



CHEMICAL STABILIZATION OF PAVEMENT SUBGRADE

The "subgrade" is the in situ material upon which the pavement structure is placed. Although there is a tendency to look at pavement performance in terms of pavement structures and mix design alone, the subgrade soils can often be the overriding factor in pavement performance.

Subgrade performance generally depends on two interrelated characteristics:

1. **Load bearing capacity.** The subgrade must be able to support loads transmitted from the pavement structure. This load bearing capacity is often affected by degree of compaction, moisture content, and soil type. A subgrade that can support a high amount of loading without excessive deformation is considered good.
2. **Volume changes.** Most soils undergo some amount of volume change when exposed to excessive moisture or freezing conditions. Expansive clay soils shrink and swell depending upon their moisture content.

Poor subgrade can not be avoided in most cases and some degree of mitigation is required when building a new road section over weak soils. Historically designers have had the option to:

- **Removal and replacement (over-excavation).** Poor subgrade soil can simply be removed and replaced with higher quality fill. Although this is a simple concept, in today's environment it most likely will be cost and schedule prohibited.
- **Additional base layers.** Marginally poor subgrade soils may be made acceptable by using additional base layers. These layers spread pavement loads over a larger subgrade area. This option is rather perilous; when designing pavements for poor subgrades the temptation may be to just design a thicker section with more base material because the thicker section will satisfy most design equations. However, these equations are at least in part empirical and were usually not intended to be used in extreme cases. In short, a thick pavement structure over a poor subgrade may not make a good pavement.

In today's environment, the use of depleting aggregate sources and the economic and environmental cost of hauling heavy rock over long distances has become unsustainable. The use of design methods that were developed in the 1930's and



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40's, when aggregate sources were located within what is now urban areas, has now been brought to the forefront of long-term sustainability and resource allocation.

- **Stabilization with a cementitious binder.** Stabilizing the subgrade with an appropriate chemical stabilizer (such as **Quicklime**, **Portland cement**, **Fly Ash** or **Composites**) increases subgrade **stiffness** and reduces **expansion** tendencies, it performs as a foundation (able to support and distribute loads under saturated conditions). In order for stabilization to maintain long-term support, a minimum unconfined compressive strength must be achieved, less than this strength the soil will only be modified.

The use of chemical soil stabilization has now been realized for its engineering benefits, economic value and environmental impact perspective in California. The issue now facing pavement designers and the engineering community in general, is one of proper design protocols, quality control of the process, and post-treatment performance verification.

SUBGRADE MODIFICATION

Modification of fine-grained subgrade soils can be provided by the application of small percentages of quicklime and water. Two primary chemical reactions, cation exchanges and flocculation–agglomeration, define modification. The effects of this chemical reaction are relatively rapid and produce an immediate improvement in the soil's plasticity, workability, uncured strength, and load-deformation properties.

The values of subgrade modification in pavement design application are reduction in shrink/swell potential of clayey subgrades, winterization of subgrade for all-weather access, and increase in uncured strength as measured by CBR and R-Value.

SUBGRADE STABILIZATION

Stabilization of subgrade soils is a method of developing a permanent foundation structure in order to reduce a corresponding base layer as measured by gravel equivalency. This method of design requires an unconfined compressive strength (UCS) equal to a corresponding strength of crushed rock (gravel) or Gravel Factor (Gf) of 1.0

The use of standardized design and testing procedures requires certain conversion factors that are readily available. The standardized procedure most often used when designing for UCS conversion is the Highway Design Manual Section 604.3.60 stating as followed:



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When a stabilized subbase, such as Lime Treated Subbase (LTS) is used as a subbase it is substituted for all, or part, of the required AS layer. The design thickness of the base and AC surfacing layers are determined as though AS is the planned subbase material. The LTS is then substituted for the AS. Since AS has a G_f of 1.0, the actual thickness and the GE are equal. When LTS is substituted for the AS, the actual thickness is determined by dividing the GE by the appropriate G_f based on unconfined compressive strength. The gravel factor for LTS is calculated from the Unconfined Compressive Strength (UCS) of the treated soil measured in MPa using the formula: $G_f = 0.9 + UCS / 6.9$

Generally, the layer thickness of LTS should be limited, with 200 mm as the minimum and 600 mm as the maximum thickness. An asphalt concrete layer placed directly on the LTS should have a thickness of at least 75mm. Because the lime treatment of the basement soil may be less expensive than the base material, the calculated base thickness can be reduced and the LTS thickness increased because of cost considerations. The base layer thickness is reduced by the corresponding gravel equivalency provided by the lime treated basement soil or subbase. A subbase layer or even a base layer may be omitted if the R-value of the basement soil is relatively high. Lime treatment (or stabilization) may in some cases increase the R-value of a soil so that the subbase or even the base layer may be omitted.

A standardized structural value is given to the stabilized base:

Caltrans Design Equation (Section 660):

$$G_f = 0.9 + (UCCS/1000) \quad \text{UCCS in psi}$$

$$G_f = 0.9 + (UCCS/6.9) \quad \text{UCCS in MPa}$$

Design Considerations:

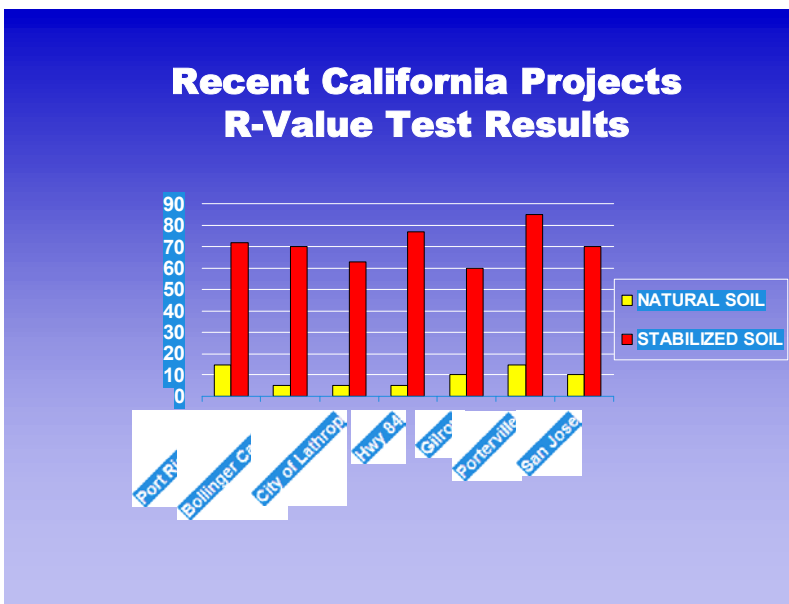
Minimum Unconfined Strength = 300 psi

Maximum G_f = 1.2

Minimum Section = 10 inches

DESIGNING WITH R-VALUE AND CBR

Unlike UCS design, where the chemical treatment is being equated with gravel equivalency, designing using R-Value or CBR is a comparison between treated and untreated soil. By improving the subgrade soils deformation resistances or bearing capacity, the new treated subgrade results can be incorporated into the pavement design.

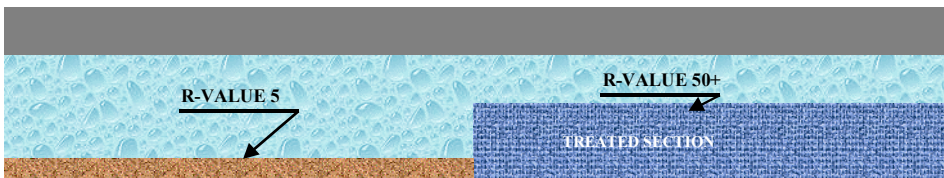


- Substantial increases in R-Value can be achieved by treating with 3 to 5 percent Quicklime.
- Increasing R-Value will significantly reduce base section in pavement design

Testing protocols for both R-Value and CBR have no requirements for curing strength of chemically treated soils.

Typical R-Value Section Reduction

SECTION COMPARISON BASED ON SUBGRADE R-VALUE			
TRAFFIC INDEX 8			
NON-TREATED SUBGRADE R-VALUE 5		TREATED SUBGRADE R-VALUE 50	
AC (THICKNESS)	4"	AC (THICKNESS)	4"
CLASS 2 AB	20"	CLASS 2 AB	7"
TEATED SECTION	0	TREATED SECTION	15"



Values obtained represent only the increase in load-deformation properties, uncured strength, and the inherent strength of a less-plastic material.



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When designing using R-Value or CBR, consideration should be given to pH testing to confirm lime demand of the proposed treated soil. Since relatively small percentages of lime is required to modify plastic soils, it's important to meet lime demand when measuring long-term strength performance. An initial pH of 12.4 will insure additional pozzolanic reaction of a chemically treated plastic material. The notion of chemically treated soil's reverting back to untreated strength behavior stems from under-supplying the chemically treated material with to little lime or to little water.

THE OPTIMIZED DESIGN

The UCS design approach maximize the benefits of a chemically treated pavement section and minimize post-treatments concerns of performance verification, shrinkage cracking, and the notion of chemical retardation.


UCS testing provides several data points that are critical to long-term performance and **Lab/Field Synchronization**. This design approach determines short and long-term strength gains, determines optimum moisture requirement for hydration versus moisture/density relationship, and exposes variability within the treated soil's matrix if performance is not achieved in field processing.


TYPICAL AB REDUCTION USING IN-PLACE TREATED SECTION

Traffic Index of 8 and Native R-Value 5					
	Non-Stabilized Section	Treated R-Value Credit 40	Treated R-Value Credit 50	Treated R-Value Credit 60	UCS 300 psi @ 7-days
AC Section (inches)	4	4	4	4	4
Aggregate Section (inches)	20	10	7	6	4
Treated Section (inches)	0	12	15	16	18
Aggregate Section Reduction (inches)	0	-10	-13	-14	-16

CHEMICAL SOIL STABILIZATION - EXPANSIVE MATERIALS IN CA

DISTRIBUTION OF POTENTIALLY EXPANSIVE SOILS

 **HIGH:** Highly
Expansive and/or High Frequency
of Occurrence

 **LOW:** Generally of
Low Expansive Character and/or
Low Frequency of Occurrence

 **Non Expansive:**
Occurrence of Expansive Material
Extremely Limited

