Concepts for Developing Stabilization Recommendations for the Soils of an Area

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•THERE IS AN INCREASING DEMAND for quality paving materials at all levels of the highway system (local, state, and federal). These quality materials must economically provide desirable strength and durability characteristics. In certain areas of Illinois as well as in many other areas of the United States, quality natural materials meeting these requirements are not locally available and must be transported a large distance at considerable cost. It is apparent that, from the economic standpoint, it is desirable to utilize locally available materials to the greatest extent possible. In many instances, quality paving materials can be obtained by appropriately modifying or stabilizing local and on-site materials.

Although considerable work has been done in the field of material beneficiation (modification and stabilization), suitable criteria are not generally available for determining which procedures or techniques can feasibly be used with a particular material in order to achieve maximum benefits at minimum cost. This is particularly true with natural soils or unprocessed granular materials.

This paper outlines the pertinent aspects of a research project that was aimed at developing stabilization recommendations for the surficial soils of Illinois.

RESEARCH OBJECTIVE

The general objective of the investigation was concerned with maximum utilization of local and on-site materials in pavement construction. Specific objectives were as follows:

1. Develop, for typical Illinois surficial deposits, guidelines and criteria necessary to determine the applicability of current materials beneficiation techniques; and
2. Develop, for specific Illinois surficial soils and materials, feasibility recommendations that will provide for effective and economical utilization of various stabilization techniques and promote maximum utilization of local materials.

This investigation was limited to a study of the applicability and utilization of the more common beneficiation techniques (lime, cement, bitumen, and lime-fly ash) and the exploration of a limited number of new techniques (combination stabilization and blending).

DEVELOPMENT OF TENTATIVE STABILIZATION GUIDELINES AND CRITERIA

Effective and economical application of various stabilization techniques can be obtained only if the capabilities and limitations of stabilizing agents are well established and understood. A literature review (1) was conducted to establish the type and nature of the stabilization reactions afforded by the various stabilizers and to establish a soil's or an aggregate's chemical and physical characteristics that affect the ability of a particular stabilizing agent to properly modify or stabilize the soil or the aggregate.

Two broad categories of stabilizing agents exist with respect to the stabilization mechanisms effected when the agent is mixed with water and a soil or aggregate. "Active" stabilizing agents, a prime example of which is lime, cause chemical reactions

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to occur in the soil-water-stabilizer system. These reactions are responsible for the improved engineering characteristics of the treated mixture. With this type of stabilizing agent, the chemical properties of a soil are very important. The literature indicated that soil properties such as organic matter content, natural soil pH, degree of weathering, type of internal drainage, horizon in the pedologic profile, predominant type of clay mineral, and, to a certain extent, texture and plasticity greatly affect the modifying or stabilizing ability of the active stabilizing agents.

"Inert" stabilizing agents, an example of which is bituminous materials, do not react chemically with the soil or aggregate, but rather provide modification or stabilization to the system by increasing the cohesion or water-proofing or both of the treated mixture. With this type of stabilizing agent, physical characteristics of the soil such as gradation, texture, and plasticity are the predominant factors that control the modifying or stabilizing ability.

Many other stabilizing agents such as cement and lime-fly ash display both active and inert characteristics, and thus both chemical and physical soil properties are important.

With the information derived from the literature survey, it was possible to establish tentative guidelines and criteria that could be used to promote effective utilization of different beneficiation techniques.

VERIFICATION OF THE APPLICABILITY OF THE TENTATIVE STABILIZATION GUIDELINES AND CRITERIA TO ILLINOIS SOILS AND MATERIALS

The next step after establishing the tentative stabilization guidelines and criteria was to verify their applicability to Illinois soils and materials. To verify the applicability of the tentative guidelines and criteria, it was necessary to sample representative Illinois surficial materials and to determine their response to treatment with various beneficiation techniques.

In order to plan an appropriate sampling program, the nature and distribution of the surficial deposits of Illinois were established. Relevant publications from the Agricultural Experiment Station, Illinois Geological Survey, and various other sources of published and unpublished information were reviewed, and a short summary was prepared (2).

Soils of Illinois

The surficial soils of Illinois are mainly derived from loess and relatively young Wisconsin age glacial drift, but in some areas older more highly weathered Illinoian age glacial drift may be found close to the surface. Figure 1 shows the extent and distribution of the main parent materials found in Illinois (8).

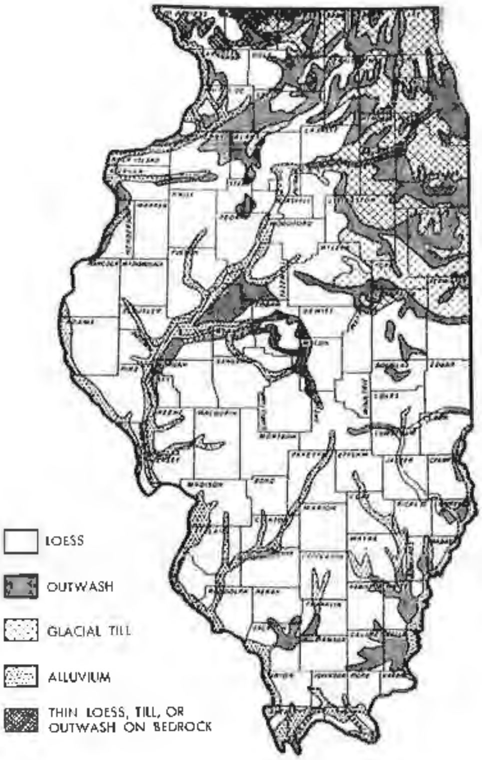

Figure 1. The extent of the soil parent materials in Illinois.

The surficial deposits of Illinois can be placed into 3 general engineering groupings: (a) highly plastic, high-clay content, fine-grained A-6 and A-7 AASHO classified soils; (b) medium-textured A-4 and low-plasticity A-6 soils; and (c) coarse-textured A-1, A-2, and A-3 gravelly and sandy soils. Data given in reference 5 indicate that a substantial proportion of the parent materials (material below the zone of weathering) of Illinois are medium-textured A-4 and low-plasticity A-6 soils. However, in general, unweathered

TABLE 1

SUMMARY OF CHARACTERISTICS OF SOIL SAMPLES

Sample	Location	Description	AASHO	LL	PI	Percent < 2μ Clay
Wisconsin loam till	Champaign County	Calcareous loam till of Wisconsin age	A-4(6)	23	7	16
Illinoian till	Sangamon County	Calcareous loam till of Illinoian age	A-6(6)	25	11	14
Fayette B	Henry County	Profile developed in calcareous silt loam	A-7-6(12)	57	34	34
Fayette C	Henry County	Peorian loess	A-4(8)	32	10	21
Plainfield sand	Cass County	Outwash deposit in Illinois River bottom	A-3(0)		NP	2
Hamburg sandy loam	Cass County	Calcareous loess from Illinois River bluff	A-4(8)	26	2.5	9
Dickinson B	Whiteside County	Profile developed in sandy outwash material	A-2-4(0)	20	2	6
Dickinson C	Whiteside County		A-2-4(0)		NP	8
Alvin B	Lawrence County	Profile developed in sandy outwash material	A-4(4)	20	1	15
Alvin C	Lawrence County		A-4(4)		NP	13
Sandy loam till	McHenry County	Calcareous sandy loam till of Wisconsin age	A-1-b(0)		NP	4
Pit-run gravels	McLean County	Pit-run materials that do not meet Illinois grade 7 specifications	A-1-b(0)		NP	4
	Bureau County		A-1-b(0)		NP	<2
Ava B	Williamson County	Highly weathered loess	A-6(10)	39	15	28

parent material will be encountered in pavement construction only in moderately deep cut sections and in material that is excavated from borrow pits. Thus, a very large percentage of the surficial materials encountered in highway construction in Illinois consists of weathered material that is fine grained in texture.

Development of Sampling Program

The literature study (1) indicated that highly plastic, fine-grained soils can be most effectively and economically stabilized with lime. Cement can be used to stabilize these fine-grained materials, but, normally, the content required by current criteria (PCA) is quite high. Fine-grained soils throughout the state have been extensively sampled and tested in connection with lime stabilization research activities at the University of Illinois (4). Consequently, the sampling program did not include fine-grained materials.

With this background information and close coordination with Department of Agronomy, University of Illinois, personnel, a limited sampling program was developed in which representative Illinois parent materials (loess, Illinoian age drift, and Wisconsin age drift) and selected typical B-horizons were sampled. A general description and classification of the 14 coarse, medium, and moderately fine-textured soil samples are given in Table 1.

Laboratory Testing Program

A laboratory testing program was conducted to determine the strength and durability response of the 14 representative soils to treatment with various stabilization techniques. The techniques considered included conventional stabilization procedures (cement, bitumen, and lime-fly ash), blending techniques, and combination procedures (lime-cement and lime-bitumen). A discussion of the laboratory procedures and a summary of the data are presented elsewhere (2).

Based on the results of the laboratory program and the results of other research at the University of Illinois, both published (5) and unpublished, the tentative stabilization guidelines and criteria were reviewed, revised, and expanded to reflect the more specific characteristics of Illinois surficial soils and materials.

APPROACH USED TO APPLY STABILIZATION GUIDELINES AND CRITERIA TO ILLINOIS SOILS AND MATERIALS

In order to systematically apply the stabilization guidelines and criteria to the development of stabilization feasibility recommendations, it was necessary to identify and classify soils of similar characteristics pertinent to soil stabilization and to collect necessary chemical and physical soil data.

A requirement of any classification system is that it be meaningful to the user. A number of classification procedures were examined to determine their relative merits. Of the currently available procedures, it was concluded that the pedological system provided the best method of soil classification for soil stabilization purposes. The potential of this system of classification in cement-soil stabilization has been demonstrated by Hicks (12), Leadabrand et al. (7), and Handy and Davidson (11).

Pedological Soil Classification System

The pedological classification system is based on the premise that a soil's structure, form, and properties are controlled by the extent of chemical and physical weathering to which a deposit has been subjected. A number of important environmental factors, often termed soil-forming factors, have been found to control the soil that is formed. The 5 soil-forming factors are type of parent material, relief, native vegetation, climate, and age or length of exposure.

Weathering of a parent material brought about by the various chemical and physical forces of the environment is most effective at the surface. The relative degree of weathering decreases with increasing depth from the surface in a manner such that various layers or horizons reflecting different stages of alteration are developed in the parent material. The horizons normally become thicker and more pronounced as soil development progresses. A vertical cross section that slices through the various horizons or layers is referred to as a soil profile. A typical soil profile is schematically shown in Figure 2 (6).

The concept of a soil profile and the variation of chemical and physical soil properties in the profile are very important to the development of stabilization recommendations. Soil properties such as texture, clay content, plasticity, pH, organic carbon content, and degree of oxidation vary in a given profile depending on the horizon. The A-horizon experiences maximum eluviation or leaching as a result of the relatively high degree of weathering. For this reason, the A-horizon normally contains relatively small amounts of soluble constituents and clay-sized particles. Normally, however, the organic matter content is rather high in the A-horizon because of the influence of local vegetation.

The B-horizon is the layer where illuviation or deposition of the material leached from the A-horizon occurs. Therefore, the B-horizon normally contains a much higher clay content and displays higher plasticity than the A-horizon; however, generally the organic matter content of the B-horizon is much lower. The C-horizon consists of relatively unaltered parent material and does not reflect the influence of the various chemical and physical weathering forces of the environment.

In some instances the C-horizon is not extremely thick and is underlain by a distinctly different parent material, well within the depth in which highway construction operations may occur. The nomenclature of this underlying layer of material varies from agency to agency.

As the degree of physical and chemical weathering changes as a result of various combinations of the soil-forming factors, profiles of differing characteristics result. The subtle differences that occur, however, are of great significance in the determination of stabilizer feasibility recommendations.

Identification and Classification of Soils in the Pedological System

A number of profile features are used by pedologists to describe a soil profile:

1. Number, thickness, and relative arrangement of horizons in the profile;
2. Organic matter content, usually reflected by the color of the horizon;
3. Drainage class, as influenced by slope, permeability, and position of water table;
4. Texture and structure of horizons;
5. Chemical and mineralogical composition;
6. Concretions and other special formations;

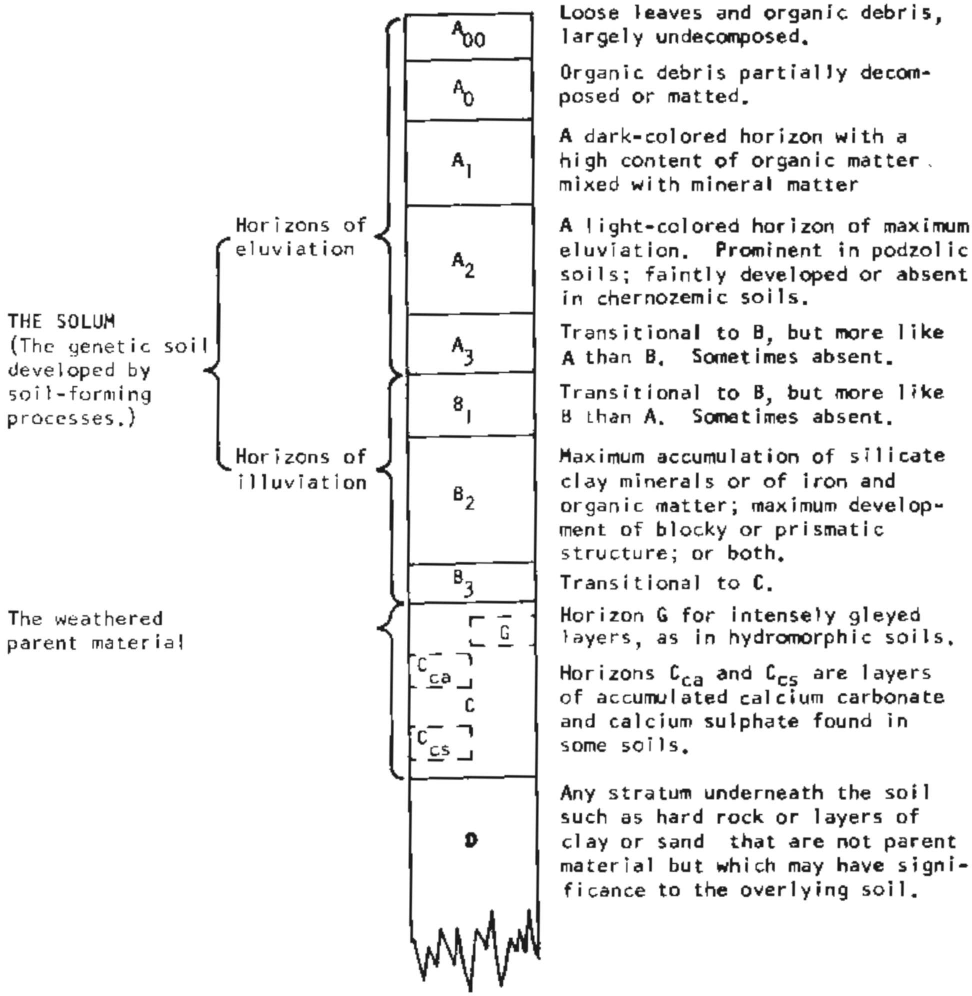

Figure 2. A typical pedologic soil profile showing the major horizons.

7. Vegetation; and
8. Geology of the parent material.

Soils that have profiles similar with regard to all of these characteristics are grouped together and form a soil type. All soil types with profiles having the same characteristics except for the texture of the surface horizon belong to the same soil series. Soils are further grouped into soil-association areas. A soil-association area is defined as a group of soils occurring together in a characteristic pattern (6). As mapped in Illinois on a statewide basis, a given soil association usually includes soil types and series developed from similar parent materials under similar vegetation conditions for approximately the same length of time (6).

Advantages of Using the Pedological Classification System

The pedologic system of soil classification offers a number of advantages in soil stabilization work. First, the basis of the pedological system is very pertinent because various chemical and physical soil properties are used as the classification criteria. Second, in most areas of the United States, extensive work has been done concerning pedologic soil mapping and classification. As a result, excellent maps and pertinent physical and chemical data are readily available from county, state, and federal agencies. For example, extensive soil information was obtained for this research project from the Department of Agronomy, University of Illinois, and the Soil Conservation Service, U.S. Department of Agriculture.

Stabilization Technological Considerations

Effective and economical utilization of stabilization procednres requires that proper consideration be given to the type and nature of the stabilizing agents, properties of the soils and aggregates, stabilization objectives, and construction techniques.

For highway-related applications, stabilization objectives can be divided into 3 broad categories: coustrnction expedient, subgrade modification, and strength and durability improvement.

Construction-expedient applications are concerned with improving vehicle-mobility problems often associated with fine-grained soils at high natural-water contents and degrees of saturation. In many cases, problems of this nature can be greatly improved or alleviated with the correct application of various stabilization techniques and procedures that effect an immediate improvement in (a) resistance to deformation, (b) load-carrying capacity, and (c) shear strength. In essence, a "working table" is created on which construction operations can be carried out in an efficient, effective, and economical manner.

Subgrade modification applications of stabilizing agents are concerned with improving engineering characteristics of the finer grained plastic subgrade soils. Stabilization of these materials will effect the following:

1. A decreased plasticity (some soils may actually become nonplastic with the amounts of stabilizer normally used);
2. A rednced swell;
3. An increased CBR, even though extensive cementing may not be obtained becanse of either a lack of "reactivity" (some soils do not display substantial strength gains when lime is added) or the use of stabilizer quantities less than required to effect substantial strength increases;
4. A decreased resilience;
5. An increased resistance to the detrimental effects of frost action, rainfall, or moisture content fluctuations; and
6. Improved workability characteristics and ease of handling.

Strength and durability improvement applications are concerned with upgrading (increased strength and durability) soils and aggregates to provide economical paving materials of subbase and base-course qnality.

In the development of stabilization recommendations, appropriate considerations must be also given to field construction of stabilized layers and construction-related problems. Improper construction of stabilized materials can lead to unnecessary and costly failures of otherwise properly designed pavements.

Field construction techniques depend on the type of stabilizing agent being used, the type of soil being treated, the stabilization objectives, and, to a certain extent, the type of equipment available.

To obtain satisfactory field construction of stabilized materials, a number of factors, including pulverization, stabilizer distribution, mixing, blending, compaction, and curing, must be pruperly controlled to ensure the quality of the stabilized mixture.

ILLUSTRATIVE EXAMPLE

An example is an appropriate method of illustrating the type of stabilization recommendations that were developed and the format of presentation that was used. As an illustrative example, stabilization recommendations will be presented for the major soils of one of the 26 soil associations in which the soils of Illinois have been grouped by the Department of Agronomy, University of Illinois, and the Soil Conservation Service (8). Stabilization recommendations have been developed (9) for the major soils in all of the 26 soil associations of Illinois.

Characteristics of Soils in Soil Association B

Soil association area B occurs in east-central and north-central Illinois (Fig. 3) and occupies 2,631,000 acres or about 7.2 percent of the state. The soils in this association have developed under grass vegetation from either 3 to 5 ft of loess over loam to silty clay loam Wisconsin glacial till or 1 to 3 ft of loess over clay loam Wisconsin

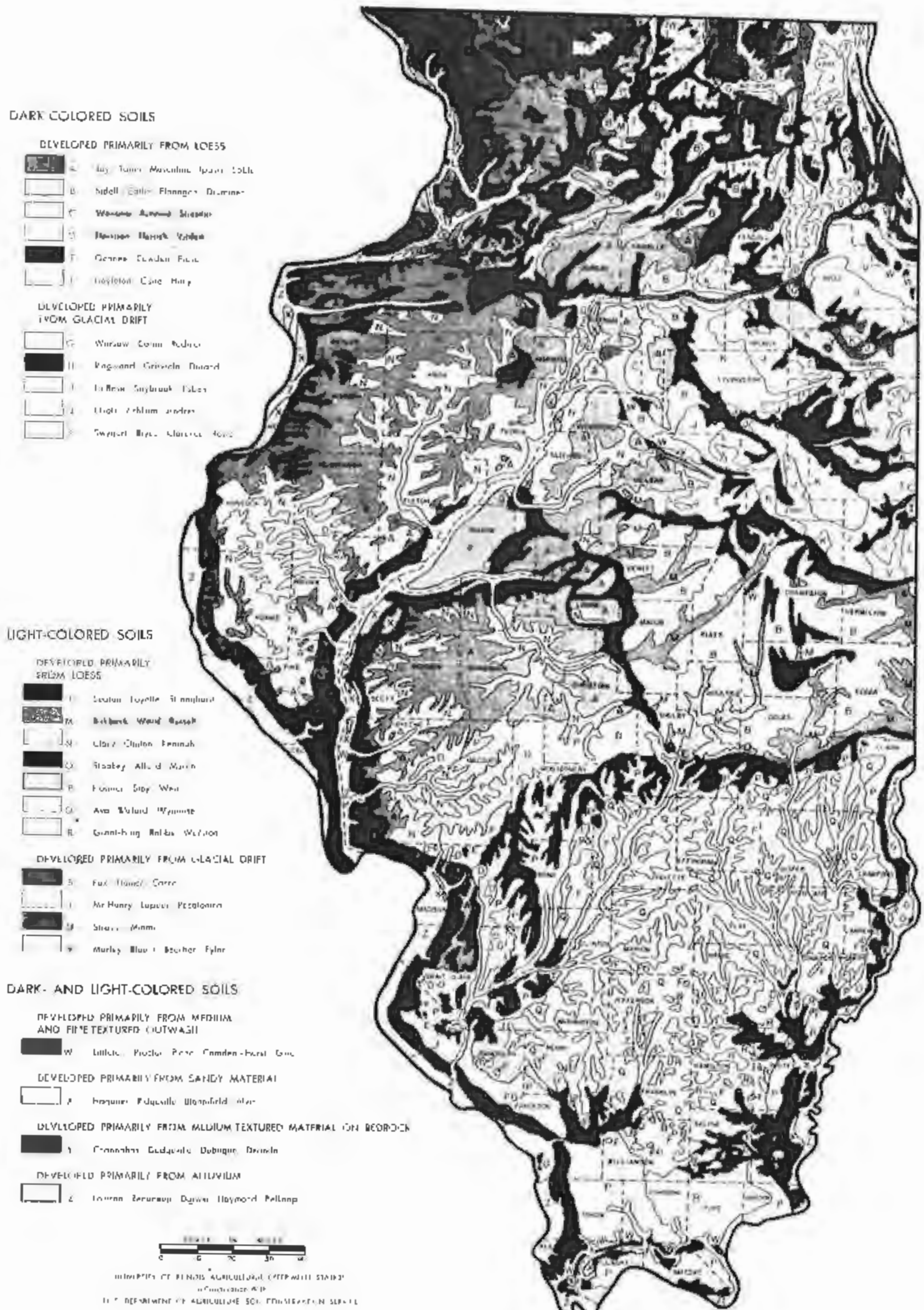

Figure 3. General soil map of Illinois.

TABLE 2

PROPERTIES OF MAJOR

Number and Name of Major Soil Series	Area of State[a] (percent)	No. of Acres	Dominant Slope (percent)	Drainage	Soil Profile and Site Description[b]	Dep Fro Surfa (in.
171 Catlin (a)	1.15	377,100	3-7	W-MW	About 1 ft of silt loam on 2 ft of silty clay loam underlain by silt loam grading to calcareous loam glacial till. Well drained, nearly level to strongly sloping soils formed from about 3 to 5 ft of loess over calcareous loam glacial till.	0-1 12-4 42-6
56 Dana (b)	0.16	51,500	3-7	MW	About 1 ft of silt loam on 2½ to 3 ft of silty clay loam underlain by noncalcareous clay loam glacial till that becomes calcareous below 4 ft. Moderately well drained, nearly level soils formed from 2 to 4 ft of loess over glacial till.	0-1 14-5 50-6
152 Drummer (a and b)	6.08	1,991,100	0-1	P	About 1⅓ ft of silty clay loam on about 1⅓ ft of silty clay loam and underlain by silt loam, loam, or sandy loam glacial drift. Poorly drained, level soils on loess (40 to 60 in. thick) covered till plains and moraines or stream terraces and outwash plains. Seasonal water tables at or near the surface.	0-1 16-3 36-6
154 Flanagan (a)	3.31	1,086,700	1-3	Imp.	About 1 ft of silt loam on 2 to 3 ft of silty clay loam and underlain by loam to silt loam till. Somewhat poorly drained level to sloping soils on loess (40 to 50 in. thick) covered till plains and moraines. Seasonal water tables above 3 ft.	0-1 14-4 44-6
481 Raub (b)	0.14	45,800	1-3	Imp.	About 1 to 1⅓ ft of silt loam on 2 ft of silty clay loam on 1 to 2 ft of clay loam underlain by calcareous loam glacial till. Somewhat poorly drained, nearly level to gently sloping soils formed in about 1⅓ to 3 ft of loess on glacial till plains. Seasonal water tables are within 3 ft of the surface.	0-14 14-50 50-60
55 Sidell (b)	0.07	23,700	6-12	W	About 1 ft of silt loam on 1 to 1⅓ ft of silt clay loam on 1⅓ to 2 ft of clay loam underlain by loam glacial till. Well drained, gently sloping to moderately steep soils formed in 2 to 3 ft of loess on glacial till plains and moraines.	0-14 14-50 50-60

[a]From reference 10.
[b]From reference 3.
[c]Data supplied by Department of Agronomy, University of Illinois.
[d]Data from engineering publications, unpublished research in Department of Civil Engineeri

Note: Parent material—(a) Loess 3 to 5 ft thick on calcareous loam to silty clay loam till or (b) loess 1 to 3 ft thick on c

SOILS IN SOIL ASSOCIATION B

Soil Classification: USDA Textural[b]	Soil Classification: AASHO[b]	Percent Passing Sieve[b]: No. 4	Percent Passing Sieve[b]: No. 200	Clay Fraction < 2μ[c] (percent)	Liquid Limit[d] (percent)	Plasticity Index[d] (percent)	Natural Soil pH[b]	Organic Carbon Content, Average Depths of Occurrence[c] (in.): < 2 Percent	1-2 Percent	> 1 Percent
ilt loam	A-6 or A-7	100	95-100	15-25	30-50	10-25	5.6-6.5			
ilty clay loam	A-6 or A-7	100	95-100	30-40	35-58	15-30	5.6-6.5	0-16	16-22	22-60
ilt loam to loam	A-4 or A-6	95-100	55-75	15-25	30-55	11-20	7.4-8.4 (calc.)			
ilt loam	A-6 or A-7	100	95-100	15-25	30-55	10-25	5.6-6.5			
ilty clay loam to clay loam	A-6 or A-7	100	60-90	30-40	35-55	15-35	5.6-6.0	0-16	16-22	22-60
oam to silt loam	A-4 or A-6	95-100	55-65	15-25	25-50	11-20	7.4-8.4 (calc.)			
ilty clay loam	A-7	95-100	85-100	30-40	35-65	15-33	6.6-7.3			
lty clay loam	A-7 or A-6	95-100	85-100	30-40	30-55	12-34	6.6-7.3	0-16	16-24	24-60
lt loam, loam, or sandy loam	A-2, A-4, or A-6	90-100	30-75	10-25	NP-50	NP-30	6.6-7.3			
lt loam	A-6 or A-7	100	95-100	15-25	30-60	15-29	5.6-6.5			
lty clay loam	A-6 or A-7	100	95-100	35-45	42-60	16-35	5.6-6.5	0-12	12-20	20-60
oam, silt loam, or silty clay loam	A-6 or A-4	95-100	55-75	15-25	30-55	11-30	7.4-8.4 (calc.)			
lt loam	A-6 or A-7	100	85-95	15-25	—	—	5.6-6.5			
lty clay loam to clay loam	A-6 or A-7	100	65-95	35-45	—	—	5.6-6.5	0-12	12-20	20-60
oam to silt loam	A-4 or A-6	100	60-70	15-25	35-50	11-20	7.4-8.4 (calc.)			
lt loam	A-6 or A-7	100	95-100	15-25	30-55	10-25	5.6-6.5			
lty clay loam to clay loam	A-6 or A-7	100	60-90	30-40	35-55	15-35	5.6-6.0	0-16	16-22	22-60
am to silt loam	A-4 or A-6	100	55-85	15-25	25-50	11-20	7.4-8.4 (calc.)			

iversity of Illinois, and various other soil reports.

m till (noncalcareous > 3½).

glacial till. Various sources of information (3, 6, 10) and data supplied by the Department of Agronomy, University of Illinois, were used in preparing Table 2, which summarizes typical ranges in pertinent soil properties and characteristics of the major soil series within soil association B.

The basic differences recognized in mapping the soils in this association are parent material and internal drainage or slope. Sidell, Catlin, and Dana are well, well to moderately well, and moderately well drained soils respectively; Flanagan and Raub are imperfectly drained soils; and Drummer is a poorly drained soil.

As a result of being developed under grass vegetation, relatively thick A-horizons of relatively high organic matter content are characteristic of these soils. Because organic matter is known to be detrimental to many stabilization reactions inherent with "active" stabilizers, typical depths of occurrence for various amounts of organic carbon are given in Table 2 for the major soils of this association. As noted, the organic carbon content is typically greater than 2 percent to a depth of 12 to 16 in. and is less than 1 percent at depths greater than 20 to 24 in.

Available information indicates that the A-horizon materials are typically A-6 or A-7; the B-horizon materials, a more plastic A-6 or A-7; and the C-horizons, A-4 or A-6 depending on the specific parent material encountered.

The average plasticity index for the A-horizon materials normally ranges from 10 to 30; the materials of the B-horizon normally display a plasticity index ranging from 15 to 35; the plasticity index displayed by the C-horizon materials depends on the specific parent material but normally ranges from 10 to 30. The clay content (<0.002 mm) for the A-, B-, and C-horizons normally ranges from 15 to 25, 30 to 45, and 10 to 25 percent respectively (except that A-horizon of Drummer ranges from 30 to 40).

Stabilization Recommendations and Rating System

After collecting and summarizing the data given in Table 2, it was possible to apply the stabilization guidelines and criteria to the individual soils and determine stabilization recommendations for the major soil series of this soil association. These recommendations are given in Table 3. Recommendations are presented concerning the feasibility of using cement, lime, bitumen, lime-fly ash, and combination stabilizing agents for stabilization (to either expedite construction, modify the subgrade, or substantially

TABLE 3

STABILIZATION RECOMMENDATIONS FOR MAJOR SOILS OF SOIL ASSOCIATION B

Number and Name of Major Soil Series	Horizon	Stabilization Objectives and Recommended Stabilizers[a]														
		Construction Expedient[b]					Subgrade Modification[b]					Strength and Durability Improvement[b]				
		C	L	B	F	COMB	C	L	B	F	COMB	C	L	B	F	COMB
171 Catlin	A	2	1	3	3	3	2	1	2	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	2	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]
56 Dana	A	2	1	3	3	3	2	1	2	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	2	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]
152 Drummer	A	2	1	3	3	3	2	1	3	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	1	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]
154 Flanagan	A	2	1	3	3	3	2	1	2	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	2	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]
481 Raub	A	2	1	3	3	3	2	1	2	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	2	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]
55 Sidell	A	2	1	3	3	3	2	1	2	3	3	2	3	3	3	3
	B	2	1	3	3	3	2	1	3	3	3	1	2	3	3	—[c]
	C	2	1	3	3	3	1	1	3	3	3	1	1	2	2	—[c]

[a]Stabilizer suitability rating where 1 = suitable, 2 = questionable, and 3 = not suitable.

[b]C = cement, L = lime, B = bitumen, F = lime-fly ash, and COMB = combinations.

[c]Combination stabilization (lime-cement or lime-bitumen or both) may be a suitable method of beneficiation. However, this recommendation is based on a very limited amount of laboratory results and the respective literature surveys.

improve strength and durability) of the material in the A-, B-, and C-horizons of each major soil series.

Stabilization recommendations for a particular material carry either a 1, 2, or 3 rating. A 1-rating indicates that the stabilizing agent should quite suitably and adequately provide stabilization if proper construction practice is used. A 2-rating indicates a questionable rating because the stabilizing agent may provide adequate stabilization but, in certain cases, adequate stabilization cannot be obtained. A 3-rating indicates that, in most cases, the particular stabilizing agent will not provide the degree of stabilization desired.

Discussion of Stabilization Recommendations

Experience with oiled earth roads in Illinois has indicated that, in some cases, periodic treatment of organic A-horizon materials with cutback bituminous materials may provide a satisfactory pavement surface layer for low traffic volume roads. Stabilization of this nature was assumed to be in the realm of subgrade modification applications. A 2-rating was assigned as the bituminous recommendation for all A-horizon materials except those that are the very high clay content and high plasticity A-7 materials, such as the A-horizon of the Drummer soils. Treatment of these fine-grained materials, in most cases, will not provide a satisfactory surface layer, and, thus, a 3-rating was assigned.

Both cement and lime can be used iu subgrade modification applications with the finer textured A-6 and A-7 materials of the B- and C-horizons. However, most data indicate that lime is more effective and efficient than cement. Consequently, lime has been assigned a 1-rating and cement a 2-rating. It is noted, however, for A-4 and low-plasticity A-6 C-horizon materials, that cement also has been given a 1-rating.

Cement can be used to obtain increased strength and durability with fine-grained A-6 and A-7 materials and, thus, a 1-rating has been assigned to these materials (B-horizon material of all major soils in this association). It should be realized, however, that the cement content required to obtain adequate durability for these fine-grained, plastic materials (PCA criteria) may be quite high, on the order of 9 to 16 percent (by soil dry weight).

Lime treatment of "reactive" fine-grained soils will effect substantial strength increases. A 1-rating has been assigned as the stabilization recommendation for lime where the soil properties indicate that reactive soils will be encountered. Many soils may display slight-to-moderate strength increases on treatment with lime, and, under certain service conditions, the lower strength lime-treated soils may be satisfactory. Thus, for those fine-grained materials that display limited reactivity, a 2-feasibility rating has been assigned with the supposition that, under certain service conditions, this can be changed to a 1-rating.

Stabilization recommendations have been presented concerning the applicability of combination procedures (lime-cement and lime-bitumen). A footnote reference is placed in Table 3 where it was felt that this procedure might be used. A 1-rating was not assigned because the rating is based on very limited data and a brief literature survey.

SUMMARY AND CONCLUSIONS

Stabilization recommendations for the major soils and materials occurring in Illinois have beeu developed (9). The general procedures and concepts used in the development of the stabilization recommendations and a typical example of the recommendations are presented in this paper.

In developing these stabilization recommendations, the pedological soil classification system was used to identify and classify soils of similar characteristics relative to soil stabilization. The soil association area concept was used to combine pedologic soil series into groups with similar characteristics and to facilitate presentation of pertinent data and feasibility recommendations.

Extensive soil data necessary to properly apply the stabilization guidelines and criteria were obtained from the Department of Agronomy, University of Illinois, the Soil

Conservation Service, the University of Illinois Engineering Experiment Station publications, and various other sources of published and unpublished data.

Although stabilization recommendations were presented only for major soils within each soil association area, by utilizing the guidelines and criteria that were developed for the soils of Illinois and by appropriate consideration of stabilization technology, stabilization feasibility recommendations can be readily determined for other soils.

The information that can be obtained from a report containing stabilization recommendations of this type is meant to facilitate the selection of a stabilizing agent or agents and to promote maximum use of local materials in various highway construction applications. However, additional factors must be considered in order to obtain quality stabilized materials meeting job requirements. Appropriate mixture design procedures must be used to satisfy job requirements for particular applications. Economic considerations, in many cases, may be very important and will often be used in the final selection of a stabilizing agent. Finally, proper construction techniques and control must be used to ensure that a quality product is obtained in the field.

It has been demonstrated that, by using the extensive soil information that is available from various sources, stabilization recommendations for large areas, such as the state of Illinois, can be developed with a minimum amount of sampling and testing. The concepts demonstrated in this paper can be used to develop stabilization recommendations for areas of other sizes such as residential areas, cities, counties, and regions.

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