BENEFITS OF CONVERSATIONAL PROGRAMMING

The major benefit to be derived from conversational programming is the tremendous computational power it provides to anyone with access to a computer terminal. The examples presented in this paper illustrate how a broad range of acceptance procedures can be tested by following a few simple instructions. Ordinarily, analyses of this type would require a working knowledge of quality-control theory, statistical analysis, computer programming, and simulation techniques. When developed as conversational programs, these analyses can be delegated to individuals with very little specialized training.

Like these examples, many of today's engineering problems require expertise in a variety of disciplines. Frequently, when individuals capable of applying the multidisciplinary approach are not readily available, these problems are referred to outside consultants. Depending on the nature of the analyses required, it may often be possible to develop general conversational programs that would permit the in-house solution of similar problems in the future. In many cases, a well-planned conversational program might obviate the need for the repeated use of outside consulting services.

Other obvious benefits are speed and accuracy. Once the program has been tested and validated, it can be depended on to produce reliable results. Because of the tremendous speed of the computer, many runs can be made in a short period of time in order to thoroughly analyze the problem at hand. In most cases, this capability would translate directly into economic savings.

Finally, conversational programming can result in the more efficient use of engineering specialists. If it appears that there will be repeated requests for a particular type of analysis, it will often be advantageous to develop a general solution and put it in the form of a conversational program. Future applications will then require minimal involvement on the part of the specialist.

CONCLUSION

Although engineers can benefit greatly from the use of computers, many do not have sufficient programming ability to take full advantage of this approach. Conversational programming provides a means to make the benefits of computer technology available to a much broader segment of the engineering profession. The examples illustrate how complex analyses can be performed by anyone capable of following simple instructions. The use of programs of this type can enable engineers to do better work, do it with less effort, and save both time and money. The reader interested in further examples of conversational programming along with the appropriate FORTRAN IV coding is referred to a publication on computer simulation by the Federal Highway Administration (3).

REFERENCES

1. Standard Specification for Precast Concrete Barrier, Annual ASTM Standards, Part 16. American Society for Testing and Materials, Philadelphia, C825-76, 1976.
2. Building Code Requirements for Reinforced Concrete. American Concrete Institute, Detroit, ACI 318-71, 1971.
3. R. M. Weed. An Introduction to Computer Simulation. Federal Highway Administration, 1976.

Quality Assurance Through Computers

S. C. Shah

A sound quality assurance program is one that must be capable of providing information to users and not just data. It is information prepared from analysis of data that is important. Such information should be provided rapidly, economically, and efficiently. Such information flow can only be accomplished through the use of computers. However, a necessary prerequisite to this flow or feedback of information is its availability at a centralized location, namely, computer files. This residence requirement further mandates a fast data-entry system on on-going operations. Louisiana's Material Test (MATT) data-reporting system comes close to satisfying the requirements of a user-oriented quality assurance feedback system. The system is an on-line computer-based system through which data generated on construction projects can be entered, corrected, updated, deleted, and retrieved through the department's terminal network system. The system, which has been in operation since the early part of 1978, is capable of providing information not only to those responsible for monitoring the construction projects but also to those involved in the planning, design, evaluation, research, and maintenance of pavement systems. Specific examples of the application of the computerized system related to quality assurance are presented in the paper. An overview of the system, with respect to design, development, hardware, and software, is also discussed. The paper emphasizes the need for a computerized quality assurance system as a subsystem of the overall pavement management system.

In recent years the task of recovering information from construction and material testing has increased enormously. This has largely been due to the accelerated quality assurance program within the Louisiana State Department of Transportation and Development (LDOT) and an increased awareness of the constant improvement in the acceptance sampling plans and specifications. Literally thousands of pieces of inspection and test-related data are generated from various sources in a year. The sheer volume of data has created two separate but related problems:

1. The continuing increase in effort required by various personnel in collecting, recording, and processing the data on a variety of test documents, and
2. The difficult and, at times, frustrating task of retrieving these data manually for use in on-going operations, research, problem solving, and planning for the future.

To resolve these problems, LDOT initiated a project that would provide an integrated computer-based system by which the various districts of LDOT can transmit the construction and material test data through the terminals for storage, analysis, and retrieval. The overall thrust was to provide easy access to the construction and material test data for final certification of construction projects and also for evaluation of construction and materials quality assurance and acceptance procedures.

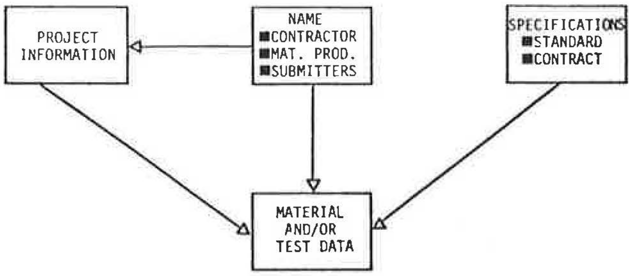
Specifically, the objectives to develop such a system can be defined in terms of the following benefits the system would provide:

1. Standardization of reporting procedures coupled with savings in time spent manually in typing, auditing, or spot-checking various test reports;
2. Availability of a continuous log of major construction material tests at a centralized location (i.e., computer files);
3. Elimination of the final manual audit of sampling and testing compliance and an accelerated certification of construction items;
4. An organized and easily accessible data file for comparative and statistical analyses with respect to processes, sampling and testing frequency, producer profiles, and specification revisions and updates; and
5. Service as an important subsystem of an overall pavement management system.

DESIGN AND DEVELOPMENT OF COMPUTERIZED SYSTEM

The system was designed and developed by using a task-group approach. Three task groups—one each for concrete, asphaltic concrete, and soil and aggregate base course—were formed; each group was represented by a project engineer, a district laboratory engineer, and staff from the central laboratory, research and development, and data-processing sections. The primary function of each group was to define user requirements with respect to input forms, map formats, and output report formats. Such a task-group approach combines user needs and knowledge with system and data-processing expertise to provide an efficient user-oriented system.

Figure 1. Composition of the MATT system.



The primary design philosophy of the project was to make the system user-oriented. Thus, the system design was geared toward maximizing the following criteria: (a) quick access to construction information via remote computer terminals that provide formatted input-output capability, (b) low core use, (c) efficient use of computer system resources, and (d) attractiveness to nonprogramming staff. To satisfy these criteria, the following principles served as a base: (a) data-entry system as opposed to a full on-line system; (b) exception reporting to minimize printing of unneeded data; (c) overnight off-line evaluation of test results as opposed to immediate on-line evaluation; and (d) elimination of many current manual, duplicated, and nonstandard reporting procedures.

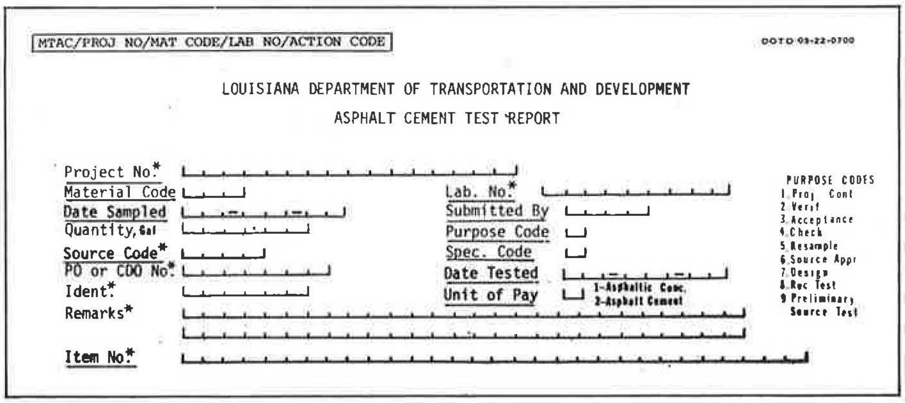
OVERVIEW OF SYSTEM'S OPERATION

Louisiana's computerized Material Test (MATT) system is composed of a number of small subsystems. Figure 1 shows the composition of the system. The three subsystems—project, specification, and name—provide support to the total system and are basic to the material subsystem. In other words, no data can be entered on any of the materials included in the material subsystem unless the project information, the specifications governing the material to be used on that project, and the names of the project engineer, contractor, and material producers are already on file in the computer.

Each of the subsystems defined in Figure 1 is represented on the computer video terminal as a map. Thus, there is a project information map, a name map, an asphalt cement test map, and so on. Furthermore, each map is a replica of the input data form. In other words, a particular map on the display screen looks similar to the input data form. This similarity provides for easy and rapid entry of test data.

The input forms for recording data are combination work-report forms. The header information on most of the forms is basically the same. In a majority of cases, these forms accompany samples sent to the laboratory for testing. The field inspectors record data pertinent to the project and sample identification in the top portion of the form (header information), and the laboratory records the test data generated by them in the respective test-item fields. This has eliminated transfer of data from one form to the other. Figure 2 is an example of the type of header information that appears on the forms. Items of information considered mandatory for data entry are underlined. This manda-

Figure 2. Type of header information on input forms.



MTAC/PROJ NO/MAT CODE/LAB NO/ACTION CODE

DOTD 03-22-0700

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

ASPHALT CEMENT TEST REPORT

Project No.*
Material Code
Date Sampled
Quantity, Gal
Source Code*
PO or CDO No.*
Ident.*
Remarks*
Item No.*

Lab. No.*
Submitted By
Purpose Code
Spec. Code
Date Tested
Unit of Pay 1-Asphaltic Conc. 2-Asphalt Cement

PURPOSE CODES
1 Proj Cont
2 Verif
3 Acceptance
4 Check
5 Resample
6 Source Appr
7 Design
8 Rec Test
9 Preliminary Source Test

tory requirement has standardized the reporting procedures throughout the state.

The MATT system is capable of on-line entry, inquiry, correction, update, and deletion of data systems. The operation of the system is briefly described here.

On-Line Operation

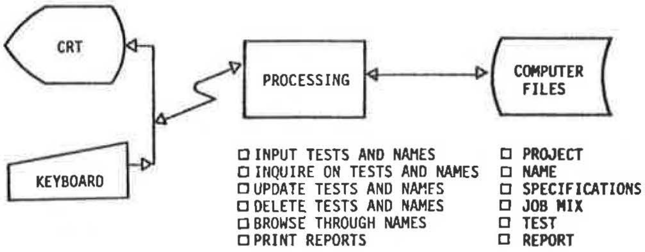
The input forms are filled out with the appropriate information by field and laboratory personnel and sent to the terminal operator for data entry. The operator enters the four-character transaction code and certain other key items of information appropriate to that subsystem. This information appears in the upper left corner of each input form (Figure 2). This transaction-line entry triggers the computer system to project the correct map format for that subsystem onto the terminal display. The information from the input form is then entered onto the screen and transmitted to the computer where it is edited for errors. If any errors are found, they are flagged and these data are returned to the terminal for correction; the error field becomes doubly highlighted as a result of this action. Once the data are error free, the program does the necessary data manipulations, after which a record is written to the test-result file for overnight processing in an off-line mode. Figure 3 depicts the daytime operations of the MATT system. Figure 4 lists the transaction lines for each MATT subsystem.

Off-Line Operation

Virtually all of the MATT system off-line processing is done after normal working hours. The test results entered during the day are processed that night by the test processor against the appropriate specification record and are flagged according to whether they pass or fail. The test processor creates logging and exception (LOGEX) report files. The data stored in the test file can be accessed for any of the operations shown in Figure 3 except report printing. The next day, logging and exception reports are provided after the LOGEX files are sorted and processed by the report program.

Another off-line operation is the purging of old processed test data from the disk and writing them on tape, where they will be kept for historical and data analysis. This purging is done as projects are completed and certified.

Figure 3. On-line operation of the MATT system.



MATT SYSTEM FILES

The MATT system uses these files: name, specification, project, mix design, test, logging and exception report, and tape files of all of the preceding except logging and exception report. A brief discussion of each of these files follows.

Name

As was pointed out in Figure 1, the name file is a prerequisite to the overall operation of the MATT system. The file is an on-line file and contains the code numbers and the corresponding names and addresses of material producers and suppliers, sample submitters (project engineers, prestress plant inspectors, and so forth), and contractors.

Specification

The specification file is also a prerequisite to any material test data entry. For security reasons the file is not an on-line file and, therefore, all new entries, updates, deletions, and so forth have to be done in an off-line mode through card input. The file contains both standard and contract (special provisions) specifications.

Project

The project file is another prerequisite to the MATT

Figure 4. List of transaction lines for on-line data management.

SUBSYSTEM NAME	MATT ID	TRANSACTION LINE
NAME	....	MTNM/SOURCE TYPE CODE/ACTION CODE (N,I,U,D,L)/SEQUENCE NO
PROJECT INFORMATION	....	MTPI/PROJ NO/ACTION CODE (N,I,U)
ROADWAY XSECTION	....	MTRC/PROJ NO/ACTION CODE (U,I)
AGGREGATE	B	MTAG/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
ASPHALT CEMENT	C	MTAC/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
LIQUID ASPHALT	D	MTLA/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
CEMENT	E	MTCT/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
STEEL BAR	F	MTSB/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
STEEL WIRE	G	MTSW/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
CONCRETE JOBMIX	A,I	MTCJ/PROJ NO/MATERIAL ID/MATERIAL CODE/ACTION CODE (N,I,U,D)
STRUCTURAL CONCRETE	A	MTSC/PROJ NO/MATERIAL CODE/LOT NO/ACTION (N,I,U,D)
PAVING CONCRETE	I	MTPC/PROJ NO/MATERIAL CODE/LOT NO/ACTION (N,I,U,D)
ASPHALT CONCRETE JOBMIX	H	MTHJ/PROJ NO/SEQUENCE NO/ACTION CODE (N,I,U,D)
ASPHALT CONCRETE INSPECTION	H	MTHM/PROJ NO/LOT NO/MIX USE/MIX TYPE/PURPOSE CODE/ACTION CODE (N,I,U,D)
SOIL ANALYSIS	L	MTSA/PROJ NO/LAB NO/ACTION CODE (N,I,U,D)
DENSITY/MOISTURE	J	MTDM/PROJ NO/MATERIAL CODE/ZONE & TEST NO/ACTION NO (N,I,U,D)
THICKNESS/WIDTH	K	MTTW/PROJ NO/MATERIAL CODE/ACTION CODE (N,I,U,D)
MISCELLANEOUS DATA ENTRY	M	MTMS/PROJ NO/MATERIAL CODE/LAB NO/ACTION CODE (N,I,U,D)
MISCELLANEOUS MAINTENANCE	....	MTMM/ACTION CODE (N,I,U,D)
REPORT REQUEST	....	MTRR/DISTRICT NO/PROJ NO/REPORT TYPE CODE/OPTION CODE/ACTION CODE (N,I,D)
REPORT RETRIEVAL	....	MTLE/DISTRICT NO/1=LOG, 2=EXCEPTION, 3=2059
NOTE......................	....	SOURCE TYPE CODES ARE: B=CONTRACTORS,C=MATERIAL PRODUCERS,D=SUBMITTERS REPORT TYPE CODES ARE: 1=COMPLETE LOGGING,2=2059,3=STAX SUMMARY OPTION CODES ARE: 1=ON-LINE,2=OFF-LINE(MAILED) ACTION CODES ARE: N=NEW, I=INQUIRY, U=UPDATE, D=DELETE & L=BROWSE

system. It contains data pertinent to the project and related cross section of the roadway. It includes information such as project location, route number, length, cost, type of surface, and base, shoulder, and related dimensions.

Mix Design

The mix design file contains information related to the mix design of both asphaltic concrete and portland cement concrete. The file is a prerequisite to entering data on the acceptance criteria of these two materials.

Test

Test results of all materials and tests appear in this file. The file contains processed test data, including pass-fail flags, of the following materials or tests: aggregates; asphalt cements; liquid asphalts; cements; steel bars; steel wires; structural concrete slump, air, and strength data; paving concrete strength and thickness data; asphaltic concrete stability, compaction, gradation, and smoothness data; soil analysis test data; density and moisture test data of embankment and base course; thickness and width measurements of base course; and miscellaneous materials (total, 104). Of all the materials subsystems, the miscellaneous subsystem is the most comprehensive and flexible one. The user has complete flexibility in adding new materials to this file and creating his or her own map for those materials.

Logging and Exception

The logging and exception file is a temporary file of one-day duration. It contains data in report format that are entered the previous day and retrieved daily by the districts.

Tape Files

As specifications change or projects are completed, records are copied to tapes and a "date deleted" field added to the record. These tapes will be made available for historical review, analysis, and examination of test data.

USES OF THE MATT SYSTEM—OUTPUT REPORTS

To function effectively, a quality assurance program must be able to provide the needed information feedback not only to those involved in testing and inspection but also to those in the planning, design, evaluation, and maintenance phases of the pavement system. A necessary prerequisite to such information flow is the availability of a computer-based data system such as the one discussed in the preceding sections of this paper. Software programs can be written to generate user-required reports such as the ones provided by the MATT system and discussed here.

Daily Construction Monitoring Reports

Each day two types of reports are routinely provided to the project engineer responsible for day-to-day monitoring of the construction project. These reports are the logging reports and the exception reports. The logging reports are the summary-type reports that consist of information relative to the sample or test such as project number, sample identification, purpose, material type, quantity, item number, and pass-or-fail comment. In some cases, critical numerical values of the measured characteristic are also listed on the printout. Such reports provide a quick means of review for the engineer of the inspection, material, and test control level associated with the multiproject activities.

The distribution of these reports is based on the sample submitter, the terminal through which data are entered, and the laboratory performing the test (laboratory number). With these three criteria, it is possible to retrieve reports on a given test at three places. Thus, if a sample is submitted by the engineer in district A, tested by district B, and entered by district C, the report on this sample will be transmitted to all three districts. This has greatly minimized delays associated with mailing of reports by the central laboratory to the nine districts and other submitters for which it does voluminous testing.

Figure 5 is an example of logging reports on three material types. Samples indicated as failing on the logging reports are supplemented with exception reports of the type indicated in Figure 6. This particular sample is listed as a failing sample under miscellaneous material tests in Figure 5. Such exception reports provide guidelines to making equitable decisions between acceptance or rejection of the sample on the basis of how critical the point of failure is. (The MATT system uses customary units only. Therefore, values in Figures 5-9 are not given in SI units.)

Certification Reports

During the life of a construction project, constant monitoring is required to ensure that sampling and testing frequencies and specification conformance are satisfied, according to stated requirements, on the multitude of materials incorporated into the project. At the end of the project, this quality assurance check is duplicated to prepare a final document identified as Form 2059. This final effort is geared toward compilation of all documents generated on that project, with emphasis on cross-referencing of passing and failing samples and an explanation of the disposition of such failing materials, tests, locations, and so forth. Prior to the implementation of the MATT system, Form 2059 was prepared manually. The complexities and difficulties encountered in this manual effort were directly associated to the length or size of the project. The larger the project in terms of materials and tests, the more complex and time-consuming this final audit.

The MATT system provides this final document at the user's request in a matter of hours. The basic format of this 2059 report is similar to that of the daily logging reports except that it is item-number oriented. In other words, all materials are reported under the item number for which they were sampled and tested. Furthermore, all coded fields appear decoded in the report.

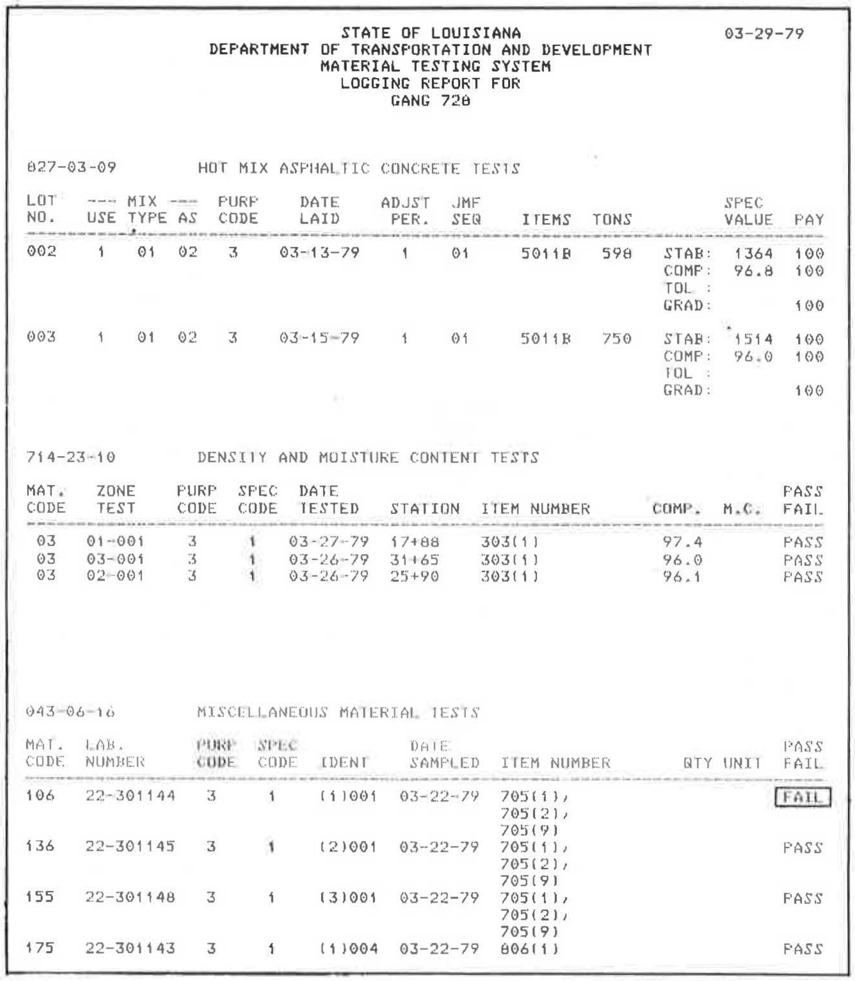
The 2059 report has three parts. Part 1 consists of a listing of all materials or tests under their respective item numbers. Part 2 lists the disposition of the failing samples as appearing in the remarks field of each failing test report. Part 3 lists all the job mix releases issued on the project. This report is reviewed by headquarters personnel prior to final acceptance of the project.

Analysis and Evaluation Reports

These reports are the summary-type reports that provide information relative to the following:

1. Distribution of reduction in pay for asphaltic

Figure 5. Computerized logging report on various materials.



```
                        STATE OF LOUISIANA                          03-29-79
              DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
                       MATERIAL TESTING SYSTEM
                         LOGGING REPORT FOR
                              GANG 728


827-03-09          HOT MIX ASPHALTIC CONCRETE TESTS

LOT   --- MIX ---  PURP     DATE     ADJST  JMF                            SPEC
NO.   USE TYPE AS  CODE     LAID      PER.  SEQ    ITEMS   TONS            VALUE  PAY
-------------------------------------------------------------------------------------
002    1   01  02   3     03-13-79     1     01    5011B   598    STAB:   1364   100
                                                                  COMP:   96.8   100
                                                                  TOL  :
                                                                  GRAD:          100

003    1   01  02   3     03-15-79     1     01    5011B   750    STAB:   1514   100
                                                                  COMP:   96.0   100
                                                                  TOL  :
                                                                  GRAD:          100


714-23-10          DENSITY AND MOISTURE CONTENT TESTS

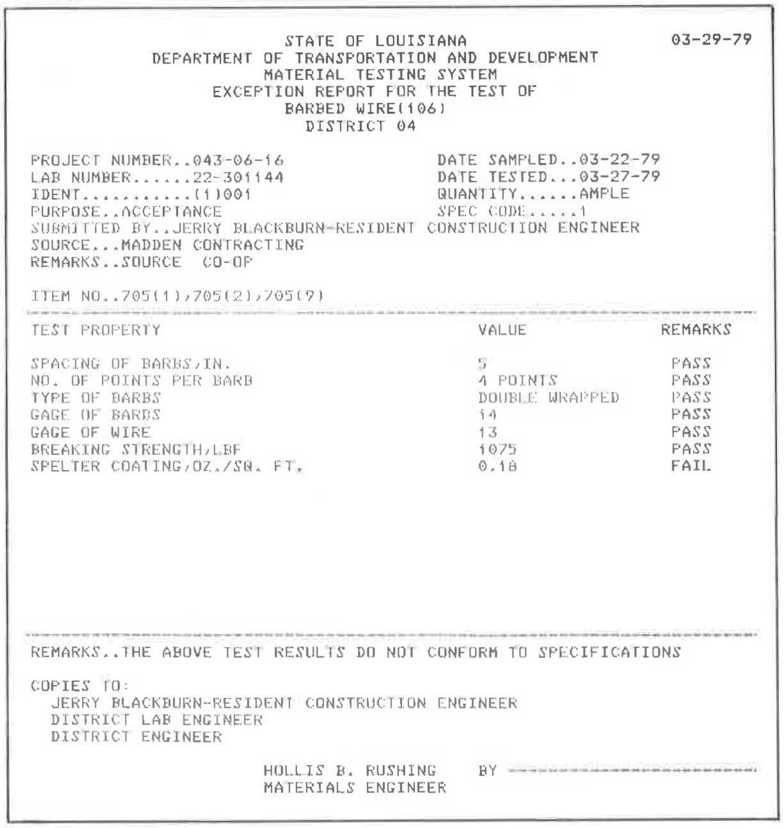
MAT.  ZONE      PURP  SPEC  DATE                                                PASS
CODE  TEST      CODE  CODE  TESTED     STATION  ITEM NUMBER         COMP.  M.C.  FAIL
-------------------------------------------------------------------------------------
 03   01-001     3     1   03-27-79   17+88    303(1)              97.4         PASS
 03   03-001     3     1   03-26-79   31+65    303(1)              96.0         PASS
 03   02-001     3     1   03-26-79   25+90    303(1)              96.1         PASS




043-06-16          MISCELLANEOUS MATERIAL TESTS

MAT.  LAB.         PURP  SPEC           DATE                                     PASS
CODE  NUMBER       CODE  CODE  IDENT    SAMPLED   ITEM NUMBER         QTY UNIT   FAIL
-------------------------------------------------------------------------------------
106   22-301144     3     1   (1)001   03-22-79  705(1),                         FAIL
                                                 705(2),
                                                 705(9)
136   22-301145     3     1   (2)001   03-22-79  705(1),                         PASS
                                                 705(2),
                                                 705(9)
155   22-301148     3     1   (3)001   03-22-79  705(1),                         PASS
                                                 705(2),
                                                 705(9)
175   22-301143     3     1   (1)004   03-22-79  806(1)                          PASS
```

Figure 6. Computerized exception report on failing material.



```
                     STATE OF LOUISIANA                          03-29-79
           DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
                    MATERIAL TESTING SYSTEM
                 EXCEPTION REPORT FOR THE TEST OF
                       BARBED WIRE(106)
                         DISTRICT 04

PROJECT NUMBER..043-06-16                 DATE SAMPLED..03-22-79
LAB NUMBER......22-301144                 DATE TESTED...03-27-79
IDENT...........(1)001                    QUANTITY......AMPLE
PURPOSE..ACCEPTANCE                       SPEC CODE.....1
SUBMITTED BY..JERRY BLACKBURN-RESIDENT CONSTRUCTION ENGINEER
SOURCE...MADDEN CONTRACTING
REMARKS..SOURCE  CO-OP

ITEM NO..705(1),705(2),705(9)
--------------------------------------------------------------------
TEST PROPERTY                                VALUE             REMARKS

SPACING OF BARBS,IN.                         5                  PASS
NO. OF POINTS PER BARB                       4 POINTS           PASS
TYPE OF BARBS                                DOUBLE WRAPPED     PASS
GAGE OF BARBS                                14                 PASS
GAGE OF WIRE                                 13                 PASS
BREAKING STRENGTH,LBF                        1075               PASS
SPELTER COATING,OZ./SQ. FT.                  0.18               FAIL




--------------------------------------------------------------------
REMARKS..THE ABOVE TEST RESULTS DO NOT CONFORM TO SPECIFICATIONS

COPIES TO:
  JERRY BLACKBURN-RESIDENT CONSTRUCTION ENGINEER
  DISTRICT LAB ENGINEER
  DISTRICT ENGINEER

                      HOLLIS B. RUSHING    BY -----------------------
                      MATERIALS ENGINEER
```

concrete and portland cement concrete construction according to specific categories (e.g., project, use, and type);

2. Variability with respect to material type, material producers, project engineer, sampling and testing procedures, and time periods (as a result of a change in the system); and

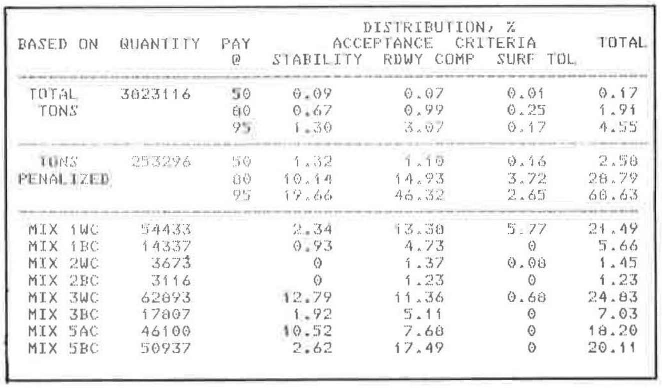
3. Failure ratio in relation to sampling and testing frequency.

Specific examples of some of the above types of reports are shown in Figures 7-9. Figure 7 shows the distribution (percentage) of the quantity of asphaltic concrete that was deficient in each acceptance criterion at each pay scale. The table also provides further breakdown of this distribution for each criterion according to mix types. Figure 8 is a summary of data showing final adjusted payment for asphaltic concrete. The table shows, for each project, the total number of tons, the total number of lots (N-LOT), the number of lots that had reduced payments (N-LOT-P), and the tons involved in the reduced payment of 50, 80, and 95 percent pay (TONS-50, TONS-80, TONS-95) as defined in LDOT's specifications. The last column (PPPP) represents the final percent pay for each project. The variability information on asphaltic concrete is provided in the format shown in Figure 9. Such periodic information indicates the trend in material or process control.

Other Uses

The MATT files provide easy access to data for simulation of specifications if any changes in these specifications are contemplated. The project information files provide instant information on projects that have to be isolated for performance evaluation relative to such factors as materials, design procedures, and construction procedures. The only constraint to the use of the system as a feedback system is that data be available in the computer files.

Figure 7. Summary of pay reduction on projects with deficiencies in asphaltic concrete acceptance criteria.



BASED ON	QUANTITY	PAY @	DISTRIBUTION, % ACCEPTANCE CRITERIA STABILITY	RDWY COMP	SURF TOL	TOTAL
TOTAL TONS	3023116	50	0.09	0.07	0.01	0.17
		80	0.67	0.99	0.25	1.91
		95	1.30	3.07	0.17	4.55
TONS PENALIZED	253296	50	1.32	1.10	0.16	2.58
		80	10.14	14.93	3.72	28.79
		95	19.66	46.32	2.65	68.63
MIX 1WC	54433		2.34	13.38	5.77	21.49
MIX 1BC	14337		0.93	4.73	0	5.66
MIX 2WC	3673		0	1.37	0.08	1.45
MIX 2BC	3116		0	1.23	0	1.23
MIX 3WC	62893		12.79	11.36	0.68	24.83
MIX 3BC	17807		1.92	5.11	0	7.03
MIX 5AC	46100		10.52	7.68	0	18.20
MIX 5BC	50937		2.62	17.49	0	20.11

HARDWARE-SOFTWARE USED

The MATT system operates with the following hardware and software configurations.

The hardware configuration includes the IBM 370 (Model 3031) computer printout unit; a 6-Mb core; six 3350, four 3330 (Mod 1), and eight 3330 (Mod 2) direct-access storage units; five 3420 nine-track magnetic tapes and one 3420 seven-track magnetic tape; two 1403 Xerox printers; a 2540 card-read punch with punch-feed read; a 3705A communication controller; and 3277 (cluster) communication terminals with 3284 printers.

The MATT system also uses these control softwares: OS/VS2, Release 3.8A; CICS/VS, Release 1.4; and VSAM, Release 2. In addition to these system control softwares, other software packages, such as SAS and Easytrieve, are also used for special-purpose analyses and reports.

MATT System Programs

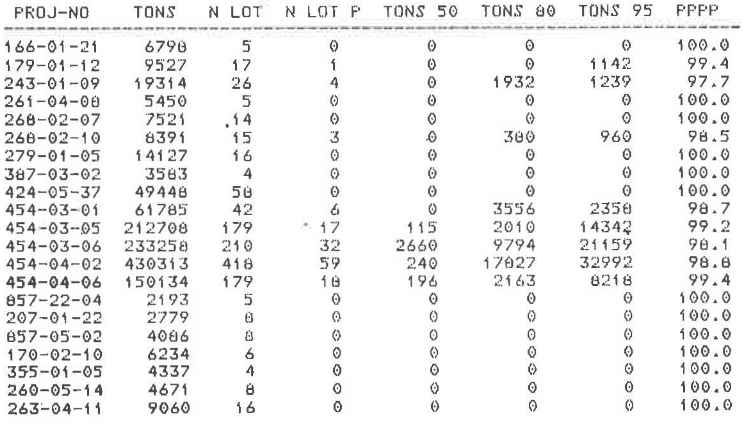
The system operates under 29 on-line programs and 9 off-line programs. All on-line programs are CICS/VS macro and/or command level COBOL and ASSEMBLER language. The largest program requires approximately 192 000 positions of memory to execute.

SUMMARY

The MATT system discussed in this paper has provided LDOT with an efficient user-oriented material test data entry-and-retrieval system through user knowledge and computer hardware-software expertise. The tedious and time-consuming process of manually typing and processing the multitude of reports generated during project construction has been reduced to a minimum. A continuous log of tests is maintained in an organized and efficient manner at a centralized location for use by managerial, operations, and research personnel. Logging and exception reports are provided daily to the field personnel for project monitoring, while special reports are made available at user request for short- and long-term decision making.

No system can be considered optimum because of the

Figure 8. Distribution of percentage of asphaltic concrete quantity according to pay scale, acceptance criteria, and mix type.



PROJ-NO	TONS	N LOT	N LOT P	TONS 50	TONS 80	TONS 95	PPPP
166-01-21	6798	5	0	0	0	0	100.0
179-01-12	9527	17	1	0	0	1142	99.4
243-01-09	19314	26	4	0	1932	1239	97.7
261-04-08	5450	5	0	0	0	0	100.0
268-02-07	7521	14	0	0	0	0	100.0
268-02-10	8391	15	3	0	380	960	98.5
279-01-05	14127	16	0	0	0	0	100.0
387-03-02	3583	4	0	0	0	0	100.0
424-05-37	49448	58	0	0	0	0	100.0
454-03-01	61785	42	6	0	3556	2358	98.7
454-03-05	212708	179	17	115	2010	14342	99.2
454-03-06	233258	210	32	2660	9794	21159	98.1
454-04-02	430313	418	59	240	17827	32992	98.8
454-04-06	150134	179	18	196	2163	8218	99.4
857-22-04	2193	5	0	0	0	0	100.0
207-01-22	2779	8	0	0	0	0	100.0
857-05-02	4086	8	0	0	0	0	100.0
170-02-10	6234	6	0	0	0	0	100.0
355-01-05	4337	4	0	0	0	0	100.0
260-05-14	4671	8	0	0	0	0	100.0
263-04-11	9060	16	0	0	0	0	100.0

Figure 9. Variability of type 1 asphaltic concrete mixture.

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VARIABLE        N      MEAN     STD      MIN       MAX      C.V.
                                DEV      VAL       VAL
----------------------------------------------------------------
STABILITY     7356   1553.28   289.96   345.00   3364.00   18.67
COMPACTION   10031     96.36     1.64    86.30    103.90    1.70

1    INCH     2783    100.00     0.09    99.00    100.00    0.02
3/4 INCH      3820     99.72     0.89    85.00    100.00    0.89
1/2 INCH      3814     91.90     4.37    71.00    100.00    4.75
NO. 4         3816     55.98     5.11    35.00     77.00    9.14
NO. 10        3816     41.88     4.56    21.00     61.00   10.89
NO. 40        3816     24.58     3.49     9.00     38.00   14.21
NO. 80        3816     11.53     2.39     4.00     23.00   20.72
NO. 200       3815      6.43     1.55     2.00     18.00   24.13
A.C. %        3816      5.06     0.39     3.00      7.10    7.68
```

dynamics of the overall system of materials sampling, testing, and construction quality assurance. However, it is felt that changes can be accommodated as they occur. Louisiana's MATT system is geared toward providing an important input to the pavement management system currently under development through an effort funded by the Highway Planning Research (HPR) Program.

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Computer-Controlled Batch Plants

Edward A. Abdun-Nur

Because of its tremendous capacity for and speed of calculation, the computer is used to produce enormous amounts of data analyses that may not be justified for the test data produced in construction control. The relatively crude test methods used in construction and the lack of knowledge about the real meaning of the tests in many instances are the reasons. Using the computer to produce simpler and fewer calculations to guide the judgment of the engineer appears to be more realistic, less costly, and, at the same time, accomplishes the task intended. On the other hand, using the computer in the control of the batching plants and the process of batching and mixing appears to have a higher payoff in quality control and quality assurance. It permits the reduction of variability and, because of its feed-forward capability, it can control the process and even abort batches out of tolerance or stop the plant when it gets out of adjustment. Continuous batching and mixing plants, as developed in Europe, have the inherent advantages of lower capital cost and lower variability due to the elimination of the stop-and-start cycle at every batch, permit more sophisticated and delicate controls, have lower maintenance costs, and elicit more positive operator reactions. Teamed with a computer that makes these plants possible, such facilities are the best that current knowledge and technology have to offer.

When one talks about computers, visions of reams of paper filled with numbers appear. In construction, these numbers are often a waste of time because no one studies them closely. Detailed analyses of test data in construction are not warranted, inasmuch as the tests themselves are relatively crude, and rarely does one know what the test really measures. Therefore, fancy and sophisticated analyses are not only unwarranted but wasteful. The computer comes in handy, however, in process control and can contribute more to quality assurance than such analyses. Because the variability in construction is higher than in most industrial operations, computerized control of processes to reduce such variability can result in significant economic payoffs and improved quality control.

In the last 20 years or so, batch plants have gone from a crude operation in which the operator pulled levers and watched weighing-scale balance beams or gauges to the pushing of buttons to achieve the same thing and on to automated plants. The automated plants go through a complete batching cycle simply at the push of one button. The sequences are controlled by punch cards, assigned standard batch code numbers, or other means that provide a succession of signals to a computer already programmed to operate the various units of the plant in the proper sequence and to generate the various weights required by the particular mix being produced. Also, a record is produced to show what is happening and, in some cases, to print a delivery ticket.

It is not the purpose of this paper to get into the details of the automated plants in current use, whether for batching concrete, bituminous mixtures, or granular base-course materials. Rather, this paper describes automated computer-controlled plants, both of the single-batch type and continuous type, that have been observed in England and France and that appear to me to have substantial merit for use elsewhere.

BRITISH EXPERIENCE

Simon Plants

Some 15 years ago, while on a trip to London, I had an opportunity to observe a continuous concrete batch plant that was being operated on a discontinuous basis to fill ready-mixed concrete trucks. The facility, located in London's West End and operated by Ready-Mixed Concrete (London) Ltd., was known as the Fulham plant.

This type of plant was developed by the Simon Company, which was in the business of manufacturing cattle-feed batching plants and decided to extend its operations into the concrete field. Basically, each bin of aggregate discharges onto a short feed belt that, in turn, discharges onto a collector conveyor belt running at right angles to the bin feed belts. Each bin feed belt has a floating section that weighs the material passing over it. An electronic device transmits signals to the bin gate to adjust the opening, as the need is determined by the weighing device. The modulation results in a continuous series of adjustments that occur in fractions of seconds, thus essentially producing a continuous monitoring of the weight that passes over the belt scale.

The collecting belt discharges into the back end of a horizontal twin-shaft mixer (very much like a pugmill), which is set at an angle of about 10° with the horizontal. Water was also fed into the back of the mixer, and the