Concrete Materials Database

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Proposed guide from the members of ACI Committee 126

CONCRETE MATERIALS DATABASE*

by C. Barry Oland and Chiara F. Ferraris

Information technology for the concrete industry has historically focused on reporting information about concrete in technical reports, scientific journals, textbooks, and other reference sources. Although archiving publications is currently the only accepted means for preserving and distributing information about concrete, it is now possible for computers to provide these functions.

Before computers can replace laboratory notebooks and published reports as a more efficient means for storing and retrieving concrete materials property data, advances in information protocol are needed, especially in the area of consensus data reporting standards. To be effective, these standards should provide guidance on the types of information to be reported in a concrete materials property database and define the relationships among the individual pieces of data. Use of these standards by database developers throughout the concrete industry will help to integrate the data collection and reporting processes and thereby eliminate the need for retyping the data and verifying its accuracy. Computerization of the data will also allow almost instant access to information that may otherwise be unavailable.

Soon after this need for advanced concrete information protocol was brought to the attention of a select group of ACI members in the late 1980s, the Technical Activities Committee authorized the formation of a new committee to deal with materials property database issues. ACI Committee 126 was organized in 1990 under the leadership of its first chairman, Geoffrey Frohnsdorff. Its mission has been to develop and report information on database formats for concrete and related materials. The committee is accomplishing this mission by preparing guides for use in developing concrete material property databases. The committee's primary responsibility is database formats and does not involve maintaining concrete materials property databases or developing computer software for database management.

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Database development

A concrete materials property database is a collection of data files in which properties of various concrete materials are organized and stored. A data file is a complete set of concrete materials property database entries or data records that contain properties, data, and information for one particular concrete. The usefulness of a concrete materials property database depends on the types and amount of data that it contains. Meaningful comparisons between concrete mixtures are only possible when properties for many different kinds of concretes are available.

Accessing the information in a database can be either easy or difficult depending on the way the data are organized and stored. Information that is consistently reported from one data file to another, constituents that are completely identified, mixture proportions that are accurately reported, property values that are stored in the same units, and test methods that are defined and described in sufficient detail to eliminate misunderstanding, enhance the overall quality of the database. To efficiently report all of the properties that may be available for a particular concrete, a comprehensive set of guidelines for establishing unique concrete identification, constituent information, processing parameters, mechanical, thermal, physical, and other properties and performance characteristics should be followed.

Database development begins with a list of essential and desirable data elements to be included in the database. Each data element represents one individual piece of information used to describe a material or to record a test result. The data elements form the basis of a data dictionary. A data dictionary is a guide for understanding the information in a database and has features similar to those in a language dictionary.[1] In the data dictionary, the description, origin, and usage of each specific piece of data presented in the database can be found. It also provides information describing the relationship of a given piece of data to all other pieces of data including the format that best fits the data. The data dictionary is a framework on which the database schema is built. A database schema is a perspective, a way of seeing the information in the database.[1] The schema provides a transition from individual pieces of information contained in the database to the user's viewpoint.

Standards that contain data elements intended for use in

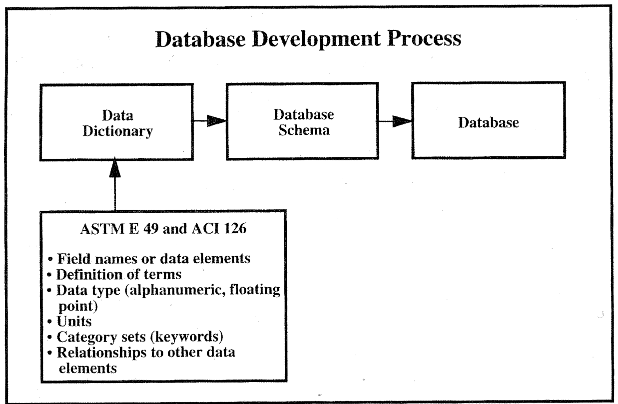

Fig 1 — Fundamentals of the database development process.

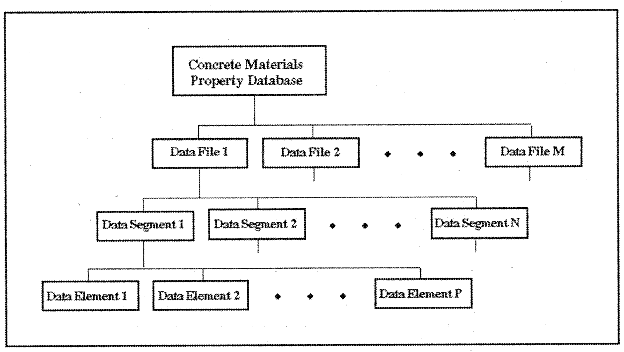

Fig 2 — Relationships among components of a concrete materials property database.

computerization of material properties continue to be developed by various national and international organizations. Selected materials property database standards that have been adopted by organizations in the U.S. are listed in Table 1. As Fig. 1 shows, information in database standards developed by organizations such as ASTM Committee E 49, Computerization of Material and Chemical Property Data, and ACI Committee 126, can be used as the foundation for database development.

Overview of the Guide

A "Guide to a Recommended Format for Concrete in a Materials Property Database"[2] was developed by ACI Committee 126. It is intended for use in establishing the content of a comprehensive concrete materials property database. Recommended formats are provided for organizing and subdividing information about concrete constituents, including hydraulic cements, aggregates, chemical admixtures, mineral admixtures, fibers, and water. It also contains recommended formats for processing information and for concrete properties and performance characteristics. The purpose of these formats is to facilitate efficient storage and retrieval of information about concrete with a computer and to allow meaningful comparisons of concrete properties from different sources. The guide is consistent with principles laid down by ASTM Committee E 49. Material-identification and data-recording standards adopted by ASTM Committee E 49 were used as examples in preparing recommended formats for concrete. These standards are identified in Table 1.

The guide is intended for use by those responsible for entering data about concrete into a computerized materials property database. It may also be helpful to those who prepare tables of concrete properties for reports and to those who might wish to share data with others, either within the same organization or between organizations. Although compliance with the recommended formats is considered essential for efficient computerization of concrete properties, the guide is not intended to replace reporting requirements established in consensus standards or contractual agreements nor is it intended to serve as a step-by-step manual for use in database management or computer protocol development.

The recommended formats in the guide cover all facets of concrete technology. Table 2 lists the nine categories of information that are addressed. Individual pieces of information associated with each of these categories are represented by either an essential or a desirable data element. Each data element consists of four components, including a data element number, data element name, data element type, and data element format. These components are defined and described in the guide. Data elements that address similar topics are grouped together to form data segments. Sets of data segments, when combined, create the foundation for a comprehensive data file. Relationships among the various components of a concrete materials property database are shown in Fig. 2. Certain data elements in the guide are intended to serve a dual role. Besides reporting essential information about the concrete, these data elements also create a unique identifier for the concrete thereby making it possible to distinguish one concrete from another. Unique concrete identification is required to make meaningful comparisons of properties for similar concretes.

Although one of the objectives of the guide is to encourage greater precision and completeness in data recording, some data elements may not always be applicable, or additional data elements may be required. When these situations arise, entries for nonapplicable data elements may be omitted, or supplementary data elements may be created to enhance the reporting process. The order of the data elements is not intended to be rigid and may be varied depending on the protocol of the database management system. It is important, however, that relationships among data elements and data segments be considered during the development of the database schema. In addition, it is suggested that entries be provided for all data elements that are designated essential to ensure equivalency among data files. Information in essential data elements is considered necessary to make comparisons of properties from different sources meaningful.[3] To accommodate the needs of all potential users, recommended formats for reporting both customary units (inch-pound) and the International System of Units (SI) are provided in the guide.[4] Consistency and use of SI units are considered essential to eliminate misunderstanding.

The guide also includes a series of general formats that are used repeatedly throughout a data file. One set of four data elements is used to report information about standards organizations such as those that issue specifications for concrete constituents and test methods for determining properties of concrete and its constituents. These data elements are used to report the name of the organization; the standard number; a designation, if applicable; and the version. Another series of formats is used to report date and time information. Dates are reported using the YYYYMMDD (year, month, day) format, and time is reported using the HH:MM (hour, minute) format for 24-h clock.

Concrete identification

It is essential to be able to be able to uniquely define a concrete. Descriptive terms, such as portland cement concrete, high-performance concrete, and fiber-reinforced concrete, may be effective

Table 1 — Materials property database standards adopted by organizations in the U.S.

Designation	Committee	Title
ACI 126.1R-97	126	"Guide to a Recommended Format for the Recommended Format for the Identification of Concrete in a Materials Property Database"
ACI 126.2R-99	126	"Guide to a Recommended Format for Concrete in a Materials Property Database"
ASTM D 6308	D 30	"Standard Guide for Identification of Composite Materials in Computerized Material Property Databases"
ASTM E 1308	E 49	"Standard Guide for Identification of Polymers (Excludes Thermoset Elastomers) in Computerized Material Property Databases"
ASTM E 1313	E 49	"Standard Guide for Recommended Formats for Data Records Used in Computerization of Mechanical Test Data for Metals"
ASTM E 1314	E 49	"Standard Practice for Structuring Terminological Records Relating to Computerized Test Reporting and Materials Designation Formats"
ASTM E 1338	E 49	"Standard Guide for the Identification of Metals and Alloys in Computerized Material Property Databases"
ASTM E 1339	E 49	"Standard Guide for Identification of Aluminum Alloys and Parts in Computerized Material Property Databases"
ASTM E 1407	E 49	"Standard Guide for Materials Database Management"
ASTM E 1443	E 49	"Standard Terminology Relating to Building and Accessing Material and Chemical Database"
ASTM E 1454	E 7	"Standard Guide for Data Fields for Computerized Transfer of Digital Ultrasonic Testing Data"
ASTM E 1471	E 49	"Standard Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases"
ASTM E 1475	E 7	"Standard Guide for Data Fields for Computerized Transfer of Digital Radiological Test Data"
ASTM E 1484	E 49	"Standard Guide for Formatting and Use of Material and Chemical Property Data and Database Quality Indicators"
ASTM E 1485	E 49	"Standard Guide for Development of Material and Chemical Property Database Description"
ASTM E 1723	E 49	"Standard Guide for Recommended Formats for Data Records Used in Computerization of Test Data for Plastics"
ASTM E 1761	E 49	"Standard Guide for Recommended Formats for Data Records Used in Computerization of Fatigue and Fracture Data of Metals"
ASTM G 107	G 1	"Standard Guide for Formats for Collection and Compilation of Corrosion Data for Metals for Computerized Database Input"
ASTM G 118	G 2	"Standard Guide for Recommended Data Format of Wear Test Data Suitable for Databases"
ASTM G 135	G 1	"Standard Guide for Computerized Exchange of Corrosion Data for Metals"
AWS A9.1	—	"Standard Guide for Describing Arc Welds in Computerized Material Property and Nondestructive Examination Databases"
AWS A9.2	—	"Standard Guide for Recording Arc Weld Material Property and Nondestructive Examination Data in Computerized Databases"
NACE RP0690-98	—	"Standard Format for Collection and Compilation of Data for Computerized Material Corrosion Resistance Database Input"

Table 1 (continued)

Designations
American Concrete Institute (ACI)
American Society for Testing and Materials (ASTM)
American Welding Society, Inc. (AWS)
National Association of Corrosion Engineers (NACE)
ACI Committee 126 on database formats for concrete materials properties
ASTM Committee D 30 on composite materials
ASTM Committee E 7 on nondestructive testing
ASTM Committee E 49 on computerization of material and chemical property data
ASTM Committee G 1 on corrosion of metals
ASTM Committee G 2 on wear and erosion

Table 2 — Categories of information in a concrete materials property database

Category	Description
Hydraulic cement	Hydraulic cement such as portland, portland blast-furnace slag, portland-pozzolan, expansive hydraulic, and natural cement used as a binding medium in concrete
Aggregate	Fine and coarse lightweight, normalweight, and heavyweight aggregate particles included in a concrete mixture
Chemical admixtures	Water-reducer, high-range water-reducing admixture, and air-entraining admixtures used in concrete to improve its properties
Mineral admixtures	Pozzolanic materials such as fly ash, raw or calcined natural pozzolans, and silica fume used in concrete for its cementitious characteristics
Fibers	Metallic and nonmetallic fibers added to a concrete mixture to produce a desired property or characteristic
Water	Water used as a concrete constituent
Processing	Batching, mixing, transporting, placing, consolidating, finishing, and curing information about concrete including mixture proportions
Properties and performance	Mechanical, thermal, physical, and other properties determined from fresh and hardened concrete
Identification	Information including descriptive terms, mixture proportions, processing parameters, and reference properties used to establish a unique concrete identifier that distinguishes one concrete from another

identifiers in a report that contains information for a limited number of concretes, but they are not well suited as identifiers in a concrete materials property database where properties for many concretes with similar compositions and characteristics are stored.

Certain data elements in the guide are used to establish unique concrete identification. Establishing a unique identifier for such a complex material requires information about the types of natural and manufactured constituents used to make the concrete, mixture proportions, methods and procedures used to process the concrete, and properties of the fresh and hardened concrete. Data elements used as identifiers are organized and subdivided into the following categories:

- Designation;
- Supplier;
- Constituents;
- Mixture proportions;
- Processing; and
- Concrete properties.

Most data elements for concrete identification serve a dual role as concrete identifiers and data elements for other information categories.

While there is no generally accepted numbering system for concrete identification analogous to the Unified Numbering System (UNS) for metals and alloys,[5] such a system could be developed in the future to standardize the way concretes are distinguished.

A separate "Guide to a Recommended Format for the Identification of Concrete in a Materials Property Database"[6] was prepared by ACI Committee 126. It contains all of the data elements considered essential for unique concrete identification. Data elements in this guide are also represented in the "Guide to a Recommended Format for Concrete in a Materials Property Database."[2]

Constituents

Information about each constituent used in a concrete

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Constituents

Information about each constituent used in a concrete mixture needs to be included in the data file because these materials have a significant influence on the properties and performance of the fresh and hardened concrete. To ensure equivalency among data files, it is important for each constituent to be fully identified using more than a single piece of information or a common name. Complete identification of every constituent also helps distinguish one concrete from another. For completeness, all available properties for each constituent should be reported.

Recommended formats for reporting essential and desirable information about hydraulic cements, aggregates, chemical admixtures, mineral admixtures, fibers, and water are included in the guide. Data elements for these constituents are organized into the following data segments.

- Designation;
- Processing;
- Composition and characteristics;
- Manufacturer recommendations; and
- Performance in concrete.

Processing

Information that is project-specific and related to production is essential to determine the type of concrete used for a given application. The production-data-related information is mixture proportioning, batching, mixing, transporting, placing, consolidating, finishing, and curing of the concrete placement and batch. Mixture proportions are probably the most important part of each data file in a concrete materials property database. These pieces of information reveal details about the composition of the concrete and provide valuable data for distinguishing one concrete from another. Reporting the mixture proportions consistently throughout the database is very important because it minimizes the possibility for confusion and misunderstanding. Meaningful comparisons of properties among concretes with similar compositions is only possible when mixture proportions are completely and accurately reported. For these reasons, recommended formats are included in the guide for reporting mixture proportions based on mass per unit volume. Numerous data elements are also included for reporting essential and desirable information about other important processing activities including batching, mixing, transporting, placing, consolidating, finishing, and curing of concrete. The details on the project information are also included here because it is essential to correlate the type of concrete used with the application.

Information for concrete processing is organized into the following data segments:

- Project information;
- Concrete specification;
- Concrete supplier;
- Concrete mixture proportions;
- Concrete batching;
- Concrete mixing;
- Concrete transportation;
- Concrete placement;
- Concrete consolidation;
- Concrete finishing;
- Concrete curing; and
- Concrete processing environment.

Properties and performance

Tests performed on fresh and hardened concrete samples are generally conducted to determine their mechanical, thermal, and physical properties. Many of these test methods are standardized, but occasionally special test methods are used to obtain data that fulfill a particular need. Because concrete properties change with time due to cement hydration and environmental factors, such as the curing conditions and exposure to temperature extremes, the age of the concrete at the time of testing and the manner in which the test specimens are cured and conditioned can be important. To ensure that all available information for a particular concrete can be reported, data elements are included in the guide to accommodate data for both fresh and hardened concrete obtained using either standard or nonstandard test methods.

Properties and performance data are organized into two data segments. The concrete property data segment contains essential and desirable data elements for reporting any property of the concrete. Results of tests performed to quantify the effects a constituent has on the properties and performance of concrete made using the constituent are reported in the concrete property data segment.

Significance of the Guide

The nonexistence of computerized tools specifically developed for materials data handling is placing severe restrictions on the ability of database developers to make large amounts of concrete information available to many users.[7,8] Building a database management system from scratch is typically time consuming and labor intensive. Consequently, this option may only be feasible for large organizations with very special needs. Off-the-shelf software intended for spreadsheet or database applications requires the database developer to use built-in program features for storing and presenting the data. These features are typically not convenient, logical, or effective. Design and analysis software and expert systems that take full advantage of the information in a comprehensive concrete materials property database are also not yet available.[9]

Steady improvements in computer hardware, and the development of more efficient software, are rapidly closing this technological gap. In the foreseeable future, it may be possible for engineers to solve a wide range of complex problems using integrated computerized systems that also incorporate information about materials including concrete. These systems may even be capable of transferring the required information about concrete from established materials property databases. The guide developed by ACI Committee 126 should help make this concept a reality and provide the concrete industry with valuable new information technology.

Future committee activities

Based on input from ACI Committee 126 members who are involved in database development, the committee has identified a number of future activities for possible committee involvement. These activities include:

- Developing a guide for use by authors in preparing concrete materials property data for entry into publications;
- Establishing a list of database-related terms and definitions that can be submitted to ACI Committee 116, Cement and Concrete Terminology, for consideration;
- Initiating committee involvement in the preparation of recommended formats for quality indicators for concrete materials property data and databases;[10,11] and
- Identifying additional materials, such as metallic and nonmetallic reinforcing materials, for which recommended formats may also be needed.

Due to the merger of ACI Committee 126 with the Committee 235, the proposed activities will be considered by members of ACI 235.

Selected for reader interest by the editors.

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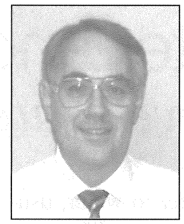

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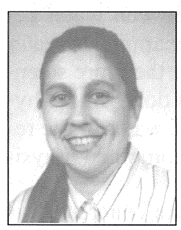

ACI member **Chiara F. Ferraris** is secretary of ACI Committee 235, Knowledge-Based Systems and Mathematical Modeling for Materials, and chairman of ACI Committee 236A, Workability of Fresh Concrete. Since 1994, she has been a physicist at the National Institute of Standards and Technology, Gaithersburg, Md. Her work focuses on rheology, sulfate attack, and alkali-silica reactivity. She obtained a PhD from the EPFL (Switzerland). Before joining NIST, she spent 6 years with W.R. Grace.