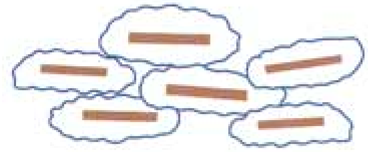
Aggregate Modification

Chemical Lime
A Lhoist Group Company

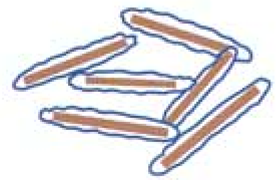
The Concept

Do you have aggregate material in your quarry that can't be sold because a small percentage of clay prevents it from meeting specification? If so, you are not alone. Many aggregates and fill materials fail to meet the specified strength, plasticity index and or sand equivalent requirements due to the presence of clay minerals on the aggregate surfaces. The addition of a small percentage of lime can substantially improve the physical properties of these marginal aggregate mixes and extend the economic life of many quarries — turning a liability into an asset.

Figure 1. Reduction of water layer with lime.



Parallel arrangement of clay particles with hydrated water layers



Edge-to-face attraction induced by thin water layer that allows attractive forces to dominate

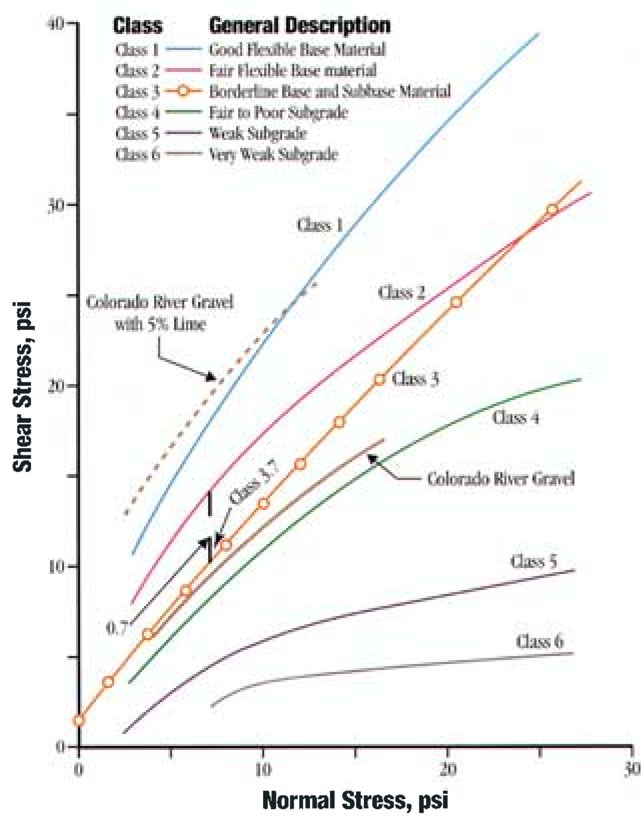
The Mechanisms

Lime reacts with the clay fraction of a soil or aggregate mix to change the properties of the clay and to actually transform the clay fraction into a beneficial component of the aggregate material. The processes responsible for these property changes, cation exchange and the flocculation/agglomeration that results, are both a result of adding lime. Initially, the divalent calcium ions (Ca^{2+}) in the clay-water system displace the weakly bonded water molecules, adsorbing to the negatively charged sites on the clay mineral surfaces. This dramatically and permanently reduces the diffused water layer surrounding the clay particles, due to the strong charge of the calcium ion.

As a result of these processes, the net negative charge of the clay particles has been largely satisfied and the water layer has been dramatically reduced. This enables the clay platelets to rearrange themselves from being parallel to one another, to an edge-to-face arrangement (Figure 1). This rearrangement process of the clay platelets is known as floccula tion and agglomeration, and is responsible for the increase in the internal friction, resulting in substantially more shear strength. Together, the processes of cation exchange followed by flocculation and agglomeration occur as rapidly as the lime can be intimately mixed with the clay, reducing the plasticity index and swell potential while increasing the shear strength.

The third and final step that occurs during aggregate modification is the pozzolanic reaction. Clay serves as the pozzolan, since it is the source of silica and

Figure 2. Chart for Classification of Subgrade and Flexible Base Material



alumina. In a lime-saturated soil-water system, the pH is 12.45, more than enough to solubilize the alumina and silica in the clay. The free calcium from the lime then combines with the alumina and silica to form calcium silicate and calcium aluminate, the foundations of Portland Cement. This is the identical process that occurs during the in situ stabilization of expansive subbases for pavement and building pad construction.

Through these processes the improvement in the shear strength and the resultant upgrade in the classification of the flexible base material are illustrated in Figure 2. Through the addition of lime, the engineering properties of the borderline Colorado River Gravel material were enhanced significantly to that of a Class 1, Good Flexible Base Material.

The strength gain characteristics associated with lime are not limited to clay alone. Research and field studies in Florida and Texas have shown significant strength gains when lime is added to limestone and caliche bases (Graves and Little, 1996). In this role, lime reacts with carbon dioxide in the soil-water-air system to form a matrix of calcium carbonate cement which bonds the carbonate aggregate material together, enhancing the strength and stiffness of the aggregate mix.

Lime being fed onto marginal aggregate.

The Process

The percentage of lime required to improve the stability of marginal aggregates is normally low, generally between 1–3% (CaO) by weight of the dry aggregate, depending on the amount of clay and the objectives of the application. To simply modify the plasticity would typically require less lime than it would to achieve a lime-saturated (pH 12.45) system where the objective would be to achieve structural strength development through the pozzolanic reaction. Carbonate aggregates with little or no clay content typically require about 1–2% lime addition for strength development and modulus improvement.

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The actual application does not require expensive or sophisticated equipment. Ideally, either quicklime or lime slurry is added to a moist aggregate and mixed in a pugmill mixer. However, with the proper system design, the entire process can be accomplished on the belt with typically very little investment.

Quicklime is fed onto the belt from a silo using a vane feeder or weighbelt. A simple water spray, with volumes linked to the belt speed, triggers the exothermic reaction, converting the quicklime to calcium hydroxide.

The final step is the thorough mixing of the calcium hydroxide with the moist aggregate, using a series of belt plows. The photos at right illustrate this simple process and the equipment involved.

Mixing of lime, water and aggregate with belt plow (see detail below).

Belt plow.

The Summary

The addition of small amounts of lime to improve the physical characteristics of aggregate materials containing clay or calcareous materials has been recognized and has been practiced for many years. Marginal or unstable aggregates have been stabilized through the mechanisms of cation exchange in conjunction with the flocculation and agglomeration of the clay particles, resulting in plasticity reduction, improved cleanliness values as well as sand equivalents. Further benefits come from the increased resource utilization and improved economics realized from the aggregate operation.

Chemical Lime has been involved in the design of numerous aggregate modification systems. Our process engineers would be pleased to assist with yours.

References

Graves, R.E., and Little, D.N., "Importance of Carbonate Fines in Improving Structural Contribution of Unbound Limestone," *Proceedings*, 4th Annual Symposium, Center for Aggregates Research, April 1996.

Little, D.N., "Comparison of In-Situ Resilient Moduli of Aggregate Base Courses With and Without Low Percentages of Lime Stabilization," *Innovations and Uses for Lime*, ASTM Special Technical Publication, No. 1135, pp. 65–77, 1990.

Chemical Lime Company

Chemical Lime Company's innovative spirit has propelled us into a leadership position in today's market. Employing technical experts in the fields we serve is one way Chemical Lime meets customer needs in the many industries we serve.

We provide customized solutions with lime-based products to varied markets including water and wastewater treatment, steel manufacturing, building construction, road and highway construction, hot mix asphalt, mine reclamation, paper production, copper, gold, and alumina processing, and flue gas desulfurization. Headquartered in Fort Worth, Texas, Chemical Lime Company has 40 locations in North America.

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