TERMINAL EVALUATION OF LATERITIC SOILS STUDIES FOR U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT AID/otr-C 1626

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1.0
INTRODUCTION

In accordance with the contract of 27 September 1979, PRC Harris, Inc. has conducted a terminal evaluation of three studies of lateritic soils which were previously documented in reports published by the U.S. Agency for International Development as follows:

- 1969 - Engineering Study of Laterite and Lateritic Soils in Connection with Construction of Roads, Highways and Airfields - Southeast Asia
- 1971 - Laterite, Lateritic Soils and Other Problem Soils of Africa
- 1975 - Laterite and Lateritic Soils and Other Problem Soils of the Tropics

The purpose of this terminal evaluation was to assess the impact of the studies and reports cited above on the state-of-the-art of road building and other construction in tropical countries where lateritic soils are found. Attention was given to determining both the technical advances and cost benefits which were realized in developing countries as a direct result of the utilization of information developed in the studies and associated reports.

The methodology utilized in carrying out this terminal evaluation consisted of both direct interviews in the U.S. with persons familiar with lateritic soils, the development and issuance of a questionnaire on the laterite studies to firms and organizations considered knowledgeable on this topic, and the evaluation of the responses to the questionnaire. Information developed from both the interviews and the questionnaire were synthesized and form the basis of this evaluation.

The terminal evaluation has been completed and the results are presented in this report. Conclusions regarding the effectiveness of the lateritic soils studies and recommendations for further work are also presented herein.

Based on the terminal evaluation, it has been determined that the laterite studies resulted in the development of satisfactory criteria and procedures for the identification, classification and testing of lateritic soils and tropical black clays. The use of the recommended design methods, specifications and construction control procedures has permitted the successful utilization of locally available lateritic soils and black clays on an increasing number of highway projects in the tropical areas of the world. Maintenance costs for these projects have been found to be comparable with similar costs for projects constructed with other materials. Construction cost-benefits have been realized on several of these projects.

The overall response to the terminal evaluation demonstrates the effectiveness of the efforts of the U.S. Agency of International Development to improve the construction of basic infrastructure in tropical countries through practical

engineering research studies. In continuation of this work, it is recommended that performance studies be conducted on highways constructed with both lateritic soils and tropical black clays after several years of service. Such studies would supplement the information contained in the laterite reports. Consideration should also be given to the conduct of studies directed toward the use of lateritic materials in the construction of such facilities as housing and dams.

Based on the success of the Laterite Soils Studies, it is recommended that other topics be considered for future practical engineering research studies. These topics include:

- Surface Treatments of Roads
- Soils of Arid Areas
- Expansive Clays

2.0
CONCLUSIONS

2.1 The use of information contained in the laterite reports has resulted in the development of construction alternatives on projects where both laterite and other materials sources were available. On a 137 kilometer long road in Malawi, the direct utilization of laterites in accordance with the recommendations and procedures presented in the reports resulted in a cost savings of $246,000 over a cement stabilization construction alternative.

2.2 Cost-benefit studies conducted on projects where laterite construction alternatives were developed, identified savings on approximately one project in four. Although cost information is limited, it is estimated that savings of over one million dollars have been realized on fourteen projects in Southeast Asia and Africa where information contained in the lateritie reports were utilized.

2.3 The overall reliability of the findings of the laterite reports is rated as good to excellent On specific topics such as the values of the geotechnical properties of local soils, 83% of the survey respondents reported good to excellent correlation with the results of their own investigations.

2.4 Maintenance costs for roads constructed using laterites are considered comparable to the maintenance costs for roads constructed with other materials.

2.5 The reports on the lateritic soils studies has received significant world-wide distribution, principally to tropical countries where lateritic soils are encountered.

2.6 Test methods, design procedures and specifications recommended in the laterite reports are utilized by one-third of the survey respondents; Africa is the principal area of use. Projects on which the use of information contained in the laterite report were identified are as follows:

AFRICA	PROJECT
Cameroon	Bamenda - Mamfe-Ekok Highway
Chad	Djermaya - Djimtilo Road
Ghana	Axim-Elubo Road
	Tena Freestone
	Yamoransa - Bekwai Road
Kenya	Kapsabet Chavakali Road
	Trans-African Highway
	Lilongwe/Mchinji/Zambia Border Road and Lilongwe By-Pass

AFRICA	PROJECT
Malawi	Salima - Benga
Mali	Ansongo - Anderambovkane Road
Nigeria	Abakaliki - Edor Highway
	Beni Sheik - Uba Highway
	Owo - Egbe Highway

SOUTHEAST ASIA	PROJECT
Thailand:	Surabaya Ind. Estate

2.7 The implementation of the recommendations presented in the laterite reports appears to be increasing, particularly in the tropical countries of Africa.

2.8 The laterite reports are principally used in the design, construction and maintenance of pavement systems for highways. There is interest, however, in the use of laterites in such works as home building and dam construction.

2.9 The need for continued practical engineering research studies and the utilization of recommendations for design and construction which result from such work has been demonstrated by the overall positive response to the questionnaire.

2.10 The response to the questionnaire has exceeded the statistical goals for random sample analyses established for this survey. Therefore, the results of the survey are considered to accurately represent the views and opinions of individuals, firms, organizations and national transportation agencies engaged in work with tropical soils.

3.0
RECOMMENDATIONS

3.1 Performance studies on highways constructed with both lateritic soils and tropical black clays should be conducted and reported after several years of service. Information developed in such studies would be a practical and useful supplement to the existing reports.

3.2 Due to the availability of lateritic materials in tropical countries, consideration should be given to the conduct of studies directed toward their utilization in construction of such facilities as housing and dams.

3.3 Based on the success of the Laterite Soils Studies, it is recommended that other topics be considered for future practical engineering research studies. These topics include:

- Surface Treatments of Roads
- Soils of Arid Areas
- Expansive Clays

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TERMINAL EVALUATION

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A.1.0
METHODOLOGY & IMPLEMENTATION

A.1.1 GENERAL

Work was initiated on this project in January 1980. At that time AID and Harris representatives met in Washington, D.C. to discuss the history of the three completed lateritic soils studies. Subsequent to the meeting and after a brief review of AID project files Harris conducted interviews in the U.S. with persons considered knowledgeable in lateritic soils. Thereafter, Harris conducted a survey of individuals, firms, organizations and national transportation agencies by means of a questionnaire. Information gained from both the personal interviews and from the analysis of the responses to the questionnaire utilized in the survey were then synthesized and evaluated.

A.1.2 INTERVIEWS

Based upon discussions with AID and a brief review of available AID project files, a list of representatives of organizations and firms considered knowledgeable in the field of lateritic soils was developed as follows:

NAME	ORGANIZATION
William C. LaBaugh	Daniel, Mann, Johnson & Mendenhall
Raymond Millard	The World Bank
Lloyd Crowther	Transportation Research Board
Alan Beers	InterAmerican Development Bank
Joseph Fiteni	Tippetts-Abbett-McCarthy-Stratton
W.J. Morin	Lyon Associates, Inc.
Peter C. Todor	Lyon Associates, Inc.
Joseph Vellozzi	Ammann and Whitney
Louis Berger	Louis Berger International, Inc.

The representatives were questioned regarding their personal knowledge of lateritic soils and their use of the AID studies reports. Where available, economic data on cost benefits associated with the use of laterites on constructed projects was requested.

A.1.3 QUESTIONNAIRE

In order to assess the impact of the lateritic soils studies a questionnaire was developed in English and dispatched to selected individuals, firms, organizations and national transportation agencies located throughout the world. A special effort was made to contact persons who either work or provide services in the tropical areas where lateritic soils are encountered.

A.1.3.1 RESPONDENT IDENTIFICATION

The initial source of potential respondents was the file materials provided by AID. Based upon a review of project files and lists of attendees at AID sponsored seminars conducted in Ghana, Brazil and Peru, a list of potential respondents was prepared. Other potential respondents were identified from information provided by the Transportation Research Board (TRB), the Inter-American Development Bank (IDB), both the Federation Internationale des Ingenieurs - Conseils (FIDIC) of Europe and the Consulting Engineers Council (CEC) of the U.S. many of whose member firms provide design services for transportation infrastructure in laterite areas, and the National Technical Information Service (NTIS) which currently sells copies of all the laterite reports. Lyons Associates, Inc. also provided information on persons who had requested and received copies of their AID sponsored reports on both Africa and the Tropics. However, this data did not include sufficient mailing identification. A total of 509 potential respondents were identified from the several sources as follows:

SOURCE	NUMBER RESPONDEES
AID Project Files	165
TRB	141
IDB	26
FIDIC	96
CEC	23
NTIS	58
TOTAL	509

In accordance with project requirements, this list was submitted to and approved by AID.

A.1.3.2 QUESTIONS

The questionnaire was developed in three parts.

- PART 1- Questions 1 through 5 provide for respondent identification and an indication of the extent of the studies reports distribution.
- PART 2- Questions 6 through 17 are technical questions developed from a review of the three reports. The purposes of these questions were to determine the extent to which reported testing methods, design procedures, and specifications were being employed, and to assess the reliability of the report findings when applied to pavements, foundations and embankment construction.
- PART 3- Questions 18 through 25 were directed toward the overall usefulness of the report and the identification of any economic benefits.

In addition, space was provided in the questionnaire for comments and the identification, where possible, of technical and cost information which any of the

respondents might have on laterite soil projects where study report information has been utilized. This questionnaire was submitted to and approved by AID.

A.1.3.3 DISTRIBUTION

In June the questionnaire was printed and mailed. At the request of AID, a second copy of the questionnaire was sent by special delivery mail to potential respondents in the countries which hosted the three completed studies, namely Thailand, Ghana and Brazil, and in the countries of Malawi and Peru. Cables were also sent to the national transportation organizations in the host countries requesting their support by encouraging the participation in the survey by their staff members through the completion of the questionnaire. Special attempts were also made to contact the Brazilian National Highway Department by telephone in order to encourage their participation.

By the end of July, eighty-five responses had been received. These responses were principally from consultants and lending institutions located in North America and Europe. An additional thirty-two responses have now been received principally from national transportation organizations located in Africa and South America.

A.1.4 FOLLOW-UP

Although provision had been made for travel outside the United States to seek additional data or to validate responses, the replies to the questionnaire did not indicate that such travel was warranted.

A.2.0
INTERVIEW EVALUATION

Interviews were conducted with representatives of five organizations and firms considered knowledgeable in the field of lateritic soils. Summaries of the interviews are presented in Table A.2.1. The persons interviewed all had knowledge of the reports and two had used them on constructed highway projects. There was general agreement that the reports are of great value in the design, construction and maintenance of highways. They also agreed that additional time may be required in order to permit the assessment of the impact of the studies on the performance of projects completed in accordance with the reported recommendations.

Cost data were available for one project which indicated a savings of $246,000, as a direct result of the use of laterites in conformance with the testing methods, design procedures and specifications presented in the AID laterite reports. Based on the engineer's estimate of construction cost, this represented a 20% savings over the construction cost of an alternative cement stabilized road which is typically employed.

TABLE A.2.1
SUMMARY OF PERSONAL INTERVIEWS

- William C. LaBaugh

  Information on the costs associated with the utilization of laterites in the construction of the 137 kilometer long Lilongwe/Mchinji/Zambia (LMZ) Border Road and Lilongwe By-Pass in Malawi were provided by W. C. LaBaugh (DMJM). He noted that much of the data used in developing a construction alternative utilizing laterites was obtained from AID reports on lateritic soils.

  In the LMZ project provision was made for the use of a subbase material between the formation level and base level, if the formation level was not adequate. Additionally, stabilization items were provided to improve in-place base which did not meet specifications. Selected grading and use of laterites resulted in all embankments exceeding the specified minimum strength as measured in CBR tests and essentially no stabilization was required. The construction bid utilizing the laterite alternative was approximately 20% below the estimate using cement stabilization. This construction resulted in a reported cost savings of $246,000.

- Raymond Millard

  Mr. R. Millard (World Bank) has extensive knowledge of laterites gained in his former position as head of the Transport and Road Research Laboratory (TRRL), England. He noted that the AID reports compiled in one convenient source, design information which previously was available only in a number of other separate reports. Regarding the continuation of practical engineering research, Mr. Millard stressed the concern for the study of "dry-compaction" techniques which must be employed in the major arid areas of the world.

- Lloyd Crowthers

  Mr. Crowthers (TRB) noted that he was aware of the reports and that some information on laterites had been included in the compendium on low volume roads which is currently in publication by TRB under Contract AID/otr-C-1591.

- Alan Beers

  Mr. A. Beers (IDB) had reviewed the reports. He noted that although IDB was not currently involved in road projects in the tropical zones of Latin and South America, the reports would be of great technical assistance on future road and earth construction projects.

- Joseph Fiteni

  Mr. J. Fiteni (TAMS) reported having recently used the AID reports test and design procedures on a highway project in Botswana with very good results.

Interviews were conducted with all of the above except Messrs. Morin and Todor who were overseas on long-term assignments and Messrs. Villozzi and Berger who could not be contacted.

A.3.0
QUESTIONNAIRE EVALUATION

A.3.1 STATISTICAL VALIDITY

Prior to the preparation of the questionnaire, a study was made of goals which should be targeted in order to assure the statistical validity of the survey. Based upon a review of procedures for evaluating random samples, it was concluded that with a questionnaire distribution of five hundred (500) a minimum total response of seventy-five (75) and minimum significant response of sixteen (16) would be required. In actuality a total of five hundred-nine (509) questionnaires were distributed and the total response was one hundred-seventeen (117). The number of significant responses to the several questions varied from a low of 23 to a high of 109. A statistical analysis of the targeted goals and the actual response is presented on Table A.3.1.

A.3.2 GENERAL ANALYSIS

A general analysis was made of the distribution and response to the questionnaire by geographic location, respondent source, and respondent affiliation. These analyses are presented on pages A-4-3 through A-4-9 of this Appendix.

A.3.2.1 GEOGRAPHIC

Respondents from 36 of the 98 countries surveyed indicated their receipt and use of the reports on the lateritic studies. Africa was the continent to which the largest number of questionnaires were sent. However, Africa produced the lowest percent of responses. The greatest percent response was in North America and primarily the United States. The rate of response may have been influenced by the international postal service.

The largest distribution of questionnaires by country was in the United States. However, many of the smaller countries throughout the world had a greater percent of responses. This is attributed to the smaller distribution of questionnaires.

The lateritic studies host countries of Thailand, Ghana and Brazil together with the countries of Malawi and Peru provided significant response. In South America 30% of the questionnaires were distributed in the countries of Brazil and Peru. These countries provided 45% of all responses from that continent. Sixteen percent of the questionnaires were distributed in Ghana and Malawi which countries produced 41% of all responses in Africa. Similarly 17% of the questions were distributed and 27% of the responses were received from Thailand in Southeast Asia.

TABLE A.3.1
SUMMARY OF STATISTICAL VALIDITY OF QUESTIONNAIRE

TOTAL RESPONSE	GOAL	ACTUAL
o Number of Questionnaires	500	509
o Number of Response	75	117
o Percent Response	15%	23%
o Deviation @ 95% Reliability	±3%	±4%

		ACTUAL		
SIGNIFICANT RESPONSE	GOAL	GENERAL	TECHNICAL	ECONOMIC & OTHER
o Number of Questionnaires	75	117	117	117
o Number of Response	12	104	31	26
o Per ent Response	16%	89%	27%	22%
o Deviation @ 95% Reliability	±8%	±6%	±8%	±7%

A.3.2.2 SOURCE

The largest source of both potential and actual respondents was the AID project files, see page A-4-10. Approximately one-third (32%) of all questionnaires were sent to persons identified from this source and produced approximately one-third (31%) of the responses.

A.3.2.3 AFFILIATION

The largest group of both potential and actual respondents was the Consultants, see page A-4-11. This group received 38% of the questionnaires and provided 46% of the responses. National transportation agencies, lending institutions and universities each provided approximately 15% of the responses.

A.3.3 QUESTIONS

The questionnaire was developed in three parts and the average number of responses varied as follows:

QUESTIONS	DESCRIPTION	AVERAGE NUMBER OF RESPONSES
1 through 5	Respondent Identification	104
6 through 17	Technical	31
18 through 25	Economic & Overall Usefullness	26

The complete analysis of the responses to the questionnaire is presented on pages A-4-12 through A-4-36 of this Appendix and a Summary is presented on Table A.3.2.

A.3.3.1 PART 1 - RESPONDENT IDENTIFICATION

The average response to the questions in Part 1 was 104 which is 89% ± 6% of all responses. This significantly exceeds the targeted response level required for statistical validity.

Most of the respondents are actively involved in the design or construction of pavement systems for roads or airports. More than one-third of the respondents had received copies of one or more of the reports. Significantly, almost one-half of the other respondents submitted requests for copies of the reports.

A.3.3.2 PART 2 - TECHNICAL RESPONSES

Only persons who had received one or more of the reports on the laterite studies were asked to respond to the technical questions. The average significant response to the questions in Part 2 was 31 which is 27% ± 8% of all responses. This exceeds the targeted response level required for statistical validity.

TABLE 3.2
SUMMARIZING SUMMARY
TERMINAL EVALUATION OF LATERITIC SOILS STUDIES
Addison C. Hicks

		Yes	No
1.	Is address label correct?	60%	40%

If "NO" please provide correct information below.

NAME: _____
TITLE: _____
ADDRESS: _____

2. Are you actively involved in the design and/or the construction of pavement systems for:

a) roads?	70%	30%
b) airports?	49%	51%

3. Please indicate your affiliation. (Check one.)

a) Government	21%	d) Educator	13%
b) Consultant	56%	e) Library	2%
c) Other - Grading Contractor			8%

4. Please indicate:

a) Do you wish to receive a copy of the results of this survey?	88%	12%
b) Do you wish your name to appear on the list of respondents?	74%	26%

5. Have you received a copy of one of the following AGC sponsored studies?

	71%	63%

If "YES", which?

STUDY	RESPONSE - % YES
a) Southeast Asia	29%
b) Africa	43%
c) Tropics	29%

(Note: If the answer to question No. 5 is "YES", please continue; if "NO", please turn to last page of this questionnaire and provide us with your comments.

6. In working with soil tropical soils, does your current investigation include any of the following work? (Check all those applicable.)

a) Grading	52%	c)	Black cotton soil		26%
b) plasticity	52%	d)	concretionary gravel		77%

	60%	40%

7. Do you employ any classification systems for soil tropical soils? (Check all those applicable.)

a) [illegible]	29%
b) U.S. Soil Taxonomy	29%
c) Phenol-Psychological [illegible]	11%
d) Other - [illegible]	11%

8. Has your organization investigated the geotechnical properties of local soils?

	77%	23%

If "YES", please rate the usefulness of your values with those presented in the Laterite Reports? (Check one.)

a) Excellent	0%	c) Fair	17%
b) Good	79%	d) Unsatisfactory	0%

9. Has any of the test procedures and standards recommended in the Laterite Reports followed by your organization?

	71%	43%

If "YES" please list the five most frequently used procedures. (Rank procedures in order of use from 0, 1, 2 - most used, 2 - next most used, etc. No rank can any number more than once.)

TEST PROCEDURES	RANK
Shrinking Limits	1
California Bearing Ratio	2
Liquidus	3
Compaction	4
Sample Preparation	5

		Yes	No
10.	Have you evaluated the variations in geotechnical properties due to sample disturbance such as sampling and pre-heating?	44%	56%

If "YES", please rate your observed variations with those presented in the Laterite Reports? (Check one.)

a) Excellent	7%	c) Fair	20%
b) Good	60%	d) Unsatisfactory	0%

11.	In the evaluation of existing pavement structures, do you conduct performance studies?	58%	42%

If "YES", please indicate which performance studies are employed? (Check all those applicable.)

a) Deflection	93%
b) Roughness	67%
c) Condemnation	57%
d) Other - Visual Inspection	21%

If "YES", are the performance studies being conducted in connection with any of the following? (Check one.)

a) Research	32%
b) Design	39%
c) Maintenance	43%
d) Other - _____	0%

12.	Do you utilize the Tropical Design Procedure recommended in the Laterite Reports for flexible pavements?	28%	72%

If "NO", please specify procedure employed.
TRRL Road Notes Nos. 29 and 31

13.	Do you determine the durability of materials such as limestone and concretionary gravel by any of the following? (Check all those applicable.)	59%	41%

a) L.A. Abrasion	57%	d) Slaking	67%
b) Hardness Index	19%	e) Impact	57%
c) Other - No Significant Response			19%

14.	Do you employ any of the following methods of soil stabilization?	68%	32%

If "YES", how do you rate their performance? (Circle one response for each item.)

EXCELLENT (1) (2) (3) (4) (5) UNSATISFACTORY

METHOD	RATING				
a) none	1	2	3	4	5
b) lime	1	2	3	4	5
c) cement	1	2	3	4	5
d) asphalt	1	2	3	4	5
e) other	1	2	3	4	5

"OTHER" - No Response

15.	Do you employ any of the following performance procedures for testing stabilized soils?	66%	34%

If "YES", please indicate your minimum acceptable values.

PROCEDURE	
a) CBR	60%
b) Unconfined Compression	57%
c) Split Tensile	7%
d) Other - Triaxial Shear +	7%

16.	Do you employ any test procedures to measure the swelling of tropical black clay (black cotton) soils? (Check all those applicable.)	62%	38%

a) Potential Volume Change	93%
b) Free Swell	57%
c) Odometer	64%
d) Other - California Bearing Ratio	29%

17.	Do you employ any of the following Standards in contracting construction? (Check all those applicable.)	72%	28%

a) AASHTO	75%
b) British Standards	57%
c) Other - American Society for Testing & Materials	36%

		Yes	No
18.	Please rank the following report topics by order of usefulness. (Rank topics from 1-8; 1 = most useful, 2 = next most useful, etc. Do not use any number more than once.)		

TOPIC	RANK
Geotechnical Properties	1
Stabilization	2
Testing Procedures	3
Classification System	4
Pavement Performance Study	5
Specifications	6
Black Cotton Soils	7
Limestone and Concretionary Gravel	8

19.	Have you utilized the test procedures, design methods or specifications recommended in the Laterite Reports on any highways, airport or other project.	29%	71%

If "YES", please identify project(s).
South East Asia and Africa only

20. How would you rate the reliability of the reported findings of the laterite studies? (Circle one response for each item.)

EXCELLENT (1) (2) (3) (4) (5) UNSATISFACTORY

TOPIC	RATING				
Paved Roads	1	2	3	4	5
Unpaved Roads	1	2	3	4	5

If "OTHER" please specify - No Significant Response

21.	Have any cost benefits associated with the use of information presented in the Laterite Reports been identified?	12%	88%

If "YES", please indicate:

PHASE OF WORK	
Construction	
Maintenance	NO DATA
Other	

"OTHER" - No Significant Response

22.	Would you recommend laterite or other tropical soil topics for future study?	82%	18%

If "YES", please specify:
1. Surface Treatments of Pavements
2. Laterite in Building Construction (Ghana)
3. Swelling of Tropical Soils
4. Laterite in Dam Construction

23.	Were alternate material sources available for use on any projects?	64%	36%
	If "YES", were cost-benefit studies conducted to establish which material would be used?	80%	20%
	Was the use of laterite soils shown to be of greater cost-benefit?	63%	37%

24. How do you rate the maintenance costs for roads constructed using laterite soils with roads constructed using other materials? (Check one.)

a) Excellent	0%	c) Fair	43%
b) Good	86%	d) Unsatisfactory	0%

25. How would you rate the overall usefulness of the Laterite Reports? (Check one.)

a) Excellent	30%	c) Fair	11%
b) Good	59%	d) Unsatisfactory	0%

- Terminology and Soil Classifications - 88% of the respondents utilize the soils terminology presented with reports.

- Geotechnical Properties - 73% of the respondents have investigated the properties of local soil; 83% of these report good to excellent correlation with property values presented in these reports.

- Testing Procedure - 55% of the respondents utilize the testing procedures and standards recommended in the reports. In order of descending use, the five most frequently used procedures are Atterberg Limits, CBR, gradation, compaction and sample preparation. With regard to the latter procedure 46% of the respondents have evaluated the variation in geotechnical properties due to sample disturbance; 67% of these report good to excellent correlation with observed variations presented in these reports.

- Pavement Evaluation - 58% of the respondents conduct performance studies as part of their evaluation of existing pavement structures. Most of the evaluations are carried out in connection with either design or maintenance and consist primarily of deflection and traffic studies.

- Design Procedure - 28% of the respondents utilize the tropical design procedures recommended in the reports. 43% of the respondents utilize TRRL Road Notes Nos. 29 and 30.

- Materials - 59% of the respondents determine the durability of materials such as ironstone and concretronary gravel by testing. The principle tests employed are Los Angeles abrasion, slaking and impact.

- Stabilization - 68% of the respondents employ soils stabilization methods all with good to excellent results. 66% of the respondents conduct performance tests (primarily CBR and unconfined compression tests) on stabilized soils.

- Black Clay - 62% of the respondents test the swelling of black cotton soils. The most frequently employed test methods are free swell, potential volume change and odometer.

- Construction Standards - 72% of the respondents utilize the following standards in descending order:

American Association of State Highway and Transportation Offficials	78%
British Standards	52%
American Society for Testing and Materials	26%

A.3.3.3 PART 3 - ECONOMIC & OVERALL USEFULNESS

Only persons who had received one or more of the reports on the laterite studies were asked to respond to these questions. The average significant response to the questions in Part 3 was 26 which is 22 ± 7% of all responses. This exceeds the targeted response level required for statistical validity.

- Topics - The respondents identified the topics presented in the reports in descending order of usefulness as follows:

  1 - Geotechnical Properties
  2 - Stabilization
  3 - Testing Procedures
  4 - Classification System
  5 - Pavement Performance Study
  6 - Specifications
  7 - Black Cotton Soils
  8 - Ironstone and Concretronay Gravel

- Utilization - 29% of the respondents utilize the test procedures, design methods or specifications recommended in the reports on projects in Southeast Asia and Africa. They rated the reliability of the reported findings as good to excellent. Projects on which the use of information contained in the Laterite Reports were identified are as follows:

AFRICA	PROJECT
Cameroon	Bamenda - Mamfe-Ekok Highway
Chad	Djermaya - Djimtilo Road
Ghana	Axim-Elubo Road
	Tena Freestone
	Yamoransa - Bekwai Road
Kenya	Kapsabet Chavakali Road
	Trans-African Highway
Malawi	Salima - Benga
Mali	Ansongo - Anderambovkane Road
Nigeria	Abakaliki - Edor Highway
	Beni Sheik - Uba Highway
	Owo - Egbe Highway

SOUTHEAST ASIA	PROJECT
Thailand	Surabaya Ind. Estate

- Cost Benefit - 12% of the respondents identified cost benefits associated with the use of information presented in the reports. Conversely 28% of the respondents identified lateritic soils as having a greater cost benefit in comparitive studies with alternate sources of materials. No cost benefit values were provided.

- Further Studies - 82% of the respondents recommended the continued study of laterite and other tropical soils. Such studies in descending order of importance are as follows:

  Surface Treatments of Pavements
  Laterite in Building Construction (Houses)
  Swelling of Tropical Soils
  Laterite in Dam Construction

- Maintenance Costs - 50% of the respondents rated as good to excellent the maintenance costs for roads constructed using lateritic soils when compared with roads constructed using other materials.

- Summary - 89% of the respondents rated the overall usefulness of the Laterite Reports as good to excellent.

A.3.3.4 SUPPLEMENTAL INFORMATION

At the end of the questionnaire provision was made to permit the respondents to offer additional comments and technical or cost information. 56% of the respondents provided comments of which 35% were considered significant. The latter are summarized on Table A.3.3. In general the reports on the laterite studies were considered both comprehensive and useful. Performance studies were cited as a necessary and useful follow up. Other topics suggested for study included surface treatments, soils of arid areas and expansive clays.

Only 3% of the resondents provided comments on additional technical or cost information. This information is also summarized on Table A.3.3.

TABLE A.3.3

SUMMARY OF ADDITIONAL COMMENTS AND TECHNICAL OR COST INFORMATION

Respondent Identification	Additional Comments
101014206	reports are considerable help as a reference document.
101019906	too much chemistry performance studies are required on roads constructed according to recommendations
101062309	correlation of quality to methods of excavation required study deterioration
101089310	uses procedures but avoids using laterites
101096910	reports are comprehensive and useful
203009906	practical data provided
207001202	recommends study of bauxite provided surface course (laterite) specification
312001503	negative experience
408001202	used with hot mix asphalt layer
413004302	practical
413007107	author of text on laterites agrees with reports
413008107	useful performance studies required
413018907	good performances where drainage is good procedure for traffic studies employed
419003207	original work contained in reports is worthwhile
504001202	studying expansive clay
504003502	researching the identification and location of laterites through aerial photography
606001906	recommends study of surface treatment with materials like concretionary gravels

TABLE A.3.3 (CONT'D)

SUMMARY OF ADDITIONAL COMMENTS AND TECHNICAL OR COST INFORMATION

Respondent Identification	Additional Comments
609003308	very useful utilizes stabilization methods in design
612002308	black cotton soil difficult
614031308	expansive clays are problem soils
614038308	using lateritic soils for dam construction in East Africa
614042308	more stringent materials requirements would lead to improved performance

	Technical or Cost Information
501008308	paper on geotechnical characterization of laterites provided
612006410	general data on aggregate testing in Sweden provided
614042308	technical note on pavement designs for Nigerian road on lateritic clay provided

A.4.0

QUESTIONNAIRE ANALYSIS

EVALUATION OF LATERITIC SOILS STUDIES DATE: 80/10/17
AID OTR-C-1626

TOTAL NUMBER OF RESPONDENTS: 117

EVALUATION OF LATERITIC SOILS STUDIES — DATE: 80/10/17
AID OTR-C-1626

CONTINENT/ COUNTRY	NUMBER OF QUESTIONNAIRES	PERCENT OF ALL QUESTIONNAIRES	NUMBER OF RESPONSES	PERCENT RESPONSE TO QUESTIONNAIRES (A)	PERCENT RESPONSE TO QUESTIONNAIRES (B)
NORTH AMERICA					
U.S.A.	105	20.6	37	35.2	31.9
CANADA	11	2.2	2	18.2	1.7
TOTAL	116	22.8	39		33.6

(A) - PERCENT RESPONSE TO NUMBER OF QUESTIONNAIRES BY COUNTRY
(B) - PERCENT RESPONSE TO TOTAL NUMBER OF QUESTIONNAIRES BY CONTINENT

EVALUATION OF LATERITIC SOILS STUDIES DATE: 80/10/17
AID OTR-C-1626

CONTINENT/ COUNTRY	NUMBER OF QUESTIONNAIRES	PERCENT OF ALL QUESTIONNAIRES	NUMBER OF RESPONSES	PERCENT RESPONSE TO QUESTIONNAIRES (A)	(B)
LATIN AMERICA					
BARBADOS	1	.2	0	0.0	0.0
COSTA RICA	6	1.2	4	66.7	8.5
DOMINICAN	6	1.2	0	0.0	0.0
EL SALVADOR	2	.4	0	0.0	0.0
GUATEMALA	5	1.0	1	20.0	2.1
HAITI	1	.2	0	0.0	0.0
HONDURAS	5	1.0	1	20.0	2.1
JAMAICA	4	.8	1	25.0	2.1
MEXICO	6	1.2	1	16.7	2.1
NICARAGUA	5	1.0	0	0.0	0.0
PANAMA	4	.8	0	0.0	0.0
TRINIDAD AND TOBAGO	2	.4	1	50.0	2.1
TOTAL	47	9.2	9		19.1

(A) - PERCENT RESPONSE TO NUMBER OF QUESTIONNAIRES BY COUNTRY
(B) - PERCENT RESPONSE TO TOTAL NUMBER OF QUESTIONNAIRES BY CONTINENT

EVALUATION OF LATERITIC SOILS STUDIES — DATE: 80/10/17
AID OTR-C-1626

CONTINENT/ COUNTRY	NUMBER OF QUESTIONNAIRES	PERCENT OF ALL QUESTIONNAIRES	NUMBER OF RESPONSES	PERCENT RESPONSE TO QUESTIONNAIRES (A)	(B)
ASIA					
AUSTRALIA	8	1.6	2	25.0	2.9
BANGLADESH	2	.4	0	0.0	0.0
CHINA	1	.2	1	100.0	1.4
INDIA	7	1.4	3	42.9	4.3
INDONESIA	11	2.2	1	9.1	1.4
ISRAEL	2	.4	2	100.0	2.9
JAPAN	4	.8	1	25.0	1.4
JORDAN	2	.4	0	0.0	0.0
KOREA	2	.4	0	0.0	0.0
LEBANON	3	.6	0	0.0	0.0
MALAYSIA	3	.6	0	0.0	0.0
NEPAL	1	.2	0	0.0	0.0
NEW ZEALAND	1	.2	0	0.0	0.0
PAKISTAN	1	.2	0	0.0	0.0
NEW GUINEA	1	.2	0	0.0	0.0
PHILIPPINES	4	.8	1	25.0	1.4
SRI LANKA	2	.4	0	0.0	0.0
SYRIA	0	0.0	0	0.0	0.0
THAILAND	12	2.4	4	33.3	5.8
TUNISIENNE	1	.2	0	0.0	0.0
TURKEY	0	0.0	0	0.0	0.0
YEMEN	0	0.0	0	0.0	0.0
SINGAPORE	1	.2	0	0.0	0.0
TOTAL	69	13.6	15		21.7

(A) - PERCENT RESPONSE TO NUMBER OF QUESTIONNAIRES BY COUNTRY
(B) - PERCENT RESPONSE TO TOTAL NUMBER OF QUESTIONNAIRES BY CONTINENT

EVALUATION OF LATERITIC SOILS STUDIES — DATE: 80/10/17

AID OTR-C-1626

SOURCE	NUMBER OF QUESTIONNAIRES	PERCENT OF ALL QUESTIONNAIRES	NUMBER OF RESPONSES	PERCENT RESPONSE TO QUESTIONNAIRES (A)	PERCENT RESPONSE TO QUESTIONNAIRES (B)
AID PROJECT FILES	165	32.4	36	21.8	7.1
TRB	141	27.7	20	14.2	3.9
IDB	26	5.1	10	38.5	2.0
FIDIC	96	18.9	31	32.3	6.1
CEC	23	4.5	12	52.2	2.4
NTIS	58	11.4	8	13.8	1.6
TOTAL	509	100.0	117		23.0

(A) - PERCENT RESPONSE TO NUMBER OF QUESTIONNAIRES BY SOURCE
(B) - PERCENT RESPONSE TO TOTAL NUMBER OF QUESTIONNAIRES

TRB = TRANSPORTATION RESEARCH BOARD
IDB = INTERAMERICAN DEVELOPMENT BANK
FIDIC = FEDERATION INTERNATIONALE DES INGENIEURS-CONSEILS
CEC = CONSULTING ENGINEERS COUNCIL (US)
NTIS = NATIONAL TECHNICAL INFORMATION SERVICE

QUESTION NO. 1

IS ADDRESS LABEL CORRECT?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	62	59.6
NO	42	40.4

QUESTION NO. 3

PLEASE INDICATE YOUR AFFILIATION.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) GOVERNMENT	23	21.1
B) CONSULTANT	61	56.0
C) OTHER	9	8.3
D) EDUCATOR	14	12.8
E) LIBRARY	2	1.8

QUESTION NO. 5

HAVE YOU RECEIVED A COPY OF ONE OF THE FOLLOWING AID SPONSORED STUDIES?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	36	35.3
NO	66	64.7

IF "YES", PLEASE INDICATE.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) SOUTHEAST ASIA	5	13.9
B) AFRICA	15	41.7
C) TROPICS	23	63.9

QUESTION NO. 7

DO YOU EMPLOY ANY CLASSIFICATION SYSTEMS FOR RED TROPICAL SOILS?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	18	60.0
NO	12	40.0

CHECK ALL THOSE APPLICABLE:

	NO. OF RESPONSES	PCT. OF RESPONSES
A) FAO-UNESCO	7	38.9
B) U.S. SOIL TAXOMONY	5	27.8
C) FRENCH PEDOLOGICAL (D'HOORE)	6	33.3
D) OTHER	6	33.3

QUESTION NO. 9

ARE ANY OF THE TEST PROCEDURES AND STANDARDS RECOMMENDED IN THE LATERITE REPORTS FOLLOWED BY YOUR ORGANIZATION?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	16	55.2
NO	13	44.8

QUESTION NO. 11

IN THE EVALUATION OF EXISTING PAVEMENT STRUCTURES, DO YOU CONDUCT PERFORMANCE STUDIES?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	19	57.6
NO	14	42.4

IF 'YES', PLEASE INDICATE WHICH PERFORMANCE STUDIES ARE EMPLOYED.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) DEFLECTION	18	94.7
B) TRAFFIC	9	47.4
C) LOADOMETER	7	36.8
D) OTHER	4	21.1

IF 'YES', ARE THE PERFORMANCE STUDIES BEING CONDUCTED IN CONNECTION WITH ANY OF THE FOLLOWING?

	NO. OF RESPONSES	PCT. OF RESPONSES
A) RESEARCH	6	31.6
B) DESIGN	11	57.9
C) MAINTENANCE	8	42.1
D) OTHER	0	0.0

QUESTION NO. 13

DO YOU DETERMINE THE DURABILITY OF MATERIALS SUCH AS IRONSTONE AND CONCRETIONARY GRAVEL BY ANY OF THE FOLLOWING?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	17	58.6
NO	12	41.4

CHECK ALL THOSE APPLICABLE.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) L.A. ABRASION	14	82.4
B) HARDNESS INDEX	3	17.6
C) OTHER	3	17.6
D) SLAKING	8	47.1
E) IMPACT	8	47.1

QUESTION NO. 15

DO YOU EMPLOY ANY OF THE FOLLOWING PERFORMANCE PROCEDURES FOR TESTING STABILIZED SOILS?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	19	65.5
NO	10	34.5

IF 'YES', PLEASE INDICATE.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) CBR	13	68.4
B) UNCONFINED COMPRESSION	6	31.6
C) SPLIT-TENSILE	1	5.3
D) OTHER	1	5.3

QUESTION NO. 17

DO YOU EMPLOY ANY OF THE FOLLWING STANDARDS IN CONTROLLING CONSTRUCTION?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	23	71.9
NO	9	28.1

CHECK ALL THOSE APPLICABLE.

	NO. OF RESPONSES	PCT. OF RESPONSES
A) AASHTO	18	78.3
B) BRITISH STANDARDS	12	52.2
C) OTHER	6	26.1

QUESTION NO. 19

HAVE YOU UTILIZED THE TEST PROCEDURES, DESIGN METHODS OF SPECIFICATIONS RECOMMENDED IN THE LATERITE REPORTS ON ANY HIGHWAY, AIRPORT OR OTHER PROJECT?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	10	29.4
NO	24	70.6

QUESTION NO. 21

HAVE ANY COST BENEFITS ASSOCIATED WITH THE USE OF INFORMATION PRESENTED IN THE LATERITE REPORTS BEEN IDENTIFIED?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	3	11.5
NO	23	88.5

QUESTION NO. 23

WERE ALTERNATE MATERIAL SOURCES AVAILABLE FOR USE ON ANY PROJECTS?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	10	43.5
NO	13	56.5

IF 'YES', WERE COST-BENEFIT STUDIES CONDUCTED TO ESTABLISH WHICH MATERIAL WOULD BE USED?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	8	80.0
NO	2	20.0

WAS THE USE OF LATERITIC SOILS SHOWN TO BE OF GREATEST COST-BENEFIT?

	NO. OF RESPONSES	PCT. OF RESPONSES
YES	5	62.5
NO	3	37.5

QUESTION NO. 25

HOW WOULD YOU RATE THE OVERALL USEFULNESS OF THE LATERITE REPORTS?

	NO. OF RESPONSES	PCT. OF RESPONSES
A) EXCELLENT	8	29.6
B) GOOD	16	59.3
C) FAIR	3	11.1
D) UNSATISFACTORY	0	0.0