other kind of soil construction; against wind and water erosion; in irrigation channels to prevent oozing losses; in the production of high quality soil bricks for housing.

29. 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 CONSOLID soil stabilisation products additives.

30. Are the CONSOLID soil stabilisation additives only effective with fine particles?

The major effect of the CONSOLID Soil Stabilisation 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.

31. How to determine the correct dosage of the CONSOLID soil stabilisation additives?

In 95 to 98% of all cases the standard quantities of CONSOLID 444, CONSERVEX and SOLIDRY 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, a simple laboratory tests are conducted, a point which is being discussed below.

32. What kind of tests shall be conducted?

In a 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).

33. 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.

34. 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 using the Consolid soil stabilisation products.

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 CONSOLID Soil Stabilisation 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.

35. What content of fines does a soil need in order to be suitable for a treatment with the CONSOLID 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.

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

The consultor 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 CONSOLID soil stabilisation additives (see CBR value), the consultor can take advantage of this fact by using material available on the site, which otherwise he would have to replace.

37. 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, since for cost reasons it is usually necessary to work with in-situ soils on secondary roads.
38. 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.

39. What is the effect of each particular additive?

CONSOLID 444 does the essential work in consolidating or stabilising the soil (soil stabilisation), particularly by irreversibly agglomerating the fine particles and thus reducing specifically the effective soil surface and by heavily diminishing the rise of capillary water.

CONSERVEX is a complementary product to CONSOLID 444 and reinforces the protection against water by blocking the capillaries. In addition, surface water will be pre-vented from penetrating the treated layer.

SOLIDRY is effective in a similar manner as CONSERVEX; it 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.

40. Does CONSERVEX not reduce the consolidating effete of CONSOLID 444?

Soil improvement can never be expressed in absolute figures; it is always relative to the soil in question. There are many undesired properties one has to cope with, and sometimes a desired effect can also have some undesired side effects. In the case of CONSERVEX, such an undesired effect is the reduction of the inner friction of the soil, which is however more than satisfactorily compensated by the positive effects the treatment yields. Yet the quantities used shall always be kept as low as possible.

41. Is it recommended 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 CONSOLID 444 solution can be better distributed and can penetrate the clay lumps more easily. Of special importance is a thorough pulverisation of the soil since CONSOLID 444 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.

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

Although in 95 to 98 out of 100 cases the same low quantities of CONSOLID soil stabilisation 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.

43. What are the application fields apart from road construction?

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

- the production of high-quality soil bricks,
- the protection of slopes from soil erosion,
• the protection of pound and lakes from seepage, etc.

44. Soil bricks: what criteria shall be applied?

In principle the same as in road construction; every cohesive soil can be processed in order to obtain high-quality soil bricks and thus a valuable construction material. The standard quantities used in road construction are also applicable for soil bricks.

45. How stable are treated soil bricks?

The dry stability of soil bricks depends upon the natural stability of the used soil in its compacted, dry stage. Values between 20 and 100 kg/cm² have been measured. By a treatment with the CONSOLID soil stabilisation additives these values can be maintained, even if walls built with such bricks are exposed to water attacks.

46. When can the soil bricks be used after production?

Soil bricks have to be dried, a process, which usually takes 1 to 4 days, depending on the humidity of the air. Produced on the soil brick plant CLU 3000, the bricks are so dense that they can even be used for wall-laying right after emerging from the press. Drying is nevertheless recommendable whenever possible.

47. What is the lifetime of such soil bricks?

Once treated, the effect will be maintained. The bricks can only be destroyed by mechanical means. Soil is a very solid construction material, unless disturbed and destroyed by water. There exist many soil constructions, for example in Egypt, which have lasted for centuries.

48. How are walls built with soil bricks?

Ordinary lime and/or cement mortars are used.

49. What are the costs of a soil brick plant?

There are a number of different machines and equipment for the production of soil bricks on the market, from small hand presses to large stationary plants. We believe that a mobile plant is best suited, i.e. a machine on which a crew of 4 to 5 workers can produce in a one-shift Operation about one million bricks per year right on the construction site. This means a daily output of approx. 3000 bricks (representing 12 tons or 6 m³ of soil). Our mobile soil brick plant CLU 3000 reaches this output. The investments for such a mobile plant is in the range of SFr. 50'000.--.

50. How can the stability of soil bricks be increased?

In case higher values than the natural dry value of a given soil are required, these can be achieved by adding small percentages of cement and/or lime hydrate. With some types of soil, cement and lime alone may even suffice. Their brittle binding power is less harmful to soil bricks than to roads since the dynamic load on buildings is far lower than it is on roads.
51. What is the weight of a soil brick compared to that of a burnt brick?

Thanks to the high compactibility and the absence of a burning process, soil bricks can obtain a density up to 30% higher than that of burnt bricks. This high density is a very desirable effect in view of the climate of soil constructions, i.e. the transfer of heat/cold is temporally considerably reduced. This renders soil houses pleasantly cool at daytime and warm at night.

52. What are the costs of soil bricks?

The costs vary to some extent, depending upon the local conditions. It can however be assumed that savings of up to 50%, compared with burnt bricks, can be achieved.

53. Can treated soil be used as plastering mortar?

Yes, this is possible; we recommend, however, to increase the natural abrasion stability of the soil by adding cement/lime. One may also use unplastered soil bricks produced on the CLU 3000 for this end; they show a very regular surface upon extruding from the press and are well suited for visible walls. Still, it may be of advantage to protect such walls from abrasion and dusting with a colourless painting. Wallpaper paste, e.g., is well suited for interior walls; for exterior walls CONSOLID emulsion can be used in order to obtain best possible water stability.

54. What happens if a soil brick house is flooded?

If the soil bricks have been manufactured correctly and water resistance obtained, nothing will happen. In highly flood-inflicted areas it may be recommendable, if one wishes to be on the very safe side, to erect the walls up to the height, which can be expected to be flooded with particularly water-resistant bricks.

55. Are soil bricks fireproof?

Yes, soil does not burn. However, should a soil brick building or part of it ever become glowing by a conflagration, this glowing part will be transformed into a more or less burnt-brick building, while the unaffected part remains as it was before.

56. 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 CONSOLID soil stabilisation 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 10cm thickness should preferably be applied with a mortar spray gun.
57. In what size containers are the products (CONSOLID 444, CONSERVEX and SOLIDRY) available?

Usually the products are shipped in 200 litre drums (CONSOLID 444, CONSERVEX) or in paper bags with 25 to 50 kg, SOLIDRY, if the size of the site is not asking for a delivery in bulk by tank trailer.

58. What is the price of the products?

The local prices can be given you by our local partners only because they are based on the local added costs for custom duties, VAT, etc. But you will find enclosed a leaflet which shows minimum/maximum application rates for the typical road application are based on the approx. price per m².

59. Is it possible if we only apply CONSOLID 444 (without CONSERVEX) in road construction?

The CONSOLID soil stabilisation 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; CONSOLID 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 CONSOLID 444; therefore to prevent this, we add in the top layer CONSERVEX (CONSERVEX) or SOLIDRY (SOLIDRY) to avoid this filling up of the voids with seeping in water. CONSOLID 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.

60. If we still have to use CONSERVEX (CONSERVEX) or SOLIDRY (SOLIDRY) can we apply it together (as a mixed blend material) with CONSOLID 444 instead of applying it after we apply CONSOLID 444 first?

The separate application of the additives is for economic reasons only, because when we treat a 250 mm layer with CONSOLID, usually only the top 100 mm of the treated soil will be additionally treated with CONSERVEX (CONSERVEX) or SOLIDRY (SOLIDRY). Due to the perfect performance more and more customers are using both additives (CONSOLID 444+CONSERVEX or CONSOLID 444+SOLIDRY) 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.

61. Has the product (CONSOLID 444) the ability to penetrate after the application?

Aqueous liquids have the natural ability to penetrate into soil; CONSOLID is spreading very wide because 1 lt of CONSOLID 444 can theoretically, diluted in sufficient water coat monomolecularly 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.
62. Is a CONSOLID system treated surface slippery when wet?

When not used as it should be used, YES. Any clayey soil, stable or instable, 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 the 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 CONSOLID soil stabilisation costs in a way that the total calculation gives savings in the range of 20% to 50% of the construction costs.

63. Can CONSOLID Soil Stabilisation System be applied during wet weather (in the rain)?

Real 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 CONSOLID Soil Stabilisation 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.

64. How soon after application can a surface (road surface) withstand the traffic?

Due to the fact that the CONSOLID soil stabilisation / consolidation 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.

65. How long- will the CONSOLID soil stabilisation system last? Will applications be required regularly?

The CONSOLID soil stabilisation 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 tune 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 following treatment with Consolid's soil stabilisation products. 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.

66. Does the CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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.

67. What is the difference between the CONSOLID soil stabilisation 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 CONSOLID soil stabilisation / consolidation 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%

68. Soil 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 CONSOLID soil stabilisation system we use, in such cases clayey 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.

69. Where is the CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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.

70. Can the CONSOLID soil stabilisation system prevent seepage?

The most spectacular visual effect of the CONSOLID soil stabilisation / consolidation 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.

Due to this advantage, the CONSOLID soil stabilisation 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.
71. Can the CONSOLID soil stabilisation 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.

72. How to calculate dosage of the CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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.

73. Why should an in situ soil be improved by adding missing fractions ahead of a treatment with the CONSOLID 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 CONSOLID soil stabilisation 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.
74. How can the effectiveness of the CONSOLID Soil Stabilisation System be proved?

The CONSOLID soil stabilisation 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 approx. 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.

75. Is Erosion control possible with the CONSOLID soil stabilisation 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.

76. How to get A4 soils (silt) under control with CONSOLID soil stabilisation 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 CONSOLID soil stabilisation 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.