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DEVELOPMENT OF A MATERIALS AND ENGINEERING DATABASE FOR SHALES OF EASTERN KANSAS

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16 Abstract

Construction site assessments as well as materials analyses are currently filed away when projects are completed. The accumulated data is not easy to access or manipulate. The past experience of contractors is also not systematically recorded and available. When similar materials or geologic units are encountered in future projects, the cycle of testing is repeated. This does not make efficient or effective use of previously gathered information.

The primary filed data included in this database are shale lithology, structure, and color. Laboratory data include second cycle slake durability (Id2), jar index, water absorption, and calcium carbonate content. For some localities, contractors provided information on excavation and shale manipulation methods required to meet engineering specifications. The database is expandable and new localities, shale units, and types of data can be added easily. The database can also be converted into a web-based format that can be readily accessed by KDOT employees, contractors, and other interested parties.

We anticipate that the development of a central database for shale materials will save the Kansas Department of Transportation many hours of field, laboratory, and administrative time. Such a database will minimize the duplication of testing. The identification of well-defined relationships between outcrop observations, test results, and engineering performance will enable the behavior of rock units to be better predicted. This should improve the success of both project planning and contractor bidding. The identification of potentially problematic units early will also save both time and money expended in redesign, remediation, and repair. This database will give KDOT inspectors and estimators a wealth of information for bids and construction of KDOT projects.

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Final Report

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THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

and

KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS

January 2007

PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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ABSTRACT

Construction site assessments as well as materials analyses are currently filed away when projects are completed. The accumulated data is not easy to access or manipulate. The past experience of contractors is also not systematically recorded and available. When similar materials or geologic units are encountered in future projects, the cycle of testing is repeated. This does not make efficient or effective use of previously gathered information.

The primary filed data included in this database are shale lithology, structure, and color. Laboratory data include second cycle slake durability (Id2), jar index, water absorption, and calcium carbonate content. For some localities, contractors provided information on excavation and shale manipulation methods required to meet engineering specifications. The database is expandable and new localities, shale units, and types of data can be added easily. The database can also be converted into a web-based format that can be readily accessed by KDOT employees, contractors, and other interested parties.

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Chapter One

Introduction and Study Objectives

Rocks broadly categorized as shales are difficult materials to properly treat in road construction projects. The named shale stratigraphic units of eastern Kansas (Zeller, 1968) include a wide range of rock types including thinly-layered shales, mudstones with massive or blocky structure (typically paleosols), and siltstones. Throughout the rest of this report the general term "shale" will be used to refer to this wide range of fine-grained rock lithologies, unless otherwise indicated. These shale rock types range from easily disaggregated soil-like materials to those that are highly durable. Some of these units are considerably more stable under water-saturated conditions than others. This is further complicated by the fact that the material properties of a given named stratigraphic interval are typically highly internally variable. Any roadwork within eastern Kansas must effectively deal with the potential instability problems presented by shale units and their high degree of variability.

There are, however, several relatively simple field and laboratory analyses and observations that can effectively aid in distinguishing between durable and non-durable units. These data include internal structure, slake durability, water absorption and carbonate content (Miller & McCahon, 1999). Furthermore, there is also a considerable amount of contractor experience with the treatment and performance of shale units encountered in past projects. There has previously been no systematic and accessible electronic storage of this data such that KDOT and its contractors can effectively use it in the planning and bidding process.

The importance of the fabric of shales (that is the shape and arrangement of their constituent particles and associated voids) has been shown to greatly influence engineering properties (Rowe, 1972; McGown et al., 1980). This is especially true of those units dominated by clay minerals. In particular, Rowe (1972) found that permeable fabrics effect engineering properties to such an extent that conventional small specimen testing produced erroneous or misleading results.

The second cycle slake durability index (Id2) has been determined by previous studies (FHWA, 1980; Dick et al., 1994) to be the best measure of the durability of the various shale rock types. Several attempts have been made to categorize these rock types based on the slake durability index, and to relate these classifications to engineering and behavioral characteristics (Bell, 1992; Dick & Shakoor, 1995). Such classifications are highly valuable during the process of making initial site assessments. In addition, durability classifications are also useful for helping to determine excavation procedures (FHWA, 1980).

A previous study examined the structural and compositional characteristics of paleosols and laminated and silty mudstones within Riley and surrounding counties in northeastern Kansas (Miller & McCahon, 1999). Paleosols contain a wide range of macro- and micromorphological features that significantly affect their susceptibility to slope failure. Furthermore, the fabric of paleosols and laminated or silty mudstones vary dramatically. Compositional variations, particularly differences in clay mineralogy and cementing agents, impact mechanical properties such as erodability and shrink swell activity. This study determined the durability of these shale units, as measured by second cycle slake durability (Id2) and jar indexes, and compared it with several measures of their chemical, mechanical, and structural characteristics. Detailed description of units in the field included lithology, color, structure (ped type, laminations, bedding, etc.), fracture orientations, and occurrence of nodules and concretions. Laboratory analyses included bulk density, water absorption, grain size, carbonate content, organic carbon content, and bulk and clay mineralogy.

The study by Miller and McCahon (1999) found that the two compositional variables that contributed most to shale durability were carbonate and clay content. Samples with >35% calcium carbonate have medium to high durability, while those with >70% clay have low durability. Units with well-developed blocky to platy structure are nearly always of low durability due to accumulated clay along the fine fractures and to oriented clay fabric within the matrix. Furthermore, low-angle (<35°) clay-coated fractures, that provide surfaces for slope failure, were found to be common features of greenish-gray to olive paleosols.

We have in this project developed a flexible and easily-used database that will provide ready access for both the Kansas Department of Transportation and existing and prospective contractors to field and laboratory data for a representative sample of shale units in eastern Kansas. This database includes the engineering treatment and performance of those units encountered in previous and current construction projects. This database can provide a continually expanding source of information for future projects, greatly improving the accuracy with which the engineering behavior and proper treatment of individual shale intervals can be predicted.

The project had two primary objectives: 1) to collect relevant field, laboratory and contractor data from a representative sample of shale units within eastern Kansas, and 2) to develop a flexible spreadsheet database suitable for uploading to an online website freely accessible to interested planners and contractors. The focus of this study has been on shales (ie. shales, mudstones, and siltstones) occurring within the Pennsylvanian and early Permian stratigraphic interval.

The database is structured to enable the various field, laboratory, and contractor data to be correlated and compared within and between project sites. The database will allow for immediate access by interested parties to queries by location, stratigraphic unit, lithologic description, and specific tests. It will also allow for future expandability and continual data input.

Chapter Two

Data Collection Methods

2.1 Sample Site Selection and Field Data Collection

Localities were selected that are representative of the range of shale rock types present within eastern Kansas. Localities were drawn primarily from the Pennsylvanian and early Permian sections, although some Cretaceous units were also examined. Sampled localities included outcrops, quarries, roadcuts, currently active construction sites, and cores. In all, 87 shale intervals were sampled located in 24 counties and representing about 40 stratigraphic formations. Localities were described as precisely as possible and many were augmented with GPS. The names of formations and members used in this study followed the stratigraphic nomenclature of Zeller (1968). APPENDIX A lists the field localities and construction sites currently included in the database

In the field, the exposures were carefully measured and any variability in rock type, structure (e.g. bedding, lamination, soil structure), and color were noted. For the purpose of this study, described units were 0.5 meters or more in thickness (units thinner than 0.5 meters cannot be distinguished on project cross sections). However, any smaller-scale heterogeneity within the described units was recorded if deemed significant. The structural features of the shales were described in the field using clearly-defined and recognized terminology. Soil structure was described according to standard soil science classification (Retallack, 1988). The Munsell color designations (Munsell, 1994), a universal standard for describing colors, were used to standardize the color descriptions.

Samples were collected for each described unit for analysis in the lab. Efforts were made to ensure that fresh unweathered samples were obtained from outcrops.

2.2 Core Samples

Cores were obtained from the KDOT regional geology offices for description and sampling. A total of 26 cores were obtained representing 10 counties and 17 shale formations or members. APPENDIX B lists the cores and core localities currently included in the database. For each of the cores, descriptions were made for each lithologically distinct interval exceeding 0.5 meters in thickness. The descriptions included rock type, color, bedding/lamination type, and soil structure if apparent. These descriptions were comparable as possible to those obtained from the outcrop. Samples for each described interval were used for laboratory analysis in the same in the same way as field samples.

2.3 Laboratory Analyses

The primary measure of shale durability is slakability. Two measures of slakability were used in this study. The Jar Index test (FHWA, 1977) is a fast and simple method to determine how dry samples respond when immersed in water. A sample of material of about 20 g is oven dried and immersed in distilled water. The resulting cohesion of the sample is recorded according to established criteria. Another and more reliable test is slake durability. The second cycle slake durability index (Id2) has been determined by previous studies (FHWA, 1980; Dick et al., 1994) to be an accurate test of shale durability. Slake durability was calculated according to procedure D4644 (ASTM, 1990), and involves determining the mass loss of ten 30g samples subjected to alternate oven drying and tumbling in a wire mesh drum immersed in distilled water.

Water absorption is another valuable analysis that can be easily determined as a secondary procedure during the jar index tests. On immersion during the jar index test, water-saturated samples that remain intact are weighed prior to and after oven drying of samples, and the percentage of water absorbed is obtained from these calculations. High water absorption is a good indicator of high clay content and low durability.

Collected samples were also analyzed for calcium and magnesium carbonates with a Chittick apparatus (Dreimanis, 1962, Mayer, 1990). Calcium carbonate is a cementing agent in many shale rock types and the percentage of carbonate is a useful predictor of durability. In a previous study (Miller & McCahon, 1999) the % CaCO3 was found to increase with slake durability index (Id2) values. With few exceptions, samples with a carbonate content above 35% were found to have medium to high durabilities based on slake durability (Id2) values.

2.4 Contractor Surveys

An important component of the database is information on treatments of specific shale units employed by contactors, and the engineering performance of those units. This information was obtained from KDOT contractors by the use of a written survey. The survey requested information on the excavation methods and shale manipulations that were used to meet Special Provisions 90M-255R1 and 90M-256. A copy of this survey form written in collaboration with the KDOT project monitor is included in the APPENDIX C.

The survey was distributed with an accompanying cover letter to a list of 60 past and current KDOT contractors. Names and contact information for these contractors were obtained from the 2003-2004 Membership Directory of the Kansas Contractors Association. All of these contractors were contacted by phone or e-mail before the survey was mailed. We received responses from 7 of the original 60 contractors contacted. The engineering data provided by these contractors was summarized and compiled for incorporation in the database.

Chapter Three

Database Construction and Description

The database program used in this project was Microsoft Access -- part of the Microsoft Office XP suite version 2002. This database program allows the easy integration of both text (through Word) and spreadsheets (through Excell) into the database. Microsoft Access is compatible with existing KDOT software, and will also permit easy conversion to a website accessible by interested users. Photoworks 2.41 and Adobe Photoshop 7.0.1 were used to import and manipulate digital images for incorporation into the database. Existing photo slides of outcrops were digitized and copied onto CD by Photoworks, a commercial photo processing company. Power Point was used to combined digitized photographs with captions and text. These images were imported into the database to illustrate descriptive terms used in the database. All images were imported into the database as JPEG files.

All locality information, field and laboratory sample data, and engineering information was input into the database in table form. The layout of the tables and definition of table columns ("fields") were set using the database "Design View." These parameters can be easily changed.

All new field and laboratory data obtained during the course of this study was input into the database. In addition, all the data collected in a previous study of lower Permian "shales" (Miller & McCahon, 1999) was also entered. For some previously sampled localities additional data from Proctor Compaction and grain size analyses are included. The most important column heading in the datasheets is the "Durability Classification" field on the "Laboratory Data" datasheets. This column provides a summary durability classification of “High,” “Medium” or “Low” for each shale interval sampled based on the field and laboratory data obtained.

A valuable, though underdeveloped, component of the database is information on treatments of specific “shale” units utilized by contactors, and the engineering performance of those units. This information was obtained from KDOT contractors by the use of the written surveys discussed above.

Each of the component datasheets of the database is described below.

3.1 List of Localities

The “List of Localities” datasheet includes locality IDs for both sampled field localities (roadcuts, quarries and natural exposures) and for construction sites for which engineering data has been provided. The letters of the ID designations refer to the locality, and the number suffix refers to a specific named unit at that locality. A locality that exposes multiple named stratigraphic units will have multiple suffix numbers.

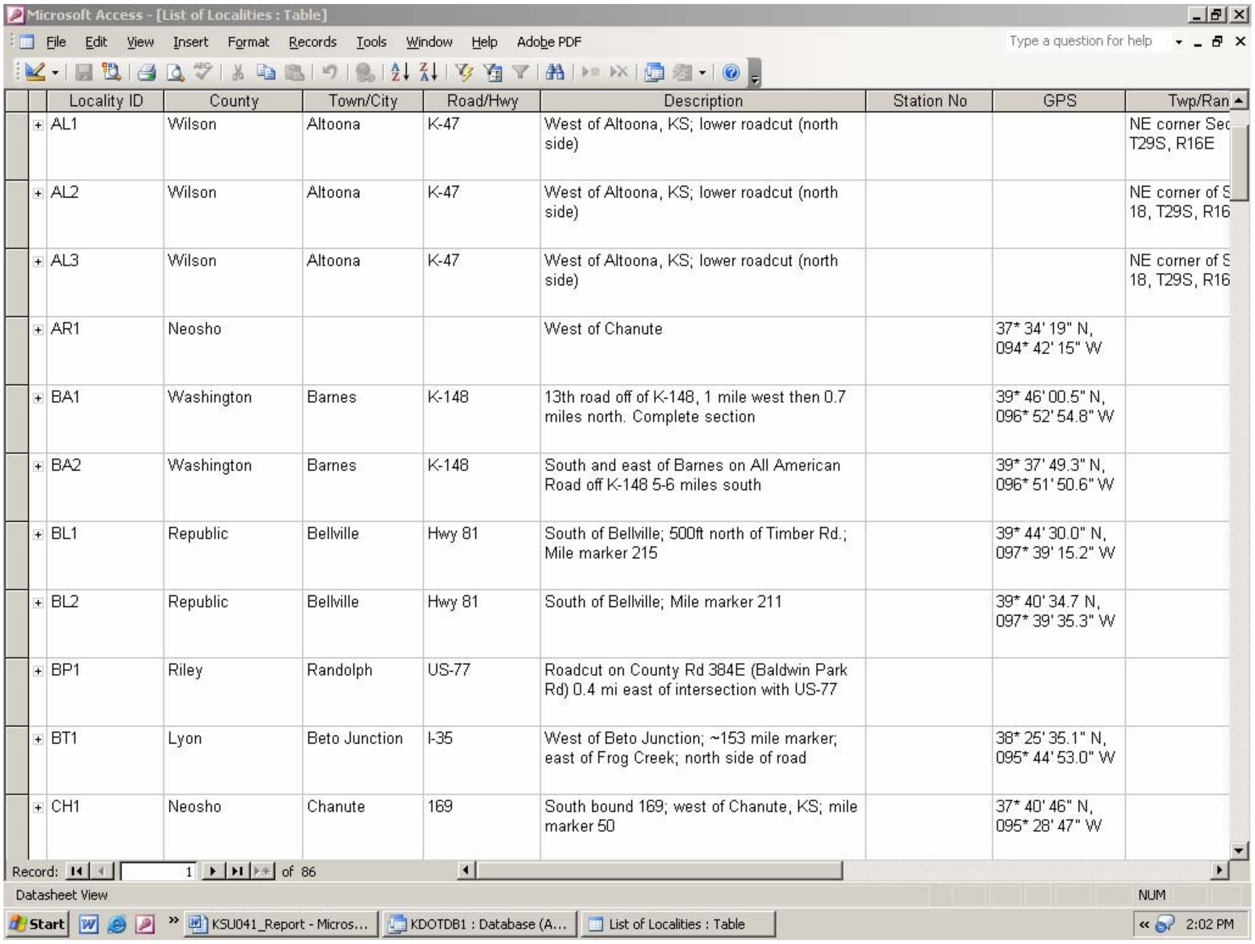
The following information is provided for all localities: county; nearest town or city; nearest road or highway; and a written locality description. In addition, GPS (latitude/longitude) coordinates are provided for many of the sites.

Figure 3.1 shows a computer screen shot of the open “List of Localities” datasheet table.

3.2 List of Cores

The locality information for the sampled cores was placed into a separate datasheet. This was done to speed access for users who are specifically searching for core data. All of the core ID designations are preceded by a lower case “c” to distinguish them from field localities. This convention is utilized throughout the database.

Like the “List of Localities” datasheets, the county, nearest town/city, nearest road/highway, and a written description is provided for each core. Also included are the project numbers, bridge numbers, and station numbers.



Locality ID	County	Town/City	Road/Hwy	Description	Station No	GPS	Twp/Ran
AL1	Wilson	Altoona	K-47	West of Altoona, KS; lower roadcut (north side)			NE corner Sec T29S, R16E
AL2	Wilson	Altoona	K-47	West of Altoona, KS; lower roadcut (north side)			NE corner of S 18, T29S, R16
AL3	Wilson	Altoona	K-47	West of Altoona, KS; lower roadcut (north side)			NE corner of S 18, T29S, R16
AR1	Neosho			West of Chanute		37* 34' 19" N, 094* 42' 15" W	
BA1	Washington	Barnes	K-148	13th road off of K-148, 1 mile west then 0.7 miles north. Complete section		39* 46' 00.5" N, 096* 52' 54.8" W	
BA2	Washington	Barnes	K-148	South and east of Barnes on All American Road off K-148 5-6 miles south		39* 37' 49.3" N, 096* 51' 50.6" W	
BL1	Republic	Bellville	Hwy 81	South of Bellville; 500ft north of Timber Rd.; Mile marker 215		39* 44' 30.0" N, 097* 39' 15.2" W	
BL2	Republic	Bellville	Hwy 81	South of Bellville; Mile marker 211		39* 40' 34.7 N, 097* 39' 35.3" W	
BP1	Riley	Randolph	US-77	Roadcut on County Rd 384E (Baldwin Park Rd) 0.4 mi east of intersection with US-77			
BT1	Lyon	Beto Junction	I-35	West of Beto Junction; ~153 mile marker; east of Frog Creek; north side of road		38* 25' 35.1" N, 095* 44' 53.0" W	
CH1	Neosho	Chanute	169	South bound 169; west of Chanute, KS; mile marker 50		37* 40' 46" N, 095* 28' 47" W	

Figure 3.1: Computer Screen Shot of List of Localities Datasheet

Note the letter and number designations for the sampled localities which are unique for each named stratigraphic unit at a given location. Note also the multiple ways in which locality descriptions can be recorded.

3.3 Named Units and Named Units for Cores

Rocks are subdivided first into “groups,” then “formations,” “members,” and sometimes “beds.” The stratigraphic units names used in this database follow the terminology and unit boundary definitions given by Zeller (1968). In order from oldest to youngest (bottom of the Kansas rock column to the top), the Pennsylvanian and Permian groups sampled in this database are the Cherokee, Marmaton, Pleasanton, Kansas city, Lansing, Douglas, Shawnee, Wabaunsee, Admire, Council Grove, Chase, Sumner, and Nippewalla Groups. Much of the Cretaceous interval is not subdivided into recognized groups.

The group, formation and member designations of the sampled shale units and cores are indicated in the “Named Units” and “Named Units of Cores” datasheets. In many cases the “shale” units are not subdivided beyond the formation, and in others the “shales” are member units within “limestone” formations. In some cases, the member units being sampled was unknown or uncertain.

As indicated earlier, it is very important to emphasize that stratigraphic intervals designated as shales include a wide range of lithologies, some of which have very low “soil-like” durabilities while others are highly durable limestone rock. Also, named “limestone” formations commonly include intervals of low durability shales and mudstones.

One of the columns in the “Named Units” datasheets is set-up to import digital images. When available, outcrop photos taken by digital camera, or converted from conventional photographs, were included to illustrate the outcrop appearance of the indicated stratigraphic intervals. These images will give users a visual overview of the named intervals at specific localities.

3.4 Field Descriptions

The rocks of eastern Kansas are highly vertically variable and it is thus usually necessary to subdivide named units into smaller sampled intervals. Each of these sampled intervals was relatively internally homogeneous. Efforts were made to avoid using sampled intervals less than

0.5 meters in thickness. Within a given locality, the entries for each sampled interval are listed from the bottom of the outcrop exposure upward.

The “Field Descriptions” datasheets include data from natural outcrops, quarries, roadcuts and cores. To make the search process for potential users easier, the field data was divided according to stratigraphic group. Most datasheets include data from a single stratigraphic group, although a few include two or three groups. Each “Field Description” datasheet is identified by stratigraphic group.

Users interested in searching for information on a particular stratigraphic interval can go directly to the appropriate datasheet. The locality ID designations of the “Field Descriptions” datasheets can then be used to obtain the specific locality information from the “List of Localities” datasheet. Those searching by locality can first access the “List of Localities” datasheet and find the stratigraphic units and locality ID designations for the localities of interest.

The “Field Descriptions” datasheets include a column for importing “Outcrop Photos.” When available, digital images of outcrops are included that illustrate the particular sampled interval being described in that datasheet entry. The users can thus have a visual image to compare with the verbal descriptions. It should be noted that in many cases the images provided show more than the defined sample interval described in the entry.

Figure 3.2 shows a computer screen shot of one of the “Field Description” datasheets.

3.5 Field Data Explanations

The column headings for the “Field Descriptions” datasheets are explained in this separate datasheet. This allows users a quick way of finding the definitions of terms used in the datasheets and for accessing descriptions of the methods used in obtaining the values shown. References are also provided to relevant sources that provide additional information. Also included in this explanatory datasheet are digital photographs combined with captions and text. These images accompany the descriptions of "Lithology," "Bedding," "Ped Structures," and "Fractures."

The following are included in the text descriptions taken from the "Field Data Explanations" datasheet. Each entry represents a separate column heading.

3.5.1 Lithology Classification

Clay-rich rocks vary greatly in their composition, texture and structure. There are a variety of ways to classify these rocks. One common classification is to use four end members: shales, sandstones, siltstones, and carbonates (limestone and dolostone). Shales have over 50% clay-sized grains, sandstones have over 50% sand-sized grains, siltstones have over 50% silt-sized grains, and carbonates have over 50% calcium or magnesium carbonate.

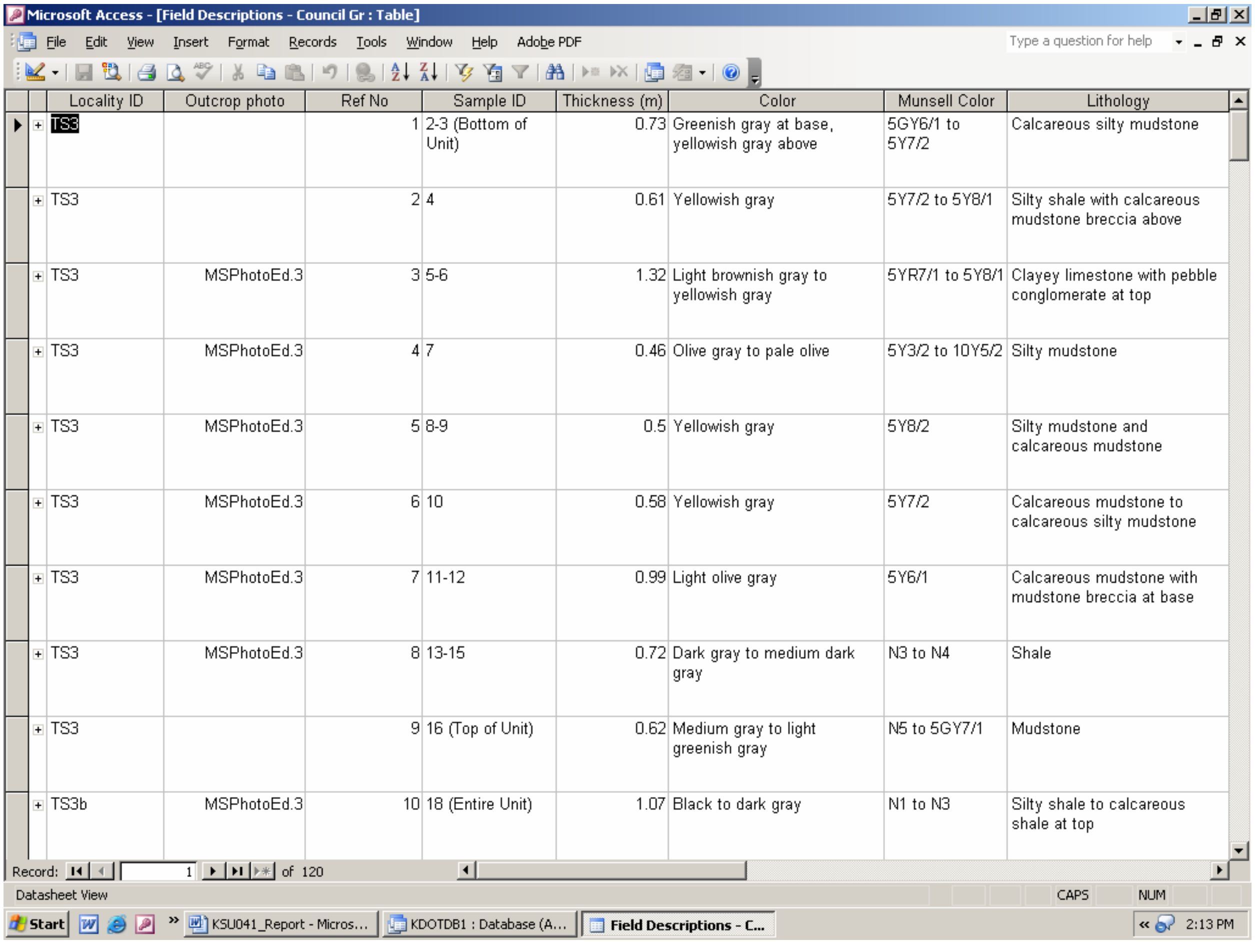
These terms are then further modified as follows: 1) silty shales have between 25% and 50% silt, 2) sandy shales have between 25% and 50% sand, 3) shaley siltstones have between 25% and 50% clay, 4) calcareous siltstones have between 25% and 50% carbonate, and 5) calcareous shales have between 25% and 50% carbonate (see Figure 2.11 in Potter, et al., 1980).

Although the term "shale" is used to refer to the broad group of all fine-grained sedimentary rocks, it is also a term used to describe texture. Fine-grained rocks that split into thin layers (<10mm thick) are classified as shales. Those that are bedded (layers >10mm thick) or massive (have no clear layering) are classified as mudstones. Thus in this database the term "shale" and its modifications is used to refer to finely layered rocks, and "mudstone" and its modifications is used to refer to bedded or massive rocks. Mudstones may, and usually do, have a variety of structural characteristic such as those created by pedogenic processes. These are described under the heading "Ped Structures."

3.5.2 Munsell Color

Color is a useful descriptor because it reflects composition (eg. Carbonate, iron and organic carbon content) as well as ancient and modern redox conditions and groundwater flow.

The Munsell color designations, a universal standard for describing colors, were used (Munsell, 1994). Three variables are used to describe a color in the Munsell system: hue, value, and chroma. Hue indicates the color in relation to red, yellow, green, blue,or purple,and is represented by a number and letter combination. Value indicates the lightness, with smaller numbers closer to black and larger numbers closer to white. The chroma notation represents the intensity or saturation of the hue as it departs from a neutral gray of the same value. The value and chroma numbers follow the hue and are separated by a slash. A typical Munsell designation of 5YR4/1, for example, indicates a yellow and red hue with a medium density and a chroma close to neutral gray. Descriptive color names are also used for ease of communication, but they are far less precise. The color designated above might be described as “brownish gray.”



Locality ID	Outcrop photo	Ref No	Sample ID	Thickness (m)	Color	Munsell Color	Lithology
TS3		1	2-3 (Bottom of Unit)	0.73	Greenish gray at base, yellowish gray above	5GY6/1 to 5Y7/2	Calcareous silty mudstone
TS3		2	4	0.61	Yellowish gray	5Y7/2 to 5Y8/1	Silty shale with calcareous mudstone breccia above
TS3	MSPhotoEd.3	3	5-6	1.32	Light brownish gray to yellowish gray	5YR7/1 to 5Y8/1	Clayey limestone with pebble conglomerate at top
TS3	MSPhotoEd.3	4	7	0.46	Olive gray to pale olive	5Y3/2 to 10Y5/2	Silty mudstone
TS3	MSPhotoEd.3	5	8-9	0.5	Yellowish gray	5Y8/2	Silty mudstone and calcareous mudstone
TS3	MSPhotoEd.3	6	10	0.58	Yellowish gray	5Y7/2	Calcareous mudstone to calcareous silty mudstone
TS3	MSPhotoEd.3	7	11-12	0.99	Light olive gray	5Y6/1	Calcareous mudstone with mudstone breccia at base
TS3	MSPhotoEd.3	8	13-15	0.72	Dark gray to medium dark gray	N3 to N4	Shale
TS3		9	16 (Top of Unit)	0.62	Medium gray to light greenish gray	N5 to 5GY7/1	Mudstone
TS3b	MSPhotoEd.3	10	18 (Entire Unit)	1.07	Black to dark gray	N1 to N3	Silty shale to calcareous shale at top

Figure 3.2: Screen Shot of a Portion of One of the "Field Description" Datasheets

Note that the title indicates that this table includes data from sampled units within the Council Grove Group. The Locality ID to the left is the same for this portion of the datasheet since all of the sampled intervals shown were from the same locality and stratigraphic unit. The Reference Numbers are unique for each sampled and described interval. The Outcrop Photo column contains photos of the indicated stratigraphic interval in JPEG format.

3.5.3 Bedding and Lamination

The presence or absence of layering in fine grained sedimentary rocks is an important factor in their durability and slope stability.

Rocks that split into layers <10 mm thick are classified as "shales" in the database, and are described as being "laminated." Those that are more thickly layers (>10mm thick) are classified as "mudstones" and are described as bedded. Visibly unlayered rocks are called "massive."

Laminations can be described as very thin (0.5mm thick), thin (>0.5mm and <1mm thick), medium (>1mm and <5mm thick), or thick (>5mm and <10mm thick). Similarly, bedding can be referred to as very thin (>10mm and <3 cm thick), or thin (>3cm and <30cm thick) (see Table 1.3 in Potter, et al., 1980). Thicker bedding classifications are not relevant for this study.

In cases where rock layers of different lithology alternate repeatedly in a section, the interval is described as "interbedded." This term is used when the individual layers are too thin (<<50cm) to be described as individual units in this database.

3.5.4 Ped Structures

The structure of shales are important contributors to durability. Many of the shale units in eastern Kansas that lack fine layering (i.e. mudstones) were at one time ancient soils. The ancient soil-forming process generates soil aggregates called peds which are often well-preserved in even very ancient lithified soils. These peds vary in size and shape. They may be platy, angular blocky, subangular blocky, prismatic or columnar. In this database, peds are described using standard soil science terminology (Retallack, 1988).

The boundaries of peds are marked by fractures that provide conduits for the movement of fluids and sites for the accumulation of clays, iron oxides, carbonate and salts. In particular, clay coatings along ped boundaries are often surfaces of weakness and sites of shrink-swell activity. Mudstones with well-developed platy, angular or subangular peds will typically disintegrate into their component peds with exposure. These units typically have a low durability.

3.5.5 Fractures and other Large Scale Fabrics

In addition to the small-scale fabric produced by pedogenesis (see "Ped Structures"), larger-scale fractures may occur in these mudstones that are called pseudoanticlines. Pseudoanticlines are undulatory fractures associated with particular types of paleosols. These fractures occur most commonly, and are best-developed, in greenish gray to olive-colored mudstones. However, they can occur in red mudstones as well. These curved fractures typically dip at angles of less than 35 degrees. They are commonly coated with clay films and slickensided (pedogenic slickensides). This makes them ideal surfaces for small-scale rotational movement (slumps).

Shales also may have other structural features that can influence their durability and slope stability (Miller & McCahon, 1999). Joints are roughly planar fractures that occur in relatively regularly-spaced parallel sets that typically intersect. Unlike faults, there is no apparent displacement across these fractures. Such fractures are ubiquitous, but their prominence and spacing varies. At an outcrop scale, joints can affect the downslope movement of material by gravity. Rock falls and slides often occur along these orthogonally oriented fractures. In some units and at some localities, shale units may be disrupted by faulting. In a few places the rocks are disrupted to the extent that the randomly-oriented blocks and clasts can be described as a breccia.

A number of other features are found in the shales of eastern and central Kansas that may have an impact on their engineering properties. Various types of nodules are commonly found in these rocks. These range from phosphate nodules in black shales, to quartz and carbonate geodes in calcareous shales, to pedogenic nodules in variegated mudstones. Carbonate pedogenic nodules (caliche nodules) are especially common in the rocks of the early Permian. These can sometimes form nearly continuous massive layers, or dense concentrations of stacked nodules (“rhizocretions”).

Boxwork structures are another unusual feature that is found within shale units. These are formed by intersecting carbonate-filled fractures. The result is a honeycomb of resistant carbonate-cemented plates with soft shales in the spaces between.

3.6 Laboratory Data

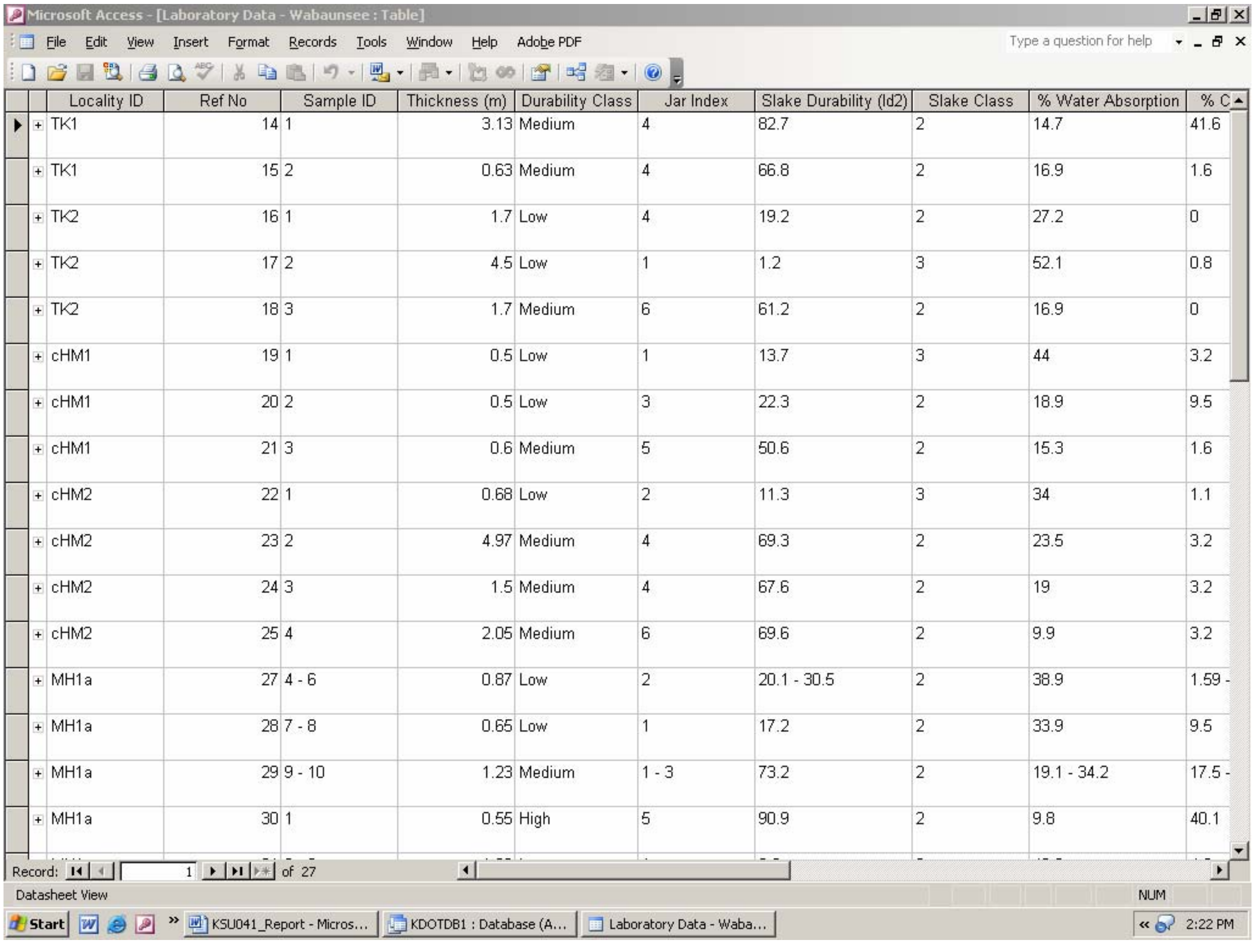
Each of the sampled intervals described in the “Field Descriptions” datasheets are entered into the “Laboratory Data” datasheets. The information from these two datasheets are linked through the reference numbers for each sampled interval (see “Use and Expandability of Database” section below). Also, like the “Field Descriptions,” these datasheets are identified by stratigraphic group.

The Second Cycle Slake Durability Index (Id2) represents the most useful and informative value in the database, and is included for most sampled localities. The slake durability index experimentally measures the combined effects of wetting and drying and mechanical abrasion on the cohesion of samples. It is also used as the basis for several durability classification systems (Bell, 1992; Dick & Shakoor, 1995). In some cases only the Jar Index value, which is a simple water immersion test, is included in the database. Water Absorption and Carbonate Content are also included for most samples. Less commonly included in the database are grain size or Proctor Compaction values.

For some sampled intervals, multiple samples were tested because of significant internal variability in lithology, structure, or fabric. In these cases a range of values is shown for a given laboratory test. The values shown are the high and low values obtained from the multiple samples.

From the users perspective, the "Durability Classification" column is probably the most important in the database. It provides a simple durability ranking that summarizes information from both the field and laboratory data.

Figure 3.3 shows a computer screen shot of one of the "Laboratory Data" datasheets.



Locality ID	Ref No	Sample ID	Thickness (m)	Durability Class	Jar Index	Slake Durability (Id2)	Slake Class	% Water Absorption	% C
TK1	14	1	3.13	Medium	4	82.7	2	14.7	41.6
TK1	15	2	0.63	Medium	4	66.8	2	16.9	1.6
TK2	16	1	1.7	Low	4	19.2	2	27.2	0
TK2	17	2	4.5	Low	1	1.2	3	52.1	0.8
TK2	18	3	1.7	Medium	6	61.2	2	16.9	0
cHM1	19	1	0.5	Low	1	13.7	3	44	3.2
cHM1	20	2	0.5	Low	3	22.3	2	18.9	9.5
cHM1	21	3	0.6	Medium	5	50.6	2	15.3	1.6
cHM2	22	1	0.68	Low	2	11.3	3	34	1.1
cHM2	23	2	4.97	Medium	4	69.3	2	23.5	3.2
cHM2	24	3	1.5	Medium	4	67.6	2	19	3.2
cHM2	25	4	2.05	Medium	6	69.6	2	9.9	3.2
MH1a	27	4 - 6	0.87	Low	2	20.1 - 30.5	2	38.9	1.59 -
MH1a	28	7 - 8	0.65	Low	1	17.2	2	33.9	9.5
MH1a	29	9 - 10	1.23	Medium	1 - 3	73.2	2	19.1 - 34.2	17.5 -
MH1a	30	1	0.55	High	5	90.9	2	9.8	40.1

Figure 3.3: Computer Screen Shot Showing a Portion of One of the Laboratory Data Datasheets

The same Locality IDs indicate the same location and stratigraphic unit while the Reference Numbers are unique for each sampled and described interval and are used to link data entries between datasheets. The Locality IDs with lower case "c" prefixes indicate cores. As explained in the text, the Durability Classification is the most important element of the datasheet and serves to summarize the lab and field data.

3.7 Lab Data Explanations

This datasheet provides detailed descriptions of laboratory methods as well as explanations of terms used in the "Laboratory Data" datasheets. Each column heading refers to one of the laboratory tests that is described in the text file below it. Following are the text descriptions taken from the "Lab Data Explanations" datasheet for each of the column headings.

3.7.1 Jar Index Test

The Jar Index test (FHWA, 1977) is a fast and simple method to determine how dry samples respond when immersed in water. A fresh unweathered sample of about 20 g is oven dried and then immersed in distilled water. The resulting behavior of the sample is then observed after two (2) hours, and Jar Index values assigned according to the following chart.

Jar Index	Behavior
1	Degrades into a pile of flakes or mud
2	Breaks rapidly and/or forms many chips
3	Breaks rapidly and/or forms few chips
4	Breaks slowly and/or develops several fractures
5	Breaks slowly and/or develops few fractures
6	No change

In some cases when the Jar Index value is a 1 or 2, the Slake Durability test was not run because typically little or no material will be retained after the procedure.

3.7.2 Slake Durability

The Second Cycle Slake Durability Index (Id2) has been determined by previous studies (FHWA, 1980; Dick et al., 1994) to be an accurate measure of mudstone durability. This test is relatively simple and repeatable, and the results correlate well with other measures of durability. The analysis need not be performed on samples for which the Jar Index is less than 3. Slake durability (Id2) values in this database were calculated according to procedure D4644 (ASTM, 1990). This procedure involves determining the mass loss of ten 30g samples subjected to alternate oven drying and tumbling in a wire mesh drum immersed in distilled water.

3.7.3 Slake Class

Slake class was determined as part of the slake durability (Id2) procedure (D4644) (ASTM, 1990). The materials retained in the wire drum after the second cycle were described using the following standard designations:

Class I -- Retained pieces remain virtually unchanged
Class II -- Retained materials consist of large and small pieces
Class III -- Retained material consists exclusively of small fragments

A sample with a high slake durability (Id2) and with Class I retained materials is relatively more durable that one with the same Id2 value but with Class III retained materials.

3.7.4 Water Absorption

Water absorption was determined as a secondary procedure during the slake durability (Id2) and Jar Index tests. On immersion during the Jar Index test, water-saturated samples that remained intact were weighed prior to and after oven drying of samples, and the percentage of water absorbed was obtained from these calculations.

Previous work comparing percent water absorption and slake durability (Id2) values (Miller & McCahon, 1999) showed that samples with high absorptions (>25%) had slake durability values below 50%.

3.7.5 Carbonate Content

Samples were analyzed for calcium carbonate with a Chittick apparatus (Dreimanis, 1962; Machette, 1986; Mayer, 1990). This procedure involves adding 50% HCl acid to a 1g crushed sample. The volume of released CO^2 gas is measured and used to calculate the mass loss of carbonate which is reported as percent carbonate.

Calcium and magnesium carbonate is the predominant cementing agent in many shales, and the percentage of carbonate has been found to be a good predictor of durability (Miller & McCahon, 1999). Units with a calcium carbonate content > 35% will likely have medium to high durability, and units with < 35% will likely have low durability.

3.7.6 Grain Size (%Sand, Silt, Clay)

A relatively few sampled intervals include grain size data. The grain size data incorporated into the database was from a previous study on Kansas mudrocks (Miller & McCahon, 1999). The percentage values for grain size included in this database were determined by elutriation (ASTM, 1970, p. 88). In this process 10g samples were crushed and sieved to pass 2mm and pretreated several times with dilute HCl to remove carbonate (Gee & Bauder, 1986). Clays were removed from each sample through settling and decanting. On removal of clays, the sands were sieved (230 mesh) out into fine-grade filter paper, then oven dried and weighed. The remaining silts were then also washed into filter paper, oven dried, and weighed. From the initial total sample weight, the percent of sands, silts and carbonate (calculated by the Chittick procedure) were subtracted to give the clay fraction percent.

Grain size data using this or other methods could be added to the database in the future.

3.7.7 Proctor Compaction (Maximum Dry Density and Optimum Moisture)

Standard Proctor compaction moisture/density curves were determined for a few shale units. About 50 to 80 lbs was collected for each sampled unit and disaggregated. Proctor compaction analyses were conducted by the Bureau of Materials and Research at KDOT using test procedure AASHTO T-99.

The mechanical compaction of “soil” (non-durable materials) in fills and embankments by rolling, tamping, or vibration is extensively employed to reduce subsequent settling and erosion. The moisture content of the material affects the degree to which it can be effectively compacted. For every “soil” there is an optimum moisture content at which maximum compaction and thus maximum dry densities are obtained. Laboratory compaction tests are designed to determine a moisture-density curve for a given material. The Standard Proctor test is the predominant laboratory method in use (Terzaghi & Peck, 1976; Bell, 1993).

As stated by Terzaghi and Peck (1967), “The engineering properties of shales with a given mineralogical composition may range between those of a soil and those of a rock.” Low durability shales should be treated more as soils than rock from an engineering perspective. The optimum moisture content and maximum dry densities of these shales is thus of interest.

In a previous study (Miller & McCahon, 1999), Proctor compaction results were plotted against both slake durability (Id2) and jar index. Surprisingly consistent trends were present in both of these correlations. Maximum dry density increased with slake durability and jar index, and optimum moisture decreased. Low durability samples with Id2 values <50% and jar indexes of 1 or 2, generally had maximum dry densities below 110 pcf.

3.7.8 Durability Classification

The Durability Classification column of the database is the most important as it provides a simple synthesis of the data provided into a single durability classification. This is a summary classification based primarily on the slake durability (Id2) values when available. The simple classification scheme of Dick and Shakoor (1995) was used with Id2 values >85% indicating High Durability, Id2 values of 50-85% indicating Medium Durability, and Id2 values <50% indicating Low Durability.

The Jar Index test results correlate roughly with the slake durability values. Indices of 1-3 generally indicate low to medium durability, and indices between 4-6 indicate medium to high durability. The water absorption also provides insight into shale durability with absorption values >25% generally associated with low durability (Miller & McCahon, 1999).

Low durability units (Id2<50% or jar index of 1 or 2) should be treated as soils for engineering purposes. Excessive erosion, slump, and debris flows are probable risks for slopes comprised of such units (Dick & Shakoor, 1995). Medium durability units have the potential for slump and debris flows, while such risks are unlikely for high durability units (Id2>85%). In addition, units with slake durability values greater than 90% are rocklike and will not likely break down with weathering (FHWA, 1980).

In the absence of slake durability values, durability classification was based on carbonate content, clay content, and ped or bedding structure (Miller & McCahon, 1999). Carbonate content >35% typically indicates medium to high durability, and clay content >70% typically is associated with low durability. Well-developed fine to medium ped structures commonly result in low durability. Also, thinly bedded or laminated units are less durable than thicker bedded or massive units.

In some cases, these additional factors were also used to modify the classification based on the slake durability results. Also the term “Mixed” has been used when the sampled interval is highly variable, or contains abundant interbeds of very different durability.

3.8 Engineering Treatment

This datasheet is set up to input the contractor data obtained through responses to the mailed survey (see APPENDIX C). This includes both the shale excavation and manipulation methods utilized by contractors at specific construction sites. These sites are identified by both locality and named stratigraphic unit within the “List of Localities” and “Named Units” datasheets.

The contractor information was placed into a separate datasheet, rather than being incorporated into the “Field Descriptions” and “Laboratory Data” datasheets. This was to enable more rapid access to those searching specifically for the engineering treatment data.

This datasheet includes: 1) excavation methods and related comments; 2) equipment used for shale manipulation and related comments; 3) the number of passes required to breakdown the “shale”; and 4) the relative amount of water needed.

Chapter Four

Use and Expandability of Database

4.1 Links between Data Sheets

The Microsoft Access database program enables datasheets to be linked in various ways. The links enable related entries from different datasheets to be easily and quickly accessed. One-to-one links directly connect individual non-duplicated entries on one datasheet with those on another. One-to-many links connect single entries on one datasheet to multiple entries on another. The result is a network of links connecting the datasheets on several levels. These link networks can be viewed and changed through the "Relationships" function on the database toolbar.

The Locality IDs for the entries on the "List of Localities" and "Named Units" datasheets are linked one-to-one. In turn, the Locality IDs from the "List of Localities" have one-to-many links to the Locality IDs of the "Field Descriptions" and "Laboratory Data" datasheets where there are multiple sampled intervals for each locality. The Locality IDs for the "Named Units" datasheet are similarly linked to the "Field Descriptions" and "Laboratory Data" datasheets. Finally, the individual sample Reference Numbers for the entries in the "Field Descriptions" and "Laboratory Data" datasheets have direct one-to-one links. The resulting link network for these datasheets is shown in Figure 4.1, which is a screen shot from the "Relationships" window of the database.

The "List of Cores" and "Named Units for Cores" datasheets also have one-to-one links through the Core IDs. These two datasheets are in turn linked by Core IDs to the corresponding IDs in all of the "Field Descriptions" and "Laboratory Data" datasheets. These are one-to-many links as described above. Thus all of the locality description information for both outcrops and cores is linked to the field and laboratory data for those localities. Figure 4.2 shows the link network for a number of datasheets to illustrate these relationships.

The remaining links are between the “List of Localities” and “Named Units” datasheets and the “Engineering Treatment” datasheet. The Locality IDs have one-to-one links to the engineering data.

One-to-one links provide a useful way to simultaneously view data entries from two different datasheets. By clicking on the (+ —) box to the left of the data entry on one datasheet, a user can pull up the corresponding entries on another datasheet. In this way, a user searching the “Named Units” datasheet, can pull-up the description of a particular locality from the “List of Localities” datasheet while still viewing the “Named Units.” Or similarly, a user can simultaneously view the lab data for a particular sampled interval while viewing the “’Field Descriptions.” Screen shots that give the visual appearance of the screen when linked entries are displayed in Figures 4.3 and 4.4.

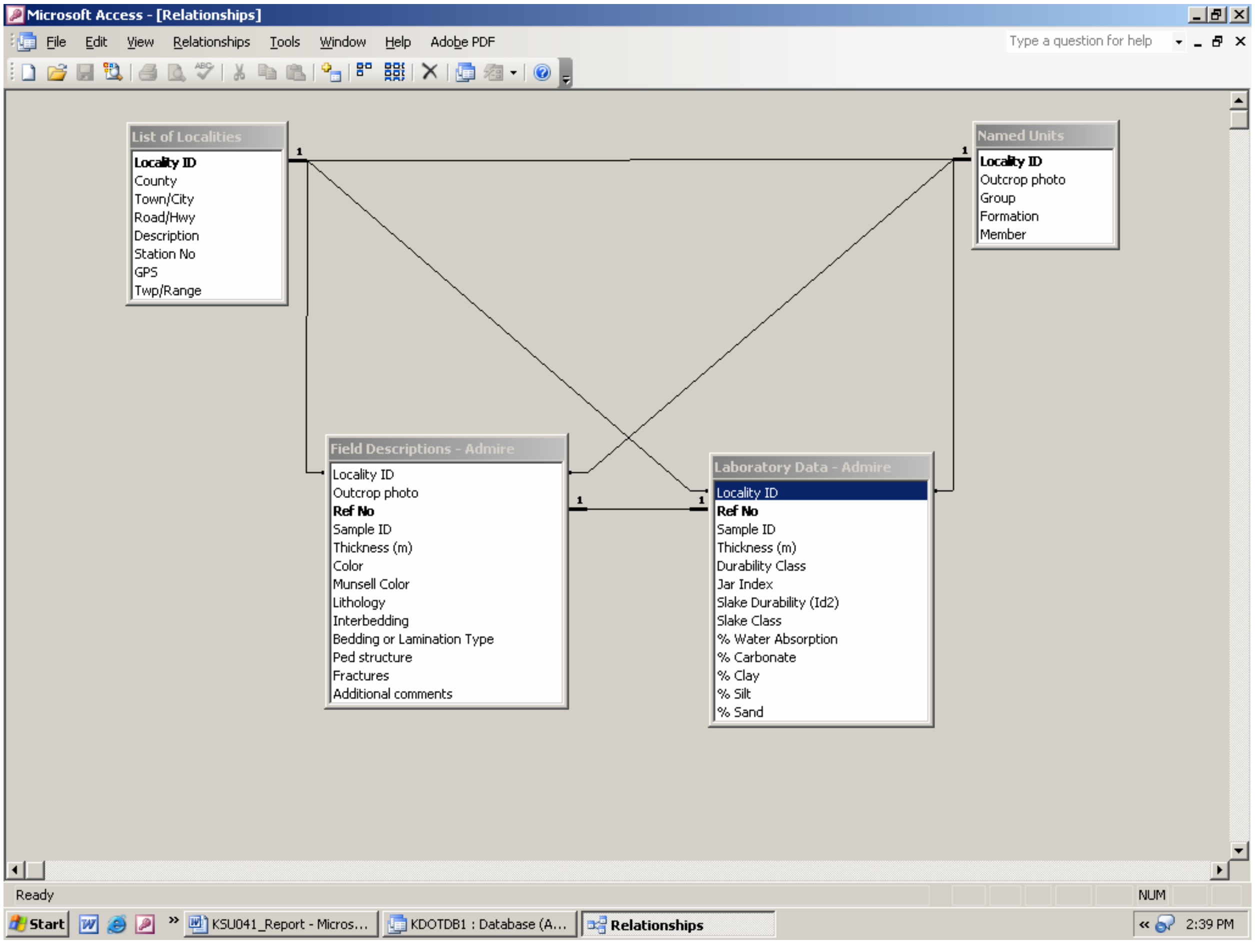


Figure 4.1: Computer Screen Shot of "Relationships" Window Showing One-to-One and One-to-Many Links between the List of Localities and Named Units Datasheets, and the Field and Lab Datasheets for a Particular Stratigraphic Group.

Note that the List of Localities and Named Units datasheets are linked one-to-one by Locality IDs, and the field and lab datasheets are linked one-to-one by Reference Number.

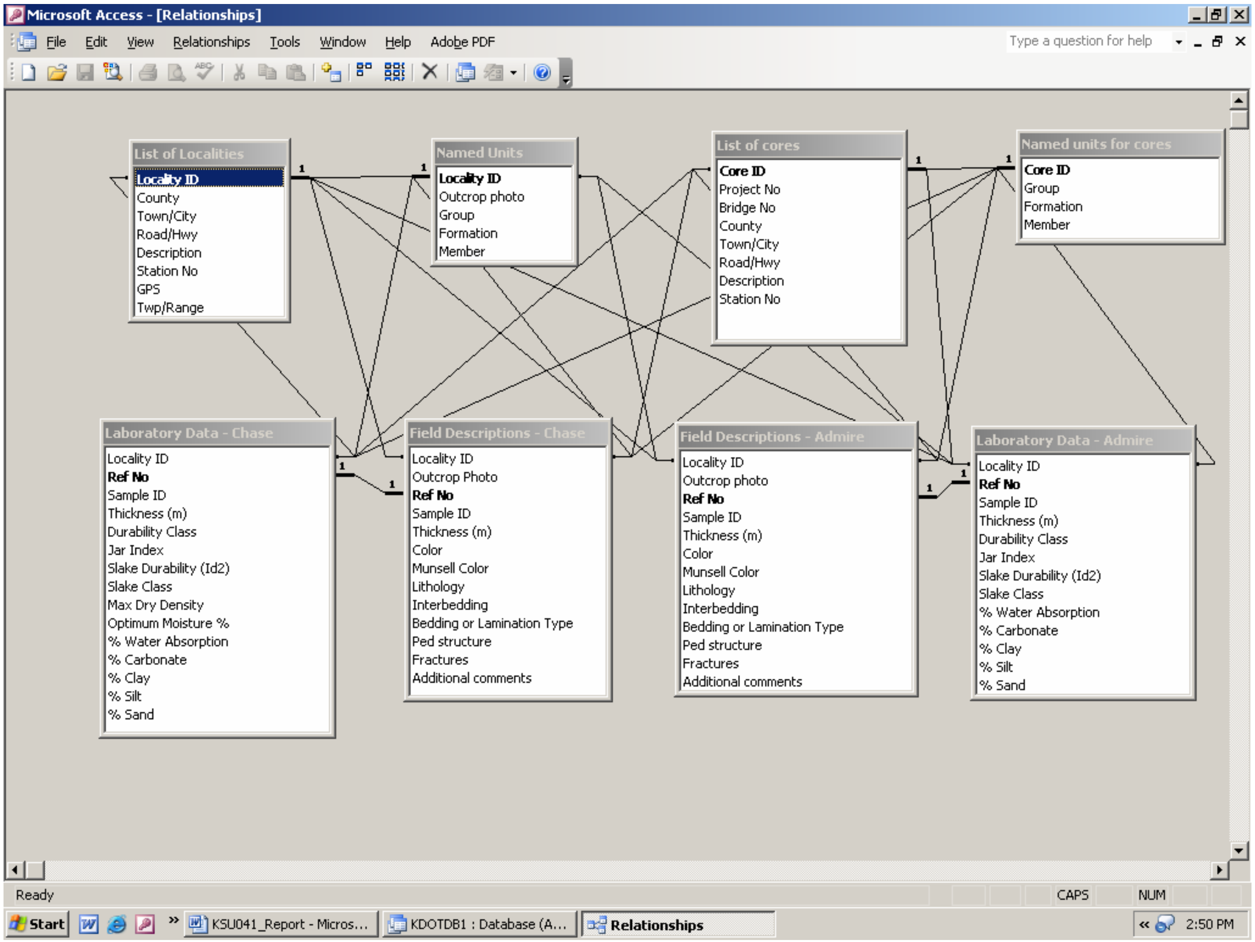
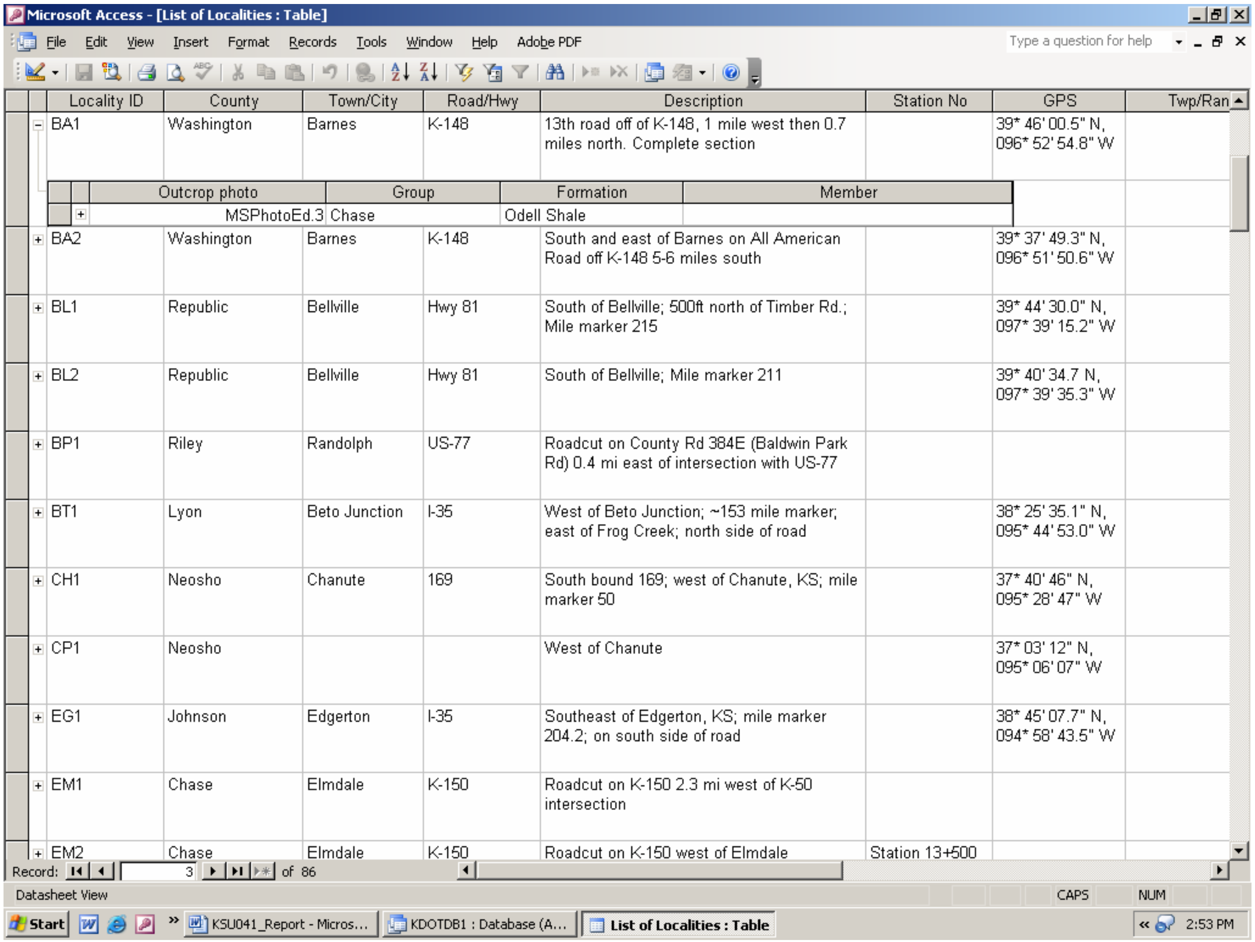


Figure 4.2: Computer Screen Shot of "Relationships" Window Showing One-to-One and One-to-Many Links between the List of Localities and Named Units Datasheets, and the Field and Lab Datasheets for Two Particular Stratigraphic Groups

This diagram gives some idea of the network of links that connect the database.

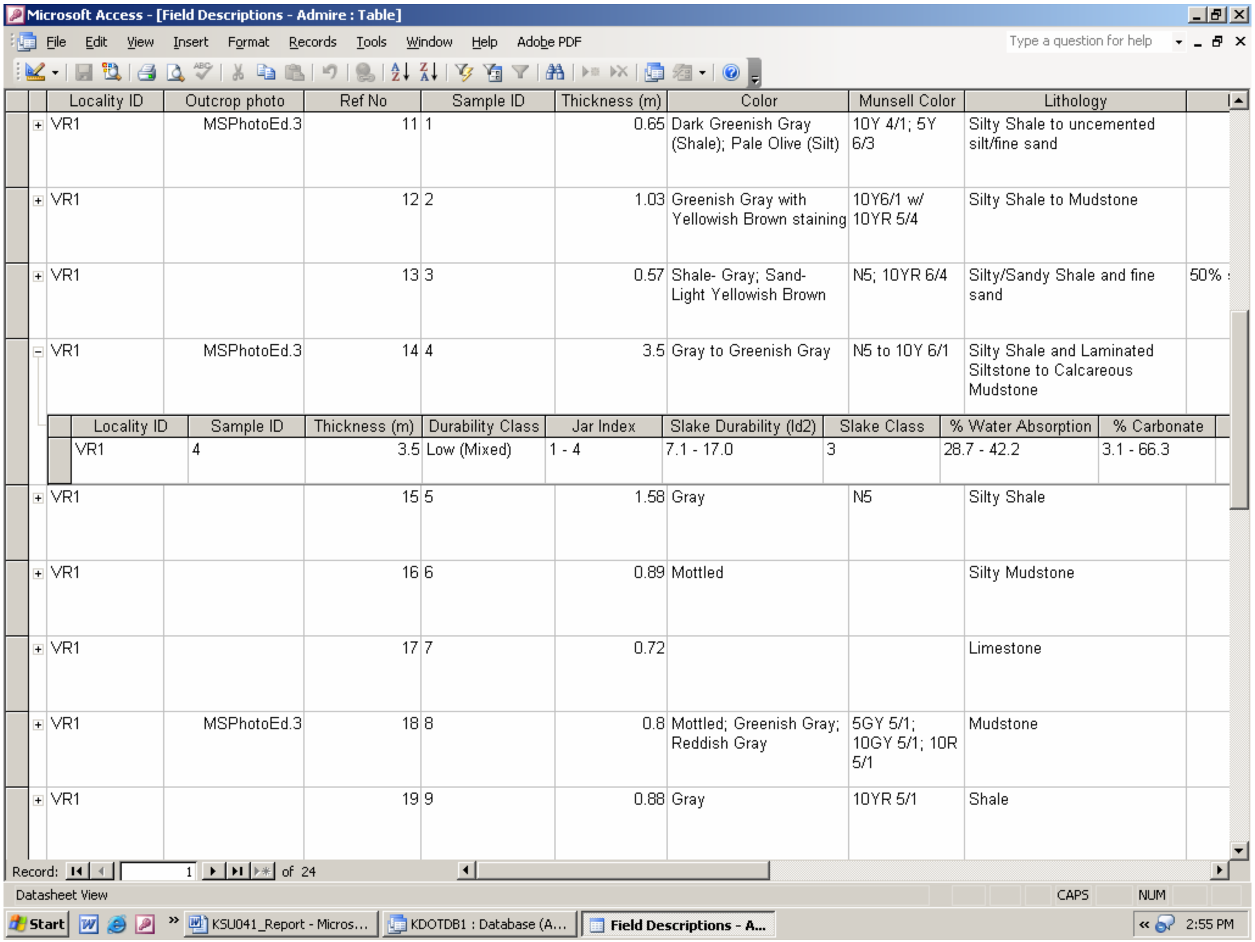


Locality ID	County	Town/City	Road/Hwy	Description	Station No	GPS	Twp/Ran
BA1	Washington	Barnes	K-148	13th road off of K-148, 1 mile west then 0.7 miles north. Complete section		39* 46' 00.5" N, 096* 52' 54.8" W	
BA2	Washington	Barnes	K-148	South and east of Barnes on All American Road off K-148 5-6 miles south		39* 37' 49.3" N, 096* 51' 50.6" W	
BL1	Republic	Bellville	Hwy 81	South of Bellville; 500ft north of Timber Rd.; Mile marker 215		39* 44' 30.0" N, 097* 39' 15.2" W	
BL2	Republic	Bellville	Hwy 81	South of Bellville; Mile marker 211		39* 40' 34.7 N, 097* 39' 35.3" W	
BP1	Riley	Randolph	US-77	Roadcut on County Rd 384E (Baldwin Park Rd) 0.4 mi east of intersection with US-77			
BT1	Lyon	Beto Junction	I-35	West of Beto Junction; ~153 mile marker; east of Frog Creek; north side of road		38* 25' 35.1" N, 095* 44' 53.0" W	
CH1	Neosho	Chanute	169	South bound 169; west of Chanute, KS; mile marker 50		37* 40' 46" N, 095* 28' 47" W	
CP1	Neosho			West of Chanute		37* 03' 12" N, 095* 06' 07" W	
EG1	Johnson	Edgerton	I-35	Southeast of Edgerton, KS; mile marker 204.2; on south side of road		38* 45' 07.7" N, 094* 58' 43.5" W	
EM1	Chase	Elmdale	K-150	Roadcut on K-150 2.3 mi west of K-50 intersection			
EM2	Chase	Elmdale	K-150	Roadcut on K-150 west of Elmdale	Station 13+500		

Outcrop photo	Group	Formation	Member
MSPhotoEd.3	Chase	Odell Shale	

Figure 4.3: Computer Screen Shot of List of Localities Datasheet with the Linked Entry for Locality BA1 from the Named Units Datasheet Displayed Simultaneously.

The (+ -) box to the left enables the user to easily view linked data. Note that this also enables photos on the other datasheet to be accessed.



Locality ID	Outcrop photo	Ref No	Sample ID	Thickness (m)	Color	Munsell Color	Lithology	
VR1	MSPhotoEd.3	11	1	0.65	Dark Greenish Gray (Shale); Pale Olive (Silt)	10Y 4/1; 5Y 6/3	Silty Shale to uncemented silt/fine sand	
VR1		12	2	1.03	Greenish Gray with Yellowish Brown staining	10Y6/1 w/ 10YR 5/4	Silty Shale to Mudstone	
VR1		13	3	0.57	Shale- Gray; Sand- Light Yellowish Brown	N5; 10YR 6/4	Silty/Sandy Shale and fine sand	50%
VR1	MSPhotoEd.3	14	4	3.5	Gray to Greenish Gray	N5 to 10Y 6/1	Silty Shale and Laminated Siltstone to Calcareous Mudstone	

Locality ID	Sample ID	Thickness (m)	Durability Class	Jar Index	Slake Durability (Id2)	Slake Class	% Water Absorption	% Carbonate
VR1	4	3.5	Low (Mixed)	1 - 4	7.1 - 17.0	3	28.7 - 42.2	3.1 - 66.3

Locality ID	Outcrop photo	Ref No	Sample ID	Thickness (m)	Color	Munsell Color	Lithology	
VR1		15	5	1.58	Gray	N5	Silty Shale	
VR1		16	6	0.89	Mottled		Silty Mudstone	
VR1		17	7	0.72			Limestone	
VR1	MSPhotoEd.3	18	8	0.8	Mottled; Greenish Gray; Reddish Gray	5GY 5/1; 10GY 5/1; 10R 5/1	Mudstone	
VR1		19	9	0.88	Gray	10YR 5/1	Shale	

Figure 4.4: Computer Screen Shot of Field Descriptions Datasheet with the Linked Entry for Locality VR1 from the Laboratory Data Datasheet Displayed Simultaneously

4.2 Expandability and Webpage Conversion

The database is both flexible and expandable and will permit both the addition of new types of data (e.g. Proctor compaction or clay mineralogy) as well as new localities and stratigraphic units. This expandability is critical to making the database a useful tool for both KDOT and its contractors. This database is intended to be a continually evolving instrument that will be receiving new data on a regular basis. The more extensive its archive of data the more useful it becomes.

Microsoft Access enables the database data to be converted into data access pages that are files in HTML format (the standard format used to create Web pages). These pages can then be viewed in a Web browser and accessed from the Internet or a company intranet. This would make the database available through the Internet. A dedicated website could be established to give both KDOT personnel and potential contractors direct access to the database.

Chapter Five

Recommendations and Implementation

5.1 Recommendations

The availability of a central database for “shale” materials should save the Kansas Department of Transportation many hours of field, laboratory, and administrative time. Such a database will also minimize the duplication of testing. The identification of well-defined relationships between outcrop observations, test results, and engineering performance will enable the behavior of rock units to be better predicted. This should improve the success of both project planning and contractor bidding. It is important that this database be used early in the design and bidding phase of projects. The identification of potentially problematic units early will also save both time and money expended in redesign, remediation, and repair. This database will give KDOT personnel and contractors a wealth of information for bids and construction of KDOT projects. Access to this data will also allow out-of-state contractors to bid more competitively.

Giving contractors access to data on “shale” unit durability and past engineering performance prior to their bidding on projects should reduce cost overruns and construction delays. It will allow them to see what previous excavation techniques and procedures were needed to meet the specification of treating “shales” as soil in embankments. Classification of shale durability will also provide a useful criteria for predicting excavation methods (FHWA, 1980).

Information from KDOT contractors is an important component of this database, although the initial response to the survey was poor. We would encourage a continuing effort to obtain and incorporate engineering data from contractors. This may become easier once the database becomes available and contractors can see its utility and value in project planning.

Below is a listing of specific recommendations:

1) KDOT and its contractors should regularly collect samples (outcrop and core) for Jar Index and slake durability (Id2) tests. These are easily obtained and involve little equipment and a relatively small time investment. Calcium carbonate content and % water absorption are also very useful measures and should be determined when a problematic unit is suspected (Miller & McCahon, 1999).
2) The simple durability classification scheme of Dick and Shakoor (1995) should be used as a consistent basis for the preliminary assessment of durability based on slake durability (Id2) values. Accordingly, Id2 values >85% indicate High Durability, Id2 values of 50-85% indicate Medium Durability, and Id2 values <50% indicate Low Durability. This classification can be adjusted or modified based on the results of other field observations and laboratory tests.
3) KDOT and its contractors should be encouraged to make and record simple field observations of "shale" units. "Shale" structure and fabric can be very helpful in recognizing potentially problematic units (Miller & McCahon, 1999).
4) All field and lab data collected by KDOT personnel should be input immediately into the database. New localities and stratigraphic intervals can be easily added.
5) The database should be made readily available on a dedicated publicly accessible website. The database should be converted to HTML data access pages and uploaded to a website.
6) Contractors and KDOT personnel should be encouraged to access the database before the design and bidding process. The data in this database are best utilized in the development of geotechnical reports and in project design. The field descriptions and laboratory tests will enable a much-

improved assessment of “shale” durability that can inform both the design and construction of cut banks.

7) Contractors should be encouraged to provide data on the engineering treatment of “shale” units for inclusion in the database. This could be done using the existing survey form.
8) Feedback from contractors and KDOT personnel on the utility of the database should be solicited. This feedback will help guide future changes and additions to the database.
9) The flexibility and expandability of the database should be used to add new types of lab data, field observations, or descriptions of engineering procedures and performance. The online database should be an evolving tool, not a static archive.
10) The information archived in this database can be used to compare and correlate different “shale” properties with durability and engineering performance. This could significantly improve the ability to predict the behavior of “shale” units, and inform both the design and construction of cut banks.

5.2 Implementation Plan

The implementation of most of the above recommendations can be accomplished with minimal delay and training. The database generated by this study can be immediately converted to HTML pages and uploaded to a dedicated website by the Bureau of Materials & Research. After the database is posted to an accessible website, there would be opportunity for some detailed feedback from both KDOT personnel and contractors on the utility of the database. This input could then be used to make final improvements on the database. The flexibility of the Microsoft Access database program should make such modifications easy to implement. The maintenance and further expansion of the database and website will be carried out by KDOT personnel.

KDOT field personnel can immediately begin collecting samples for jar and second cycle slake durability (Id2) tests. The only equipment required is the slake durability apparatus, drying ovens, and a balance. The predictive value of these tests are well worth the time investment. Consideration should also be given to run additional tests such as Chittick analysis for determining calcium carbonate percentage when a potentially problematic unit is encountered. Basic field descriptions of shale units (i.e. lithology, structure, and color) can also be made during initial project investigations from either outcrop exposures or cores. Both field descriptions and sample collection must reflect the internal variability of the named stratigraphic units of interest. Described and sampled intervals should be relatively homogenous. Generalized descriptions for named units will not accurately reflect the engineering properties of the shales encountered.

Field and laboratory data obtained by KDOT personnel can begin to be added to the database at any time. This should occur on an ongoing basis, so that this data is made immediately available to its users. The automatic posting of data to the database will minimize the loss of information, and build an accessible archive.

After the database is available at a dedicated website, its existence and utility can be actively promoted to all potential KDOT contractors. Contractors should be pointed to the website as part of the design and bidding process.

Probably the most difficult recommendation to implement is the involvement of KDOT contractors in proving engineering treatment data for incorporation into the database. However, this should become easier after the website database is being actively used and its practical utility is recognized. Contractor information could be collected via surveys like the one used in this project, and input into the database by KDOT personnel. Alternatively, access to the database could be set-up to permit contractors to directly input data.

In summary, the database assembled here will only be effective to the extent that it is accessed by as many users as possible, and that it is used as a central expanding repository for shale durability data.

REFERENCES

ASTM, 1970, Special Procedures for Testing Soil and Rock for Engineering Purposes. ASTM Special Technical Publication 479, 5th ed., American Society for Testing and Materials, Philadelphia.

ASTM, 1990, Annual Book of ASTM Standards, section 4: Soil and Rock; Dimension Stone; Geosynthetics: American Society for Testing and Materials, Philadelphia, p. 863-865.

Bell, F.G., 1992, Engineering Properties of Soils and Rocks, 3rd edition: Butterworth-Heinemann Ltd., Oxford, U.K., 345p.

Bell, F.G., 1993, Engineering Treatment of Soils: E & FN Spon, London.

Dick, J.C. and Shakoor, A., 1995, Characterizing durability of mudrocks for slope stability purposes. In: Hanberg, W.C. and Anderson, S.A. (eds.), Clay and Shale Slope Instability, Geological Society of America, Reviews in Engineering Geology, v. 31, p. 17-27.

Dick, J.C., Shakoor, A., and Wells, N., 1994, A geological approach toward developing a mudrock-durability classification system: Canadian Geotechnical Journal, v. 31, p. 17-27.

Dreimanis, A., 1962, Quantitative gasometric determination of calcite and dolomite by using chittick apparatus: Journal of Sedimentary Petrology, v. 32, p. 520-529.

FHWA, 1977, Design and Construction of Compacted Shale Embankments, Vol. 3, Slaking Indexes for Design, Interim Report No. FHWA-RD-77-1: Federal Highway Administration, Offices of Research & Development, Washington, D.C.

FHWA, 1980, Design and Construction of Compacted Shale Embankments, Summary, Report No. FHWA-TS-80-219: Federal Highway Administration, Offices of Research & Development, Implementation Division, Washington, D.C.

Gee, G.W. and Bauder, J.W., 1986, Particle-size analysis. In: A. Klute (ed.), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, 2nd ed.: American Society of Agronomy, Madison, Wisconsin, p. 399-404.

Machette, M., 1986, Calcium and magnesium carbonates. In: Singer, M.J., and Janitzky, P. (eds.), Field and Laboratory Procedures Used in a Soil Chronosequence Study: United States Geological Survey Bulletin 1648, p. 30-33.

Mayer, L., 1990, Introduction to Quantitative Geomorphology; Prentice Hall, Englewood Cliffs, NJ, p. 147-150.

McGown, Aa, Marsland, A., Radwan, A.M., and Gabr, A.W.A., 1980, Recording and interpreting soil macrofabric data: Geotechnique, v. 30, p. 417-447.

Miller, K.B., and McCahon, T.J., 1999, Sedimentologic and Mechanical Analysis of Uppermost Pennsylvanian and Permian Mudstones in Northeast Kansas: Final Report K-TRAN Project KSU-97-5: Kansas Department of Transportation.

Munsell, 1994, Munsell Soil Color Charts, revised edition: Macbeth Division of Kollmorgen Instruments Corp., New Windson, N.Y.

Potter, P.E., Maynard, J.B., and Pryor, W.A., 1980, Sedimentology of Shale: Study Guide and Reference Source: New York: Springer-Verlag.

Retallack, G.T., 1988, Field recognition of paleosols. In: J. Reinhardt and W.R. Sigleo (eds.), Paleosols and Weathering through Geologic Time: Principles and Applications: Geological Society of America Special Publication 216, p. 1-20.

Rowe, P.W., 1972, The relevance of soil fabric to site investigation practice: Geotechnique, v. 22, p. 195-300.

Terzaghi, K., and Peck, R.B., 1967, Soil Mechanics in Engineering Practice, 2nd edition: John Wiley & Sons, Inc., New York.

Zeller, D.E., 1968, The Stratigraphic Succession in Kansas, Geological Survey of Kansas Bulletin 189.

Appendix A

Field Localities

Locality ID	County	Road/Hwy	Group	Formation
AK1	Riley	K-113	Council Grove	Eskridge Shale
AK2	Riley	K-113	Council Grove	Eskridge Shale
AL1	Wilson	K-47	Lansing	Plattsburg Limestone
AL2	Wilson	K-47	Lansing	Plattsburg Limestone
AL3	Wilson	K-47	Kansas City	Bonner Springs Shale
AR1	Neosho		Cherokee	Cabaniss
BA1	Washington	K-148	Chase	Odell Shale
BA2	Washington	K-148	Chase	Odell Shale
BL1	Republic	Hwy 81	Colorado	Greenhorn Limestone
BL2	Republic	Hwy 81	Colorado	Greenhorn Limestone
BP1	Riley	US-77	Chase	Winfield Limestone
BT1	Lyon	I-35	Shawnee	Calhoun Shale
CH1	Neosho	169	Kansas City	Lane Shale
CP1	Neosho		Cherokee	Cabaniss
EG1	Johnson	I-35	Lansing	Stanton Limestone
EM1	Chase	K-150	Chase	Matfield Shale
EM2	Chase	K-150	Chase	Matfield Shale
FR1	Riley	K-18	Council Grove	Grenola Limestone
FS1	Bourbon/Crawford	US-69	Cherokee	Cabaniss
FUL1	Linn	Hwy 69	Marmaton/Cherokee	
HM1	Franklin	I-35	Douglas?	Lawrence?
JC1	Geary	Hwy 77	Chase	Matfield Shale
JC2	Geary	Hwy 77	Chase	Matfield Shale
KR2	Riley	K-408	Council Grove	Blue Rapids Shale
KR2b	Riley	K-408	Council Grove	Speiser Shale
KR3	Riley	K-408	Chase	Wreford Limestone
LAW1	Douglas	K10	Shawnee	Oread Limestone
LB1	Osage	I-35	Wabaunsee	Scranton Shale?
LO1	Miami	US-69	Kansas City	Lane Shale
LO2	Miami	US-69	Kansas City	Chanute Shale
LY1	Morris	K-77	Chase	Nolans Limestone
MAPH1	Wabaunsee	I-70	Council Grove	Johnson Shale
MAPH2	Wabaunsee	I-70	Council Grove	Red Eagle Limestone
MH1a	Wabaunsee	I-70	Wabaunsee	Wood Siding
MH1b	Wabaunsee	I-70	Wabaunsee	Wood Siding
MH1c	Wabaunsee	I-70	Admire	Onaga Shale
MI1	Miami	US-169	Kansas City	Lane Shale
MI2	Miami	US-169	Kansas City	Chanute Shale
NDX1	Cowley	K-15 & K-38	Chase	Matfield Shale
NL1	Greenwood	54 Hwy	Shawnee	Oread Limestone

NL2	Greenwood	54 Hwy	Shawnee	Oread Limestone
OG1	Geary	I-70	Chase	Matfield Shale
OL1	Johnson	US 56	Lansing	Vilas Shale
OL2	Johnson	US 56	Lansing	Stanton Limestone
OL3	Johnson	US 56	Kansas City	Bonner Springs Shale
OW1-1	Franklin		Lansing	Stanton
OW2-1	Franklin		Lansing	Vilas Shale
PA1	Miami	US-169	Kansas City	Lane Shale
PA2	Miami	US-169	Kansas City	Cherryville Shale
PA3	Miami	US-169	Kansas City	Chanute Shale
PD4	Riley	K-177	Council Grove	Eskridge Shale
PD5	Riley	K-177	Council Grove	Easly Creek Shale
PD5a	Riley	K-177	Council Grove	Stearns Shale
PD5b	Riley	K-177	Council Grove	Bader Limestone
PD6	Riley	K-177	Chase	Matfield Shale
PD7	Riley	K-177	Chase	Matfield Shale
PLA1	Miami	K-7 (Hwy 169)	Kansas City	
PX1	Wabaunsee	I-70	Admire	Janesville Shale
PX2	Wabaunsee	I-70	Council Grove	Foraker Limestone
PY1	Jefferson	US-24	Shawnee	Oread Limestone
PY2	Jefferson	US-24	Douglas	Lawrence
RR2	Riley	US-77	Chase	Doyle Shale
SC1	Riley	K-113	Chase	Matfield Shale
SC2	Riley	K-113	Chase	Matfield Shale
STAN1	Johnson	Hwy 69	Lansing	
STC1	Chase	K-177	Council Grove	Eskridge Shale
STC3	Chase	US-50	Council Grove	Roca Shale ?
TK1	Shawnee	US 75	Wabaunsee	Scranton Shale?
Tk2	Shawnee	US 75	Wabaunsee	Scranton Shale?
TO1	Shawnee		Shawnee	Calhoun Shale
TO2	Shawnee		Shawnee	Topeka Limestone
TO3	Shawnee		Shawnee	Topeka Limestone
TR1	Greenwood		Shawnee	Oread Limestone
TS1	Pottawatomie	K-13	Council Grove	Grenola Limestone
TS2	Pottawatomie	K-13	Council Grove	Roca Shale
TS3	Pottawatomie	K-13	Council Grove	Johnson Shale
TS3b	Pottawatomie	K-13	Council Grove	Red Eagle Limestone
VR1	Wabaunsee	I-70	Admire	Janesville Shale
WA1	Washington	US-36		Dakota
WA2	Washington	US-36		Dakota
WA3	Washington	US-36		Dakota
WA4	Washington	US-36		Dakota
WA5	Washington	US-36	Colorado	Greenhorn Limestone
WM1	Franklin?	Hwy. 4	Shawnee	Tecumseh Shale
WR1	Wabaunsee	I-70	Council Grove	Easly Creek Shale
WS1	Dickinson	K-18	Chase	Doyle Shale

Appendix B

Core Localities

Core ID	Project No	County	Group	Formation
cCPC1	K-7342-01	Dickinson	Chase	Doyle Shale
cDXR1	K-6413-01	Cowley	Council Grove	Grenola Limestone
cDXR2	K-6413-01	Cowley	Council Grove	Roca Shale
cEHC1	K-7372-01	Dickinson	Sumner	Wellington
cFR1	160-19 K-6405-01	Crawford	Cherokee	Cabaniss
cFR2	160-19 K-6405-01	Crawford	Cherokee	Cabaniss
cFR3	160-19 K-6405-01	Crawford	Cherokee	Cabaniss
cFR4	160-19 K-6405-01	Crawford	Cherokee	Cabaniss
cGR1	160-025 K-2489-01	Elk	Wabaunsee	Auburn Shale
cHM1	99-37 K-6819-01	Greenwood	Wabaunsee	Scranton Shale
cHM2	99-37 K-6819-01	Greenwood	Wabaunsee	Howard Limestone
cKAC1	K-7392-01	Comanche	Nippewalla	
cMCT1	15-21 K-7344-01	Dickinson	Sumner	Wellington
cOMC1	70-21 K-6794-01	Dickinson	Chase	Winfield Limestone
cOMC2	70-21 K-6794-01	Dickinson	Chase	Doyle Shale
cOTC1	15-14 K-6781-01		Chase	Odell Shale
cPWR1	K-6820-01	Pawnee		Dakota
cRPR1	24-14 K-6619-01	Clay	Sumner	Wellington
cRR1	K-6794-01	Dickinson	Chase	Winfield Limestone
cRR2	K-6794-01	Dickinson	Chase	Doyle Shale
cTBC1	K-5655-01		Chase	Odell Shale
cTP1	69-54 K-7891-01	Linn	Pleasanton	Tacket
cTP2	69-54 K-7891-01	Linn	Pleasanton	Seminole
cUPR1	K-6815-01	Geary	Council Grove	Blue Rapids Shale
cUPR2	K-6815-01	Geary	Council Grove	Easly Creek Shale
cWTC1	K-7372-01	Dickinson	Sumner	Wellington

Appendix C

Survey

Effort to work shale formations to meet Special Provision 90M-255R1 and 90M-256

COUNTY: ________________________ **LOCATION:** ________________________________

SHALE FORMATION/MEMBER: ____
Please indicate in your responses below if any intervals WITHIN the named shale member or formation required special treatment.

Bedrock Over Shale Formation/Member (circle) Yes No

Depth of Shale Formation/Member Below Surface (circle) 0-1 m 1-4 m >4 m

Method to Excavate Shale Formation/Member – Select all that apply.

W Blasting
W Ripping
W Scrapers
W Scarifier
W Excavator
W Other ____

Comments: ____
____
____
____

Equipment Used to Manipulate Shale – Select all that apply

W Motor Grader
W Sheepsfoot Roller (Straight Shanks)
W Pad Drum Roller (Tapered Shanks)
W High Speed Soil Compactor (Tamper)
W Rotary Crossshaft Mixer
W Track Loaders/Tractors
W Other ____

Comments: ____
____
____
____

Number of Passes Needed to Break Down Shale (circle)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Water Needed to Aid in Breakdown – Select one, provide quantity if possible

W Less than typical soil on project
W Same as typical soil on project
W more than typical soil on project

K - TRAN

KANSAS TRANSPORTATION RESEARCH
AND
NEW - DEVELOPMENTS PROGRAM

A COOPERATIVE TRANSPORTATION RESEARCH PROGRAM BETWEEN:

KANSAS DEPARTMENT OF TRANSPORTATION

THE UNIVERSITY OF KANSAS

KANSAS STATE UNIVERSITY