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SOIL STABILIZATION USING CEMENT (BODENVERFESTIGUNG MIT ZEMENT), (U)
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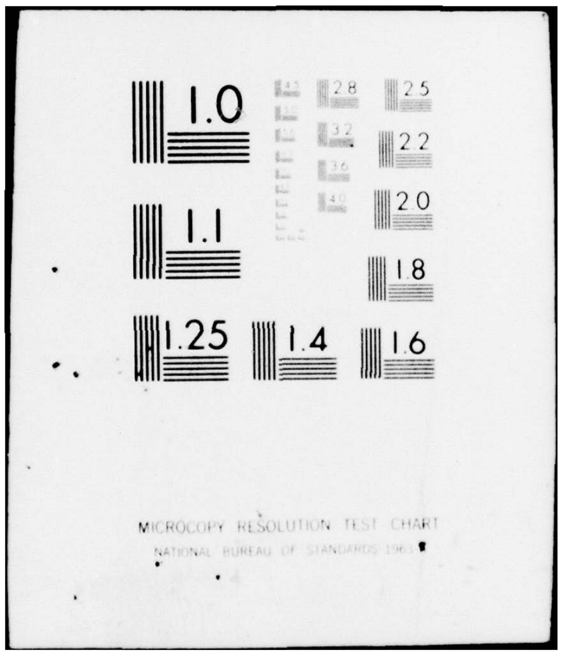
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SOIL STABILIZATION USING CEMENT

W. Bürger

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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In concrete construction, the construction materials, especially the additives, must often be brought in over long distances. The requirements connected with the granular structure of a concrete mixture are subject to certain specific and strict rules. Soil stabilization however uses soils in the manner in which they are available on the spot, in other words, at the particular location. It should thus be considered a regional construction technique. The engineer must somehow get along with the strain line range over →

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SOIL STABILIZATION USING CEMENT

By Engineer W. Bürger, Rheinbach

Soil Stabilization and Concrete Construction Method

In approaching this topic we must first of all emphasize that a soil mixture, stabilized with cement, by no means is the same thing as "poor concrete." We must draw a basic distinction between soil stabilization using cement and the generally customary and well known manner of making concrete (1).

In concrete construction, the construction materials, especially the additives, must often be brought in over long distances. The requirements connected with the granular structure of a concrete mixture are subject to certain specific and strict rules. Soil stabilization however uses soils in the manner in which they are available on the spot, in other words, at the particular location. It should thus be considered a regional construction technique. The engineer must somehow get along with the strain line range offered to him by nature.

Another very decisive factor, as we compare the two construction methods, results from the water allocation. In any kind of soil stabilization, the water addition is determined by means of the Proctor test which gives us the optimum water content. In contrast, we have the water-cement factor in concrete construction. These differing production methods also explain the fact that, in the soil stabilization construction method, not every soil particle can be enveloped with cement glue. According to the British and American view, soil stabilization from the very beginning was considered a new structural or construction element--with its own technical laws; Bilfinger also speaks in terms of a new construction material which was to be tested in keeping with its peculiarities; on the other hand, the basic principles of the concrete construction method in the beginning were still used in Germany as criteria for soil stabilization in terms of execution and application. But it was clearly realized that soil stabilization could offer other solutions, that is, other than simply replacing conventional concrete construction (2). As usual, engineers at that time started with the compression resistance. Here, climatic conditions in central Europe, with their fluctuations, may have contributed to the fact that the compression resistance value was not set too low. Oberbach at that time suggested strength figures of 80-100 kg/cm^2 in order to prevent "the danger of collapse [decay]" which relates particularly to the action of frost.

Kübler (3) likewise wrote something like this in 1967: "It took some doing in Germany to get away from an opinion which sprang from the identification of stabilization [consolidation] with concrete, in other words, that one should thus attain the greatest possible strength figures."

The Memorandum on Soil Stabilization Using Cement (4) which was published in 1955, presents a subdivision in terms of fields of application. The following were proposed for 28-day compression resistance figures:

(a) For underground improvement: 50-80 kg/cm^2;

(b) As foundation and as independent consolidation of traffic surfaces: 80-120 kg/cm^2;

(c) In special cases, for example, soil stabilization, as independent roadway stabilization without a supporting cover layer: 150 kg/cm^2.

<u>Some More Recent Findings</u>

The compression resistance values determined about 20 years ago can no longer be considered to be valid values in practice today considering the past experience and discoveries.

In 1968 a seminar was held at the Darmstadt Technical College on soil stabilization using cement, under the direction of Professor Dr. Klein, head of the Department of Road Construction and Railroads and simultaneously Director of the Highway Experimental Institute; on that occasion Engineer Buchholz, manager of Strabag-AG, commented on this problem and charted new ways (5). It was suggested that the compression resistance values be established in terms of an upper and a lower limit. The lower limit is established by the frost resistance of the soil to be stabilized. In the upper limit, one must observe the crack formation, which must be prevented or at least restricted. Such cracks develop in supporting layers, stabilized with cement, due to shrinkage, temperature differences, and traffic loads. They can be propagated through the supporting [superposed] layers and they appear at irregular intervals.

Compression resistance figures therefore should not be selected too high. From this viewpoint, the compression resistance depends on the type of roadway surface and, in case of bituminous surfaces, on the total thickness of the bituminous layer to be applied and, last but not least, on the traffic load.

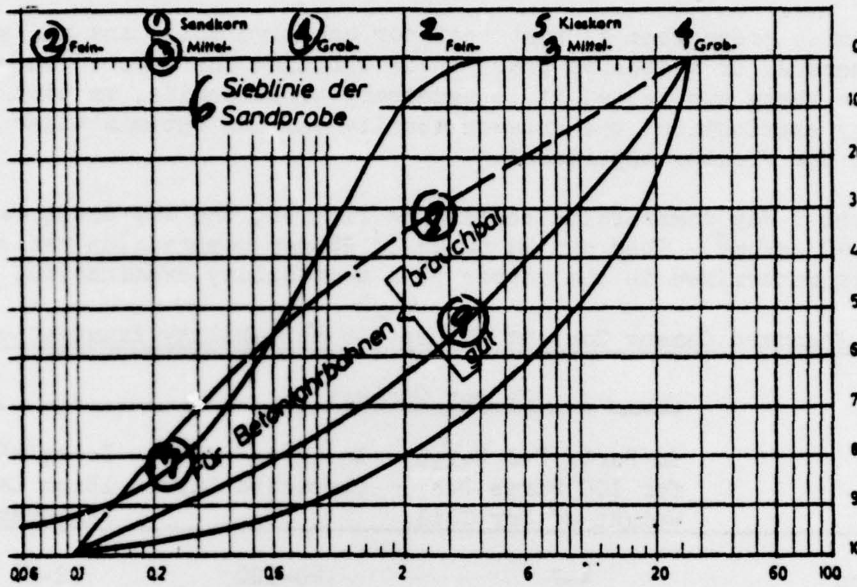

Figure 1. Granular Distribution in Concrete Road--Soil Stabilization Using Cement. The use of available sand for stabilization with cement did not result in any advantage in terms of cost as compared to the construction of a concrete road. --Granulation Curve.

Legend: 1--Sand Grain; 2--Fine; 3--Medium; 4--Coarse; 5--Gravel Grain; 6--Screen Line of Sand Sample; 7--For Concrete Roadway; 8--Usable; 9--Good.

Back in 1950-1952, Professor Reinhold, of the Darmstadt Technical College, for the first time after the war used the soil stabilization construction method in the construction of residential development streets in the Rhine-Main region and was thus confronted with the problem of crack formation; essays on this question can also be found in the last two volumes of Dokumentation Strasse (6). Related topics were discussed in related American, Russian, Romanian, and Czechoslovak technical literature. The Pospich Highway Development Institute in Brünn [Brno] took up the topic of the critical cover layer thickness on cement-stabilized supporting layers (7).

Tests

The "Provisional Memorandum on Suitability Tests for Soil Stabilization Projects Using Cement" (8) was published in 1968. In investigating the soil-cement mixtures, it is necessary--in the case of non-cohesive soils--to determine the required cement content in accordance with the compression resistance. In cohesive soils it is furthermore necessary to examine the frost resistance through the frost test. The TVV [abbreviation unknown] draft likewise prescribes a frost test for cohesive soils and all soils with brittle, porous, or weathered grain in determining the cement content. In addition to these two tests, it is necessary to determine, as part of the suitability examination, the Proctor density and the optimum water content as part of the Proctor experiment.

For the 7-day compression resistance figures, the TVV draft calls for values of 40 kg/cm^2. They can be 60 kg if 28-day compression resistance figures are determined in the course of a suitability examination.

Table 1. Standard Cement Content Values for Suitability Examination (9)

Soil Type	Cement Content		
	In Parts Per Weight for 100 Parts Per Weight of Dry Soil	In kg/cm^3 of Compacted Layer	In kg/m^2 With 15 cm Layer Thickness
Gravel Sand	4-7	80-120	12-18
Sand, Silty Sand	6-10	120-160	18-24
Uniform Sand	8-12	150-200	22.5-30
Silt	7-12	120-200	18-30
Clay	10-16	180-240	27-36

Table 2. Soil Test (9)

Color of Supernatant Liquid After 24 Hours	Suitability of Soil for Cement Stabilization
Clear to Bright Yellow	Usable
Deep Yellow	Limited Usefulness
Brownish to Reddish	Objectionable

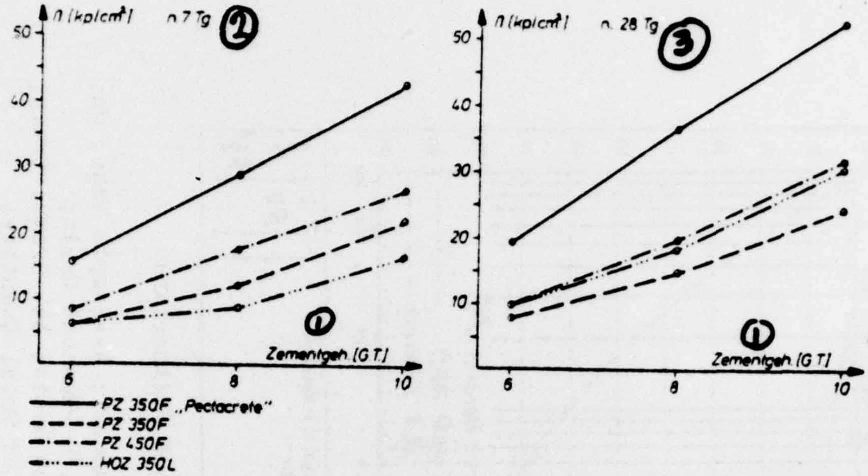

Figure 2. Compression Strength of Soil-Cement Mixtures Matched Up With Cement Content.

Legend: 1--Cement Content (Part by Weight); 2--After 7 Days; 3--After 28 Days.

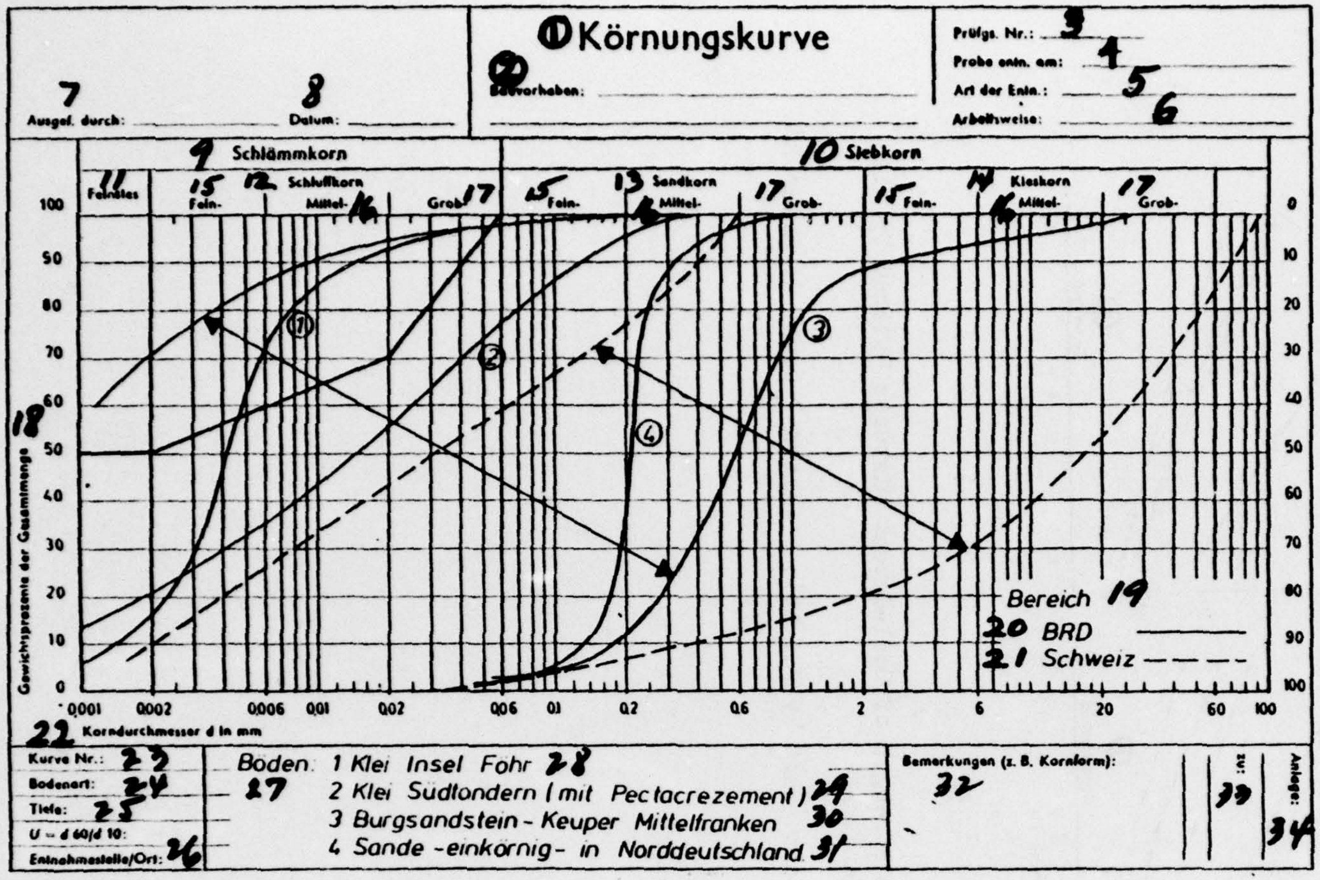

Figure 3. Range of Stabilization Using Cement in West Germany and Switzerland.

Legend: 1--Granulation Curve; 2--Construction Project; 3--Test Number; 4--Sample Taken On; 5--Type of Sampling; 6--Method; 7--Prepared By; 8--Date; 9--Washout Grain; 10--Screen Grain; 11--Very Fine; 12--Silt Grain; 13--Sand Grain; 14--Gravel Grain; 15--Fine; 16--Medium; 17--Coarse; 18--Percent by Weight of Total Quantity; 19--Area; 20--West Germany; 21--Switzerland; 22--Grain Diameter d in mm; 23--Curve Number; 24--Soil Type; 25--Depth; 26--Sampling Point, Place; 27--Soils; 28--1, Clay, Föhr Island; 29--2, Clay, Southern Tondern 30--3, Burg Sandstone-Keuper, Central Franconia; 31--4, Sands, Single-Grain, in North Germany; 32--Remarks (for example, grain shape); 33--To; 34--Enclosure.

Cement Types

All types of cement, listed in DIN [German Industrial Standard] 1164 (10) are authorized for soil stabilization projects. The TVV draft in this context particularly mentions the fact that cement with water-repellent properties--hydrophobic cement--can be advantageous here. These special cement types with hydrophobic properties include Pectacret cement. Hydrophobic qualities prevent premature reaction due to soil moisture or excessive air humidity. These advantages emerge similarly in precipitation-rich weather. Hydrophobic cement types normally cannot be mixed into a cement pap in water. They can therefore also be stored out in the open without any protection against moisture.

The binding and hardening process does not set in--as in the case of standard cement types--upon the addition of water in the mixer. The binding process is initiated only due to the mixing process with the mechanical stress on the individual cement particles due to the mixing action, respectively, the grinding process in the soil, after the water-repellent layer enveloping the cement particles, has been interrupted in terms of its protective effects. The water-repellent advantageous properties however continue to be preserved after the cement has been added to the soil and after it has hardened in the consolidated layer.

It was learned rather early from laboratory investigations that it is not only the quantity of the cement added to the soil misture which influences stabilization but that the type of cement also has some effect on the soil-stabilized layer (11). In some more recent investigations, Paulmann (12) established that the requirement for a certain compression resistance, when we use different, deviating cement types, which however are entirely in keeping with DIN, is complied with. In the very uniform-granular find sand used in this series of experiments with U-1.8, the maximum compression resistance figures were achieved with Pectacret cement PZ 350 F, compared to other standard cement types, at identical cement content.

In summary, Otto (13) noted the following advantages for Pectacret cement: not sensitive to precipitation, something which is very important especially for soil stabilization; greater compression resistance with same cement quantity; increased frost resistance, hence, particularly suited for stabilization of cohesive soils.

Comprehensive suitability tests were conducted in recent years for soil stabilization using cement. Valuable knowledge was derived from them. Nevertheless, renewed suitability tests are necessary for each construction project.

Use in Various Soils

The use of soil stabilization cement is possible in practically all soils. But it can be restricted in terms of its economical aspects to an increased effort involved in the grinding and mixing work when we deal with cohesive soils, respectively, soils with higher plasticity. The following table shows the widespread way in which this method was employed in various soils from the very beginning. It was compiled on the basis of wartime experiences.

Figure 3 shows the broad range of cement use in Switzerland and West Germany. We can see that cement was also used in the "D" area in spite of the difficulties involved in soil work. Under special conditions it will however be recommended to use lime in preparing moist and cohesive soils with high percentages of very fine particles for stabilization with cement. By adding small quantities of lime, we can render cohesive soils mixable in the course of a structural change and we can prevent the formation of clods.

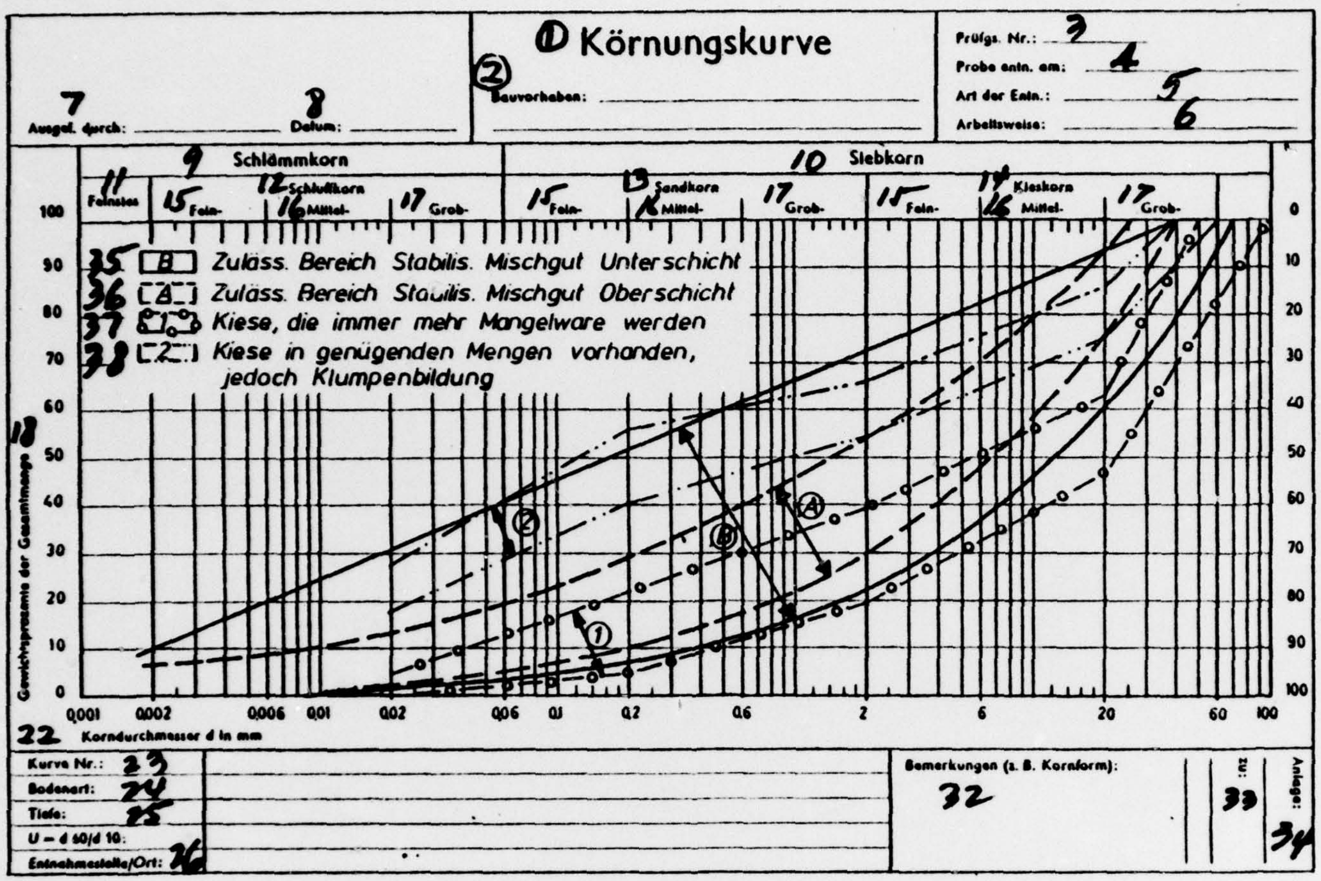

Figure 4. Grain Distribution Ranges for Fully-Bound Roadbed in Switzerland.

Legend: [For items 1-34, please see Legend Figure 3]; 35--Permissible Range, Stabilized Mixing Material, Lower Layer; 36--Permissible Range, Stabilized Mixing Material, Upper Layer; 37--Gravel Types Which Are Becoming Increasingly Scarce; 38--Gravel Types Available in Sufficient Quantities But Involving Clod Formation.

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