Physical Testing Data for Indiana Limestone and Other Building Stone Materials: A Computer Database

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ABSTRACT

For more than 40 years, the Indiana Geological Survey has conducted physical tests on a variety of industrial mineral commodities, mostly in response to requests for information on the performance of Indiana Limestone (Salem Limestone, Mississippian). This report consists of a compilation in Microsoft® Excel 2000, Corel® QuattroPro®, and Microsoft® Access 2000 on CD-ROM of those data that resulted from test procedures developed through and standardized by the American Society for Testing and Materials. The authors intend that the electronic datafile within this document be dynamic and that additional data will be added to the database as new tests are performed and the results of those tests compiled.

INTRODUCTION

Bulletin 42-C (Rooney, 1970) was the first publication of the Indiana Geological Survey (IGS) to summarize the results of its ongoing physical testing program of dimension stones. Rooney (1970) abstracted in tabular form the American Society for Testing and Materials (ASTM) test results for dimension stone produced from the Salem Limestone (referred to in this report by its trade name "Indiana Limestone"), the Geneva Dolomite Member of the Jeffersonville Limestone (Devonian), Louisville Limestone (Silurian), the Laurel Member of the Salamonie Dolomite (Silurian), and the so-called "Cincinnatian Rocks" (Table 1).

The data set summarized in Table 1 represents the midpoint of what will be referred to as Phase I of the Indiana Geological Survey physical testing program. Phase I spans the years from the early 1950s when the testing program began to late 1987 from which time the Baldwin Press (the instrument used to test the stone) was calibrated annually. In 1990, modern electronic data readouts were installed as part of a retrofit to the press necessitated by its age. Phase II, then, covers the testing period from 1987 to the present during which quality assurance/quality control (QA/QC) factors are higher than the standards of Phase I, although both phases adhered to the appropriate ASTM standards.

This statement does not imply, however, that the test results compiled during Phase I were inaccurate or that the data sets should no longer be relied upon to contribute to the evaluation of the overall performance of the dimension stone facies of the Salem Limestone (namely, Indiana Limestone). Rather, the test results compiled during the second phase of the testing program are certifiable and have been determined within QA/QC limits common to commercial testing laboratories throughout the United States. ASTM standards for each of the tests performed have been closely followed since the inception of the Indiana Geological Survey physical testing program. Although most of the test results summarized in this report pertain to Salem Limestone, test results for other building stones are included, as well. The tests performed on materials that are not from Indiana are important for the comparison of their performance to Salem Limestone.

GEOLOGIC OCCURRENCE

Salem Limestone formed as an element of platform carbonate deposition within the Illinois Basin during the Middle Mississippian (Valmeyeran). The name "Salem Limestone" was proposed by Cumings (1901) to replace the name "Bedford Limestone" for rocks lying above the Harrodsburg Limestone and beneath the Mitchell Limestone (Rexroad, 1986). The term "Mitchell Limestone," which is no longer in use, corresponded closely to the present Blue River Group, of which the St. Louis Limestone is the bottom formation. The Salem Limestone, which belongs to the Sanders Group, is bounded by the Harrodsburg Limestone beneath and the St. Louis Limestone above (Carr, 1986). Brown (1987) determined that separate facies within the Salem demonstrated a shallowing-upward progradational sequence that is conformable with the Harrodsburg Limestone and the basal part of the St. Louis Limestone.

The dimension stone facies (also known as shoal facies) of the Salem Limestone consists of an extensively cross-bedded and fossiliferous grainstone that accumulated in a high-energy shoal environment. The grains or pellets that constitute the framework of the unit are medium to fine in size, usually well sorted and are composed mostly of

Table 1. Physical properties of dimension stone produced from the Salem Limestone, Geneva Dolomite, Louisville Limestone, Laurel Member, and Cincinnatian rocks (from Rooney, 1970)

	Abrasion Resistance C241-51*					Absorption by Weight (pct) C97-47*				
	Number of samples	Mean	Minimum	Maximum	Std. Dev.	Number of Samples	Mean	Minimum	Maximum	Std. Dev.
Salem Limestone	121.0	8.8	4.9	15.9	2.5	154.0	5.4	2.8	8.6	1.2
Geneva Dolomite						9.0	2.7	0.4	5.0	
Louisville Limestone						11.0	1.6	0.4	2.9	
Laurel Member	6.0	17.7	13.7	25.7		17.0	1.6	0.5	3.7	
Cincinnatian rocks	2.0	29.7	29.5	29.9		2.0	0.4	0.4	0.4	

	Specific Gravity C97-47*					Compressive Strength (psi) C170-50*					Modulus of Rupture (psi) C 99-52*				
	Number of samples	Mean	Min.	Max.	Std. Dev.	Number of Samples	Mean	Min.	Max.	Std. Dev.	Number of Samples	Mean	Min.	Max.	Std. Dev.
Salem Limestone†	154	2.28	2.14	2.42	0.06	65	9,640.0	5,830.0	14800.0	2260.0	61.0	1070	656	1640	241.0
Geneva Dolomite	9	2.51	2.34	2.71		9	10,700.0	5,690.0	16,100.0						
Louisville Limestone	10	2.63	2.57	2.69		13	>17,615.0	11,600.0	>24,000.0		1.0	2490	2490	2490	
Laurel Member	17	2.56	2.30	2.78		18	>13,440.0	7,400.0	>24,000.0		8.0	2209	1004	3730	
Cincinnatian rocks	2	2.72	2.71	2.72		2	22,400.0	19,980.0	23,270.0		2.0	1990	1740	2240	

* American Society for Testing Materials test number.

† Test data from "Physical Constant Data of the Salem Limestone," unpublished report by Myra J. Fox (1967) on open file at the Indiana Geological Survey.

microfossils (including the foraminiferid *Globoendothyra baileyi*), macrofossil fragments, and whole diminutive forms of macrofossils. Various tidal currents and near-shore currents active in the Mississippian seas during Valmeyeran time (circa 340 million years ago) graded the dimension limestone facies of the Salem Limestone (Indiana Limestone) carbonate sands to a mean grain size of about one millimeter. The dimension stone facies (Indiana Limestone) dominates the Salem Limestone and averages 18 meters (60 feet) in thickness along its outcrop, which trends from eastern Owen County southeastward to Washington County (Shaver and others, 1986). The depositional environment of Indiana Limestone was comparable in some ways to the near-shore to lagoonal zones of the modern-day Bahamas. Brown (1990) noted concentrations of ooids (tiny limestone concretions that form in a high-energy current zone) near the top of some shoal deposits within the dimension stone facies. The ooids suggest water depths of 2 meters (6 feet) or less. Desiccation cracks and other indicators of subaerial exposure are lacking, which demonstrates that the shoal facies was not exposed above water level (Brown, 1990). Textural variations within the dimension stone facies can be attributed primarily to subenvironments within the overall shoal setting of the Salem (fig. 1). The portions of the Salem that have been quarried most extensively exist along the outcrop belt from Bloomington in Monroe County southward to the Bedford area in Lawrence County. Along the trend of this outcrop the dimension stone is massive in appearance, well graded, and uniformly cemented with calcite both as a primary and secondary cementing agent.

CHARACTERISTICS OF INDIANA LIMESTONE

As a natural material, Indiana Limestone exhibits different colors that vary from buff to gray, and hosts a variety of textures, which results from the sorting, and arrangement of the framework or grain structure of the stone. These textural differences are represented by industry terms such as "select," which is a fine to medium sand-size grainstone and "rustic," which is a less well-sorted grainstone that includes a mix of fine to coarse sand sizes. Similarly, the degree of calcite cementation varies and the combination of these factors results in variations in pore-moisture content and in the minor differences in material strength found in Indiana Limestone. The current edition of the Indiana Limestone Institute Handbook (1998) lists minimum physical strength values, which were derived from tests performed on samples provided

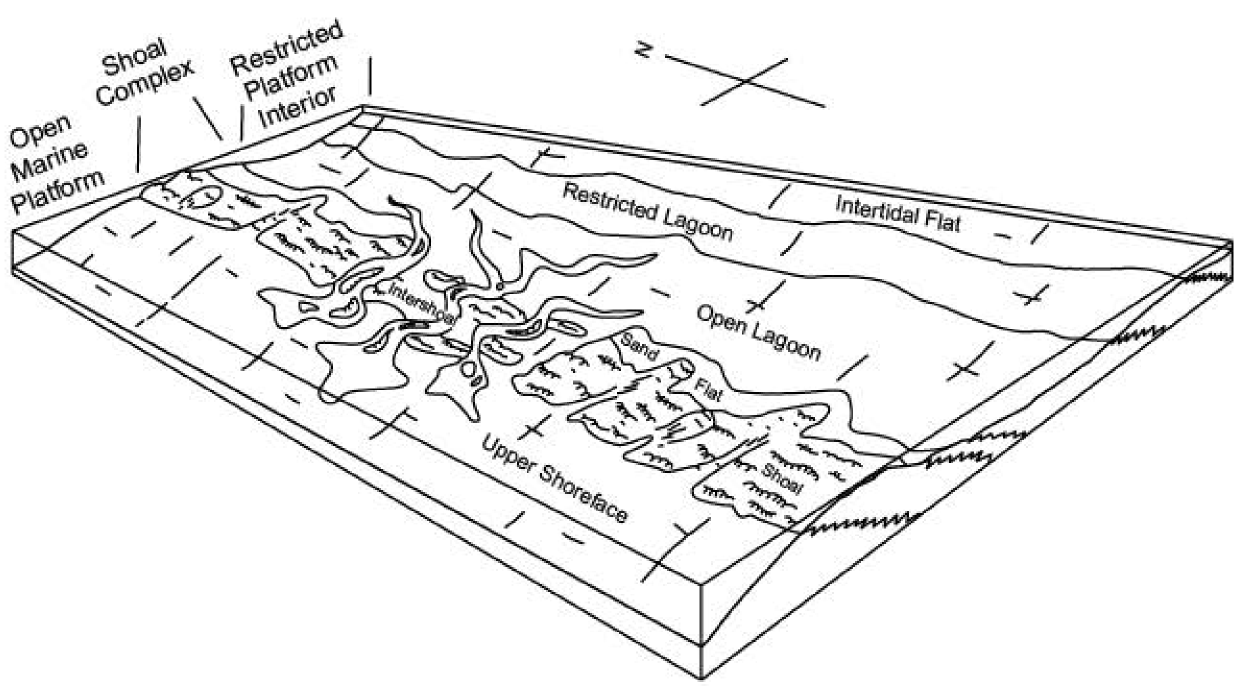

Figure 1. Block diagram that illustrates the spatial relationship of the major facies identified within the Salem Limestone and bounding formations (from Brown, 1990).

by the dimension limestone industry over a period of many years. Assuming the absence of structural flaws such as joints and seams, which are explained below, all Indiana Limestone will meet or exceed the minimum strength requirements established for Type II Dimension Limestone under ASTM C-568.

To the many architects and artisans who use the stone, the intrinsic value of Indiana Limestone as a building material derives as much from its general uniformity of color and texture as it does to its enviable record for durability and overall performance in structures, some of which were built more than 100 years ago. The homogeneity of color and texture within batches of stone quarried for specific jobs results in milled products that look virtually identical from piece to piece and that respond nearly identically to cutting and shaping methods.

Despite the fact that Indiana Limestone is a remarkably uniform and high-quality dimension stone, on outcrop or where exposed in a quarry, the lithology exhibits a variety of characteristics common to all limestones. Joints or cracks that occur throughout the entire thickness of the Paleozoic rocks in Indiana affect the Salem Limestone as well. Similar to fractures on a concrete road surface or parking lot, the bedrock joints are the result of loading from younger bedrock units deposited above the Salem, but that have long since succumbed to eons of erosion. Similarly, horizontal stresses build within the Earth's crust and contribute to the fracturing process. Surface water that percolates downward on its way to the water table gradually dissolves the sides of the bedrock joints to form grykes, sink holes, and cave entrances. Known collectively as karst, these limestone solution features are often filled with a reddish soil called terra rosa (mud-filled grykes are called "mud seams" in the stone industry). All karst features constitute a liability to the dimension stone industry as these structures spoil what would otherwise be high-quality reserves. Even where joint planes have not been solutionally enlarged, they form zones of weakness that cause preferential breakage of the stone. For this reason, wary quarry operators align their cuts parallel to major joint trends so that they are working with, instead of against, the natural stone failure trends. Ironically, the presence of enlarged joints and other limestone-solution features appear to have a direct correlation to stone color. Premium buff, for example, is frequently found in juxtaposition with the very features normally avoided by quarriers.

Stylolites, also called "crow's feet" by the dimension stone producers, are saw-toothed imperfections formed during the diagenetic process (namely, the process of sedimentary rock formation). Though structurally sound in general, the presence of stylolites in finer grades of Indiana Limestone is controlled by suppliers and fabricators alike. Sparry calcite seams (also known as "glass seams"), though classed within the same category by industry, do not constitute a flaw that results in structural weakness. All dimension limestone quarry operations grade their stone prior to shipment to fabricators, for example, as "standard buff, clear," "standard buff, one-seam," and so forth; the fabricators who buy blocks that contain seams are expected to cut them out during the fabrication process. Open seams, or "drys" as they are known in the industry, represent a potential plane of weakness in the stone and are not permitted in finished products in any grade of Indiana Limestone.

WORKABILITY AND DURABILITY

Indiana Limestone has long been known as an exceptionally workable material that may be carved and cut into a variety of configurations limited only in its applications by the imagination of the architect, the capabilities of the fabrication equipment, and the limitations typically related to size that are dictated by transportation and construction considerations. This quality derives from the uniform grading of the particles that make up the stone and by the uniform cementation of the framework by calcium carbonate.

As a "free stone," Indiana Limestone can easily be cut or carved either with or against the grain using a variety of fabrication equipment with minute aesthetic differences in the finished product. This ease of shaping, combined with its remarkable durability, has made Indiana Limestone the product of choice for many projects since the first commercial quarry was opened near the town of Stinesville, Indiana, in 1827 (Rooney, 1970). Monuments and structures throughout the United States bear witness to the durability and lasting beauty of this natural material. Post-tensioning applications allow Indiana Limestone to be fabricated as load-bearing spans up to 30 feet in length. All materials have application limits that should not be exceeded and Indiana Limestone is no exception. Through experience, the Indiana Limestone Institute recommends that Indiana Limestone used in wall panels be a minimum of 2 inches thick. These and other guidelines, including recommended safety factors, can be found in the *Indiana Limestone Institute Handbook* (1998), which is available from the Indiana Limestone Institute of America, 400 Stone City Bank, Bedford, Indiana 47421.

PHYSICAL TESTING PROCEDURES AND RESULTS

Testing Procedures

As building systems have evolved through the years from the traditional bearing-wall designs to thinner veneer applications, the importance of physical testing has increased. In earlier times, testing was necessary to establish the minimum physical properties. Because most Indiana Limestone production exceeds these minimums, Indiana Limestone quarriers often find it desirable to periodically test their production runs to establish more accurate or more current data. Such information is sometimes required by the project specification and is used along with the Indiana Limestone Institute's Safety Factor Technote by the project engineer to determine maximum design loads and stresses and in the design of anchors and supports. More information on this topic is available upon request from the Indiana Limestone Institute.

The Indiana Geological Survey has served the dimension limestone industry's needs for physical testing over the past several decades, the results of this physical testing program being of benefit to its ongoing research on the physical and chemical properties of industrial minerals throughout the state. The Indiana Geological Survey physical testing of building stone materials follows the ASTM standard tests: C-97, C-99, C-170, C-241, and C-880 (American Society for Testing and Materials, 1998). The basic parameters of these tests are discussed below.

1) **ASTM test C-97 — Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone**. This procedure is in two parts and is performed on three cubes of limestone that are 2 inches per side. Calculation of absorption is expressed as a percentage of the sample weight comparison of the specimen dry and after 48 hours of immersion in distilled water. Absorption is useful in predicting the approximate porosity and permeability of the stone, which, in turn, affects the strength of the material. Bulk specific gravity is calculated by the formula: Bulk Specific Gravity = A/(B-C) where A is the weight of the dried specimen, B is the weight of the soaked and surface-dried specimen in air, and C is the weight of the soaked specimen in water. Although C-97 has no value as a means of evaluating the stone's safety factors, it is a useful means of indicating the differences between various types of dimension stone and between variations within stones of the same type (for example, comparison of gray and buff Indiana Limestone). The data have direct application to the abrasion resistance test (C-241) discussed below.

2) **ASTM test C-99 — Standard Test Method for Modulus of Rupture of Dimension Stone**. Modulus of rupture is performed on rectangular prisms of limestone that are 4 inches wide by 8 inches long by 2.25 inches thick, the test being performed with load perpendicular to grain and load parallel to grain on each of five specimens. This test method evaluates the bending strength of limestone by the formula $R = 3Wl/2bd^2$, where R is the modulus of rupture, W is the breaking load, l is the length of the span, b is the specimen width, and d is the specimen thickness. The test results are useful in the determination of the ability of stone segments to carry load where the load-bearing segment is subject to flexure. Modulus of rupture is also useful as one criterion in quality control tests of batches of stone.

3) **ASTM test C-170 — Standard Test Method for Compressive Strength of Dimension Stone**. The compressive strength test utilizes at least ten cubic specimens that are 2 inches on a side. Five specimens are loaded perpendicular to grain and five are loaded parallel to grain. Results are derived from the formula C = W/A, where C is the compressive strength in pounds per square inch, W is the total load in pounds at the time of specimen failure, and A is the area of the bearing surface (for example, typically 4 square inches). Bearing strength information is essential to the determination of the load-bearing capacity of Indiana Limestone in simple compression or static load. Specimens used to determine absorption and bulk specific gravity may double in their application to C-170.

4) **ASTM test C-241— Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic**. Abrasion resistance is determined for a minimum of six specimens that measure 2 inches by 2 inches by 1 inch. Three specimens are abraded parallel to grain and three are tested perpendicular to grain. Although C-241 calls for the abrasion to be done both parallel and perpendicular to grain, most requests for this test specify that the samples be abraded parallel to grain. The abrasion loss test apparatus used by the Indiana Geological Survey is one of a very few working models remaining in the United States and revisions to the ASTM C-241 standard, therefore, seem likely. Abrasion resistance (H_aG) is calculated from the test parameters by the following formula: $H_a = 10G(2000+W_s)/2000W_a$ where G is the bulk specific gravity (determined in test C-97), W_s is the average weight of the specimen (original weight plus final weight divided by 2), and W_a is the loss of weight resulting from the grinding operation. Application as tread surfaces on stairs and as paving stones are but two of the many uses of Indiana Limestone. Test C-241 is one means by which the stone's resistance to foot traffic may be evaluated. The test also provides another mechanism for comparing the performance of Indiana Limestone with various lots and colors of the same product, as well as a means of comparing its performance with other building stone materials.

5) **ASTM test C-880 — Standard Test Method for Flexural Strength of Dimension Stone**. The results of C-880 are similar in concept to the results of C-99, modulus of rupture with the important exception that the C-880 test is typically applied to specimens thinner than 2 inches. Although the Indiana Geological Survey performs this test on a request basis, the Indiana Limestone Institute prefers the ASTM test C-99 as a better portrayal of the bending strength of Indiana Limestone at job thicknesses of 2 inches or greater. The Institute strongly recommends that facing stone not be milled to dimensions thinner than 2 inches. Test C-880 must be performed on a minimum of five specimens that measure 1 inch by 1.5 inches by 12 inches. Larger specimens having

the same dimensional proportions may also be submitted for testing, but the length to thickness ratio must be 10. Consequently, for the Indiana Geological Survey testing facility to process a rectangular prism of Indiana Limestone that is 2 inches thick, the specimen must be 20 inches in length. The Survey's loading equipment will not, however, accommodate specimens greater in length than 28 inches (namely, 2.8 inches thick). The formula by which flexural strength (σ) is calculated follows: $\sigma = 3/4\ WL/bd^2$, where W is the maximum load, L is the span, b is the width, and d is the depth. This test is requested less frequently than is C-99.

The rate at which specimens are loaded, whether in C-99, C-170, or C-880, has a profound effect on the test results. Rapid loading rates tend to skew test results toward higher indicated strengths while slower load rates have the opposite effect. For this reason, scale factors must be applied by architectural design engineers when attempting to apply laboratory test data to the loading of building stone under application conditions. The ASTM standards all specify loading rates, but primarily for the sake of consistency and reproducibility of test results.

The specimen dimensions noted in Table 2 are those used specifically by the Indiana Geological Survey, but they fall within the guidelines detailed for each of the ASTM standard tests. When dimension limestone samples are submitted to the IGS for analysis, the following information should be provided by the requestor:

1) Each sample suite must be accompanied by location information (within 100 meters [300 feet]), quarry name, owner, and ledge from which stone was removed. When known, the date of quarrying should also be noted.
2) Accuracy of test results for C-99, C-170, C-241, and C-880 depends upon the even distribution of load on the bearing face of the test specimen. It is vital, therefore, that all samples be cut as closely as possible to the specified dimensions and that cut faces be both smooth and square.
3) When possible, the individual requesting IGS testing services should mark the samples for orientation (for example, rift or grain; top or bottom) with reference to their original position in the quarry face.
4) If the requestor desires that ASTM tests C-99, C-170, or C-880 be run for specimens in both dry and saturated states, he or she must submit twice the normal number of samples.

THE PHYSICAL TESTING DATABASE

The Data

The Physical Testing Database contains all physical testing results and sample documentation information for dimension stone and building materials tested by the Indiana Geological Survey from 1987 to January 2000. Most of the materials tested are samples of the Salem Limestone submitted to the

Table 2. Summary of ASTM tests conducted by the Indiana Geological Survey and the corresponding sample specifications

ASTM Test Number	Test Name	No. of Specimens *	Specimen Dimensions	Remarks
C-97	Absorption and bulk specific gravity	3	two-inch cubes	Samples supplied for C-170 may also be used for C-97
C-99	Modulus of rupture	5 5	4 X 8 X 2.25 inches 4 X 8 X 2.25 inches	Load parallel to grain or rift Load perpendicular to grain or rift
C-170	Compressive strength	5 5	two-inch cubes two-inch cubes	Load parallel to grain or rift Load perpendicular to grain or rift
C-241	Abrasion resistance to foot traffic	3 3	2 X 2 X 1 inches 2 X 2 X 1 inches	Abrasion parallel to rift or grain Abrasion perpendicular to rift or grain
C-880	Flexural strength	5	1 X 1.5 X 12 inches	Larger specimens with the same dimension ratio may be run

*For tests to be run on both dry and saturated specimens, the numbers must be doubled.

IGS by Indiana quarry operators or by building contractors who use Salem Limestone products. The Physical Testing Database is not exclusively a database of Salem Limestone physical properties. Rather, the database contains test results for various dimension stones of Indiana, including a sandstone unit within the Mansfield Formation (Pennsylvanian), for example, as well as a sampling of rocks and building materials from other states and from around the world.

The data contained in the IGS Physical Testing Database does not represent a systematic sampling of any Indiana dimension stone resource or reserve and, therefore, statistical summaries of these data should not be considered definitive assessments of the physical properties of dimension stone resources and reserves. The database does, however, contain sufficient data to allow the user to make preliminary assessments of Salem Limestone characteristics (the best-represented dimension stone in the database), to assess the need for additional testing of the Salem and other Indiana dimension stones, and to compare building stone materials currently produced in Indiana (Salem Limestone and Mansfield Formation) with a variety of other building materials. Most of the tested samples were submitted to the IGS by quarry operators and building contractors interested in assessing the characteristics of a particular product or reserve.

Disclaimer and Registration

The Physical Testing Database was edited for accuracy, completeness, and consistency to insure that database queries will yield accurate and complete results. Despite efforts to maintain the highest quality of data accuracy, the IGS cannot guarantee the database to be free of error. The IGS provides these data "as is" without guarantee or warrantee of any kind, express or implied. The IGS makes this database available as a public service, and will not be liable for any damages, losses, or claims consequent to the use of these data. If you, the user, recognize errors, we would appreciate your calling them to our attention so we can include necessary corrections in future versions of the database.

A registration form is included in this publication to facilitate communication with users of the database. We will notify registered owners when the next version is available. Upon receipt of notification, registered owners may have their copies of the database updated for a minimal charge by returning the original CD-ROM to the IGS. An updated CD-ROM will be mailed to the registered owner.

Structure of the database

The database files are provided as Microsoft® Excel 2000 and Corel® QuattroPro® 8.0 spreadsheets (named *IGSdata.xls* and *IGSdata.wb3* on the CD-ROM) and as a Microsoft® Access 2000 database (named *IGSdata.mdb* on the CD-ROM). Each spreadsheet contains three worksheets named **All Data**, **Sample Data**, and **Specimen Data**. **AllData**, **SampleData**, and **SpecimenData** are database tables in the Microsoft® Access 2000 database. Users who operate either Microsoft® Excel 97 or Corel® QuattroPro® 8.0 or a later version of either of these spreadsheet programs can begin using the IGS Physical Testing Database immediately after unarchiving the appropriate distribution file.

Each physical test result is an average of data obtained from several specimens tested under similar conditions (see ASTM test requirements), consequently the physical testing database contains two types of data: specimen data and sample data. Specimen data are the test results obtained from individual test specimens. These data are stored in the Specimen Data worksheets in either the Excel® 2000 or QuattroPro® 8.0 spreadsheets and the Specimen Data table in the Access® 2000 database. The sample data are averages computed from appropriate sets of the specimen data. These data are stored in the Sample Data worksheets in either the Excel® 2000 or QuattroPro® 8.0 spreadsheet and the Sample Data table in the Access® 2000 database. The All Data worksheets in the Excel® 2000 or QuattroPro® 8.0 spreadsheet and All Data table in Access® 2000 database contain the combined specimen and sample data. The data are provided in these three formats to facilitate access to both types of testing data, make comparisons of data, compute statistics, and graph relationships.

Each line (row) in the Specimen Data worksheets or database table contains identification information and test results for a single specimen. Each line (row) in the Sample Data worksheets or database table contains identification information and test results for a single sample. The All Data worksheets and database table contain both the specimen and sample data arranged so that all the specimen data for a sample occur together and that block of data is followed by the averaged data for the sample (yellow-shaded lines in the worksheets).

Two types of variables—identification variables and analytical variables—are arranged in similar order in all the distribution files. Identification variables identify the specimen or sample by designating the source, type of material, date, and so on. Analytical variables contain testing results and qualifiers for the analytical values.

Table 3 contains a complete listing of the identification variables used in the Physical Testing Database distribution files. Identification variables are listed in the order in which they occur in the files. Each identification variable name is followed by columns that indicate which files contain the variable, provide a definition for the variable, and provide helpful remarks about the variable's contents and use.

Table 4 contains a complete listing of the analytical variables used in the Physical Testing Database distribution files. Analytical variables are listed in the order in which they occur in the files. Each analytical variable name is followed by table columns that indicate which files contain the variable, provide a definition for the variable, and provide helpful remarks about the variable's contents and use.

FUTURE WORK

From its inception in the early 1950s, the Indiana Geological Survey physical testing program has evaluated building stone materials by analyzing discrete specimens or sets of specimens with little attention paid to the stratigraphic and spatial position of the rock from which the samples were taken. In recent years our understanding of the geologic environments in which the Salem Limestone formed has improved markedly. Given adequate field work, it is now possible to link variations in the physical and geochemical properties of the Salem to established depositional models. For this reason, dimension stone samples on which the Indiana Geological Survey performs standard ASTM tests will be linked to their spatial positioning within the quarry so that the testing program may more effectively advance our understanding of the Salem Limestone. All specimens collected by IGS geologists will be labeled with respect to their vertical position and compass bearing. Coupled with a detailed geologic description of the quarry and the particular bench and face from which the stone is removed, the data derived from the ASTM tests may provide a tool to aid in locating high-quality dimension limestone.

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The authors acknowledge John B. Patton, Robert Blakley, and Myra Fox for their early effort to establish a dimension stone testing program at the Indiana Geological Survey. We also acknowledge Donald D. Carr, who managed the dimension stone testing program from 1987 until his retirement in early 1996 and Bill McDonald who helped to coordinate the testing program between the Indiana Geological Survey and the dimension limestone industry. We gratefully acknowledge the many limestone producers, the Indiana Limestone Institute of America, and various dimension stone users who provided the specimens that make up the data set included within this report. Finally, the authors appreciate the helpful comments and suggestions offered by the technical reviewers Nancy Hasenmeuller, Brian Keith, Nelson Shaffer, of the Indiana Geological Survey and Jim Owens, Director of the Indiana Limestone Institute.

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Table 3. Identification variables used in the Physical Testing Database

Variable Name	All Data	Sample Data	Specimen Data	Definition	Remarks
Sort Order	X	X	X	sequential number set, allows user to quickly restore the order of any of the database tables (worksheets)	This can be deleted or replaced with user-defined sort order.
Sample ID	X	X	X	unique identification number formed by combining report data, original sample number, specimen number, and code for test and test conditions	
Sample Number	X	X	X	original sample number with specimens	Original sample numbers are not unique in the database and, therefore, cannot be used as a unique identifier.
Specimen Number	X		X	original numbers to differentiate specimens in a sample set	
ASTM Test	X		X	ASTM test number	
ASTM Test Name	X		X	ASTM test name	
Moisture	X		X	moisture condition of tested specimens	
Orientation	X		X	orientation of load with respect to bedding (rift)	
Data Type	X	X	X	differentiates specimen data and sample data	
Date	X	X	X	date analysis completed	
Sampled Material	X	X	X	name of tested rock unit or material unit	Most rock unit names are formal rock unit names; some, however, are informal rock names, trade names, or other such designations.
Remarks	X	X	X	miscellaneous information about the sampled dimension stone or building material	
County	X	X	X	county where sample was collected	

Table 4. Analytical variables used in the Physical Testing Database

Variable Name	All Data	Sample Data	Specimen Data	Definition	Remarks
ModRup DryParCnt	X	X		specimen count for modulus of rupture (C-099) measured dry, load parallel to bedding	
ModRup DryParVal	X	X	X	modulus of rupture (C-099) measured dry, load parallel to bedding	
ModRup DryPerCnt	X	X		specimen count for modulus of rupture (C-099) measured dry, load perpendicular to bedding	
ModRup DryPerVal	X	X	X	modulus of rupture (C-099) measured dry, load perpendicular to bedding	
ModRup DryRanCnt	X	X		specimen count for modulus of rupture (C-099) measured dry, load random with respect to bedding	
ModRup DryRanVal	X	X	X	modulus of rupture (C-099) measured dry, load random with respect to bedding	
ModRup WetParCnt	X	X		specimen count for modulus of rupture (C-099) measured wet, load parallel to bedding	
ModRup WetParVal	X	X	X	modulus of rupture (C-099) measured wet, load parallel to bedding	
ModRup WetPerCnt	X	X		specimen count for modulus of rupture (C-099) measured wet, load perpendicular to bedding	
ModRup WetPerVal	X	X	X	modulus of rupture (C-099) measured wet, load perpendicular to bedding	
ModRup WetRanCnt	X	X		specimen count for modulus of rupture (C-099) measured wet, load random with respect to bedding	
ModRup WetRanVal	X	X	X	modulus of rupture (C-099) measured wet, load random with respect to bedding	

Variable Name	All Data	Sample Data	Specimen Data	Definition	Remarks
CmpStr Qualifier	X	X	X	qualifier for compressive strength (C-170) measured dry, load parallel to bedding	A few extremely strong specimens did not yield when subjected to compressive strength loading; in these cases "greater than" is recorded in the CmpStr Qualifier value and the maximum load is reported in the appropriate compressive strength variable.
CmpStr DryParCnt	X	X		specimen count for compressive strength (C-170) measured dry, load parallel to bedding	
CmpStr DryParVal	X	X	X	compressive strength (C-170) measured dry, load parallel to bedding	
CmpStr DryPerCnt	X	X		specimen count for compressive strength (C-170) measured dry, load perpendicular to bedding	
CmpStr DryPerVal	X	X	X	compressive strength (C-170) measured dry, load perpendicular to bedding	
CmpStr DryRanCnt	X	X		specimen count for compressive strength (C-170) measured dry, load random with respect to bedding	
CmpStr DryRanVal	X	X	X	compressive strength (C-170) measured dry, load random with respect to bedding	
CmpStr WetParCnt	X	X		specimen count for compressive strength (C-170) measured wet, load parallel to bedding	
CmpStr WetParVal	X	X	X	compressive strength (C-170) measured wet, load parallel to bedding	
CmpStr WetPerCnt	X	X		specimen count for compressive strength (C-170) measured wet, load perpendicular to bedding	
CmpStr WetPerVal	X	X	X	compressive strength (C-170) measured wet, load perpendicular to bedding	
CmpStr WetRanCnt	X	X		specimen count for compressive strength (C-170) measured wet, load random with respect to bedding	
CmpStr WetRanVal	X	X	X	compressive strength (C-170) measured wet, load random with respect to bedding	

Variable Name	All Data	Sample Data	Specimen Data	Definition	Remarks
SpGrv Cnt	X	X		specimen count for bulk specific gravity (C-097)	
SpGrv Val	X	X	X	bulk specific gravity (C-097)	
Abs Cnt	X	X		specimen count for absorption (C-097)	
Abs Val	X	X	X	absorption (C-097)	
AbrRes DryParCnt	X	X		specimen count for abrasion resistance (C-241) measured dry, load parallel to bedding	
AbrRes DryParVal	X	X	X	abrasion resistance (C-241) measured dry, load parallel to bedding	
AbrRes DryPerCnt	X	X		specimen count for abrasion resistance (C-241) measured dry, load perpendicular to bedding	
AbrRes DryPerVal	X	X	X	abrasion resistance (C-241) measured dry, load perpendicular to bedding	
AbrRes DryRanCnt	X	X		specimen count for abrasion resistance (C-241) measured dry, load random with respect to bedding	
AbrRes DryRanVal	X	X	X	abrasion resistance (C-241) measured dry, load random with respect to bedding	
FlxStr DryParCnt	X	X		specimen count for flexural strength (C-880) measured dry, load parallel to bedding	
FlxStr DryParVal	X	X	X	flexural strength (C-880) measured dry, load parallel to bedding	
FlxStr DryPerCnt	X	X		specimen count for flexural strength (C-880) measured dry, load perpendicular to bedding	
FlxStr DryPerVal	X	X	X	flexural strength (C-880) measured dry, load perpendicular to bedding	

Variable Name	All Data	Sample Data	Specimen Data	Definition	Remarks
FlxStr DryRanCnt	X	X		specimen count for flexural strength (C-880) measured dry, load random with respect to bedding	
FlxStr DryRanVal	X	X	X	flexural strength (C-880) measured dry, load random with respect to bedding	
FlxStr WetParCnt	X	X		specimen count for flexural strength (C-880) measured wet, load parallel to bedding	
FlxStr WetParVal	X	X	X	flexural strength (C-880) measured wet, load parallel to bedding	
FlxStr WetPerCnt	X	X		specimen count for flexural strength (C-880) measured wet, load perpendicular to bedding	
FlxStr WetPerVal	X	X	X	flexural strength (C-880) measured wet, load perpendicular to bedding	
FlxStr WetRanCnt	X	X		specimen count for flexural strength (C-880) measured wet, load random with respect to bedding	
FlxStr WetRanVal	X	X	X	flexural strength (C-880) measured wet, load random with respect to bedding	

Registration Form

INDIANA
Geological
Survey

611 North Walnut Grove
Bloomington, IN 47405

phone (812) 855-2687
FAX (812) 855-2862
url: www.indiana.edu/~igs

Physical Testing Data for Indiana Limestone and Other Building Stone Materials: A Computer Database

Name: ____________________

Company: ____________________

Address: ____________________

____

City: __________ State: __________ Zip: __________

Telephone: ____________________

User Category:

Government ________

Industry ________

Academic ________

Private citizen ________

Signature: ____________________

Date: ____________________