

Post Construction Failure Analysis of Road Pavements in Ghana.

Dr. Francis Achampong[1*], Dr Fred Boadu[2], Peter Klu Agbeko[3],Reginald Adjetey Anum.

1. Lecturer, Department of Earth Science, University of Ghana,P.O.Box LG 25,Legon, Ghana-West Africa
2. Associate Professor Duke University, Durhan, N, C. USA
3. Department of Urban Roads Koforidua, Eastern Region, Ghana
4. Assistant Researcher, Department of Earth Science, University of Ghana.

*Contact of corresponding author : +233-271-811-363, Achampongf @yahoo.com

Abstract

Premature road pavement failure occurs when it can no longer perform its traditional function of carrying vehicles and people from one location to another in safety and comfort before the anticipated design life. Usually premature pavement failure of Ghana roads results in frequent road accidents with loss of life and properties, high transportation costs of goods and services, high maintenance costs of vehicles and increase in travel time. A classical example of pavement failure is the Koforidua BY –Pass Road where the design life was fifteen (15) years but it failed in less than six (6) months after being opened to vehicular traffic.

The objectives of this research were to investigate the causes leading to the early deterioration of the road pavement and recommend remedial approach to ameliorate the current situation.

Desk Study of contract documents, as built drawings, visual road condition survey, structured questionnaire, in situ field tests and laboratory tests were conducted.

The forensic studies revealed that the premature pavement failure were due to lack of geotechnical investigation, insufficient drainage system, poor construction methods, the inclusion of sub standard materials, inadequate quality control and quality assurance program

It was recommended that the design phase should provide adequate drainage system for the road way. Where poor to marginal construction material do not meet the specifications, it should be stabilized. Proper construction methods should be employed and also dedicated personnel are needed to monitor the QC/QA program.

Keywords: Premature, deterioration, remediation, quality control, subgrade.

1. Introduction

1.1 Background of the Study

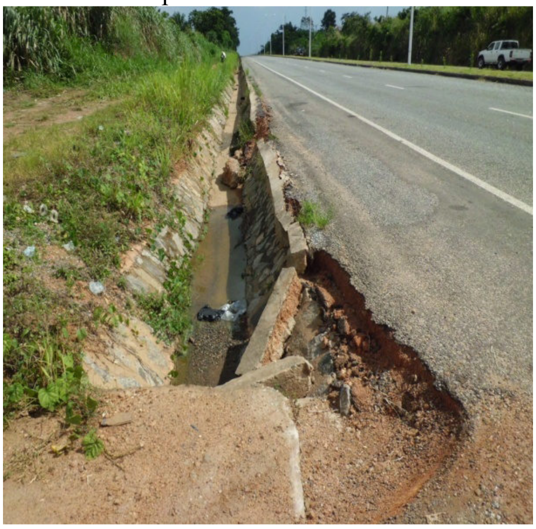
Premature road pavement failure occurs when it can no longer performs its traditional function of carrying vehicles and people from one location to another in safety and comfort before the anticipated design life. Failure is therefore defined as an unacceptable difference between the expected design life and the observed performance (Leonard, 1982). A classical example of pavement failure is the Koforidua By-Pass road where the design life was fifteen (15) years but failed in less than six (6) months after being opened to vehicular traffic. Usually premature pavement failure of Ghana roads results in frequent road accidents with loss of life and properties, high transportation costs of goods and services, high maintenance cost for vehicles and discomfort to motorists. Moreover, there is high government budgeting and spending on road maintenance.

Premature failure of road pavements are generally attributed to the poor design, incorporation of poor to marginal materials, poor workmanship and lack of quality control and assurance program during construction.

The current Koforidua By-Pass is a 9 kilometer four lane dual carriageway which was fully funded by the government of Ghana. The road is a major arterial serving communities linking it and providing an alternative south –north connection which avoids the congested Central Business District (CBD) of Koforidua, thereby easing traffic congestion and thus reducing travel time for motorists. This Koforidua highway is a surface dressed wearing course with a vegetative median of 2 meters width. The total carriageway width is 14.6 meters. The north and south bound lanes are 7.3 meters apiece with shoulders of 2 meters on both sides and drainage structures at some selected sections. Four critical intersections on the road have been signalized to facilitate traffic management. Street lights were virtually installed at every 40 meter intervals along the median for safety and security of motorists and pedestrians.

The construction started in April 2007 and completed in June 2011 by Messers China Water & Electricity (Gh) Ltd. Unfortunately, the joy and excitement that the new road brought to the inhabitants of the Koforidua municipality were truncated as “this magnificent piece of edifice” failed prematurely. Within the first six months after opening to traffic, there was structural failure. Potholes were developed in the travelling lanes. There were alligator cracks and rutting along the travelling lane near the median as shown in figure 1. Water seepage from the subgrade was rampant along the concrete curb butting the vegetative median. This catastrophic failure has necessitated more capital infusion to preserve initial investment by undertaking remedial works and in some places total reconstruction in less than six months after the substantial completion of the project.

1.2 Objectives of the study
The major goal of this research is to investigate the causes leading to the early deterioration of the road pavement and the remedial approach to ameliorate the current situation.
The specific objectives cover the following:
Adequacy or inadequacy of the drainage system in the roadway
Evaluation of the subgrade, sub-base, -base and the wearing course materials
The appraisal of method of construction practices such as compaction techniques
Quality control and quality assurance or lack of by the consultants.
To reduce the probability of premature pavement failures by incorporating the findings of the study to prescribe the state-of-art procedures for the execution of future road construction



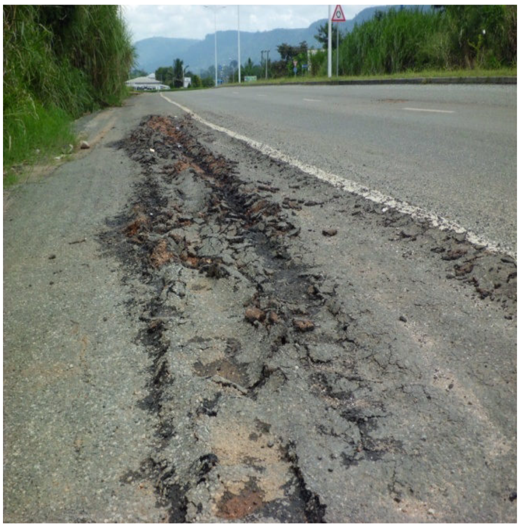


Fig 1: A 3- month old road surface showing poor drainage works and premature road surface failure.

2. Methodology

2.1 Investigative Program
2.1.1 Desk study
A thorough review and analysis of the existing construction records, the contract documents and test results were examined at the Department of Urban Roads and the Messers China Water and Electricity (Gh) Ltd. Company offices in Koforidua, the Eastern Regional capital of Ghana. Some of the reviewed documents are the following:

i) Agreement, Letter of Acceptance, Performance Bonds, conditions of contract
ii) Contractors' Bids, Contract Data, (iii) Specifications (iv) Drawings (v) Bill of quantities (vi) Laboratory test results.

2.1.2 Preliminary Investigation
2.1.2.1 Visual road surface condition survey
Visual condition survey of the existing pavement was performed to establish the extent of pavement distresses as well as the state of drainage structures. This survey was done to ascertain the need for pavement rehabilitation or reconstruction at selected sections of the road pavement under review. Field data collected during the visual survey have been presented below.
2.1.2.2 Structured questionnaire
An interactive investigation was undertaken with the Department of Urban Roads where a detailed questionnaire was given to the Chief Engineer (Materials)
2.3 Field Tests
2.3.1 Dynamic Cone Penetration Test (DCPT)
Dynamic Cone Penetration Test is an in-situ test using a cone penetrometer, the data from which can be used for soil identification and ground profiling and other soil parameters. The test was carried out to assess the subgrade and the conditions of other pavement layers
2.3.2 Trial Pits
Shallow excavations were made for the purposes of investigating whether the pavement layers were built to conform with the plans and specifications. Random soil and gravel samples were collected for gradation analysis and Atterberg's Limits tests
2.3.3 Field Density Test
Field density test was carried out using the densometer to find out the relative compaction of the various layers

of the road pavement

3. Results

The results are listed in the tables in Appendix A.

4. Discussion

4.1 Desk Study

From the reviewed documents, geotechnical feasibility studies including hydrogeological investigation were not conducted. The drainage system was inadequate.

4.2 Observations from the visual road surface condition's survey

Massive shoving, rutting, depressions and potholes as well as longitudinal cracks were mostly observed on the wheel path of the inner lane of the pavement surface. This lane was adjacent to the median. There was seepage of water from the subgrade and some fractured bedrock to the road surface near the median.

4.3 Response from the Structured Questionnaire

The Chief Materials Engineer's responses revealed that there was no proof rolling of the subgrade soils to ensure their structural integrity. Moreover, there were mass filling of the sub-base and base materials at the distressed sections of the pavements and the rollers or compacters just compacted the surface layers instead of the compaction being carried out in layers of 180 mm as required by the specifications.

To sum it all, the Material Engineer conformed that there was no effective monitoring and supervision on the Koforidua By- Pass road due to logistics problems such as personnel, equipments and vehicles.

4.4 Gradation Analysis and Plasticity Index results

For the base material, the grading did not meet the project grading curve or project specification. The plasticity index was also above 10 percent which exceeded the project requirements or specifications.

The sub-base material barely met the project specifications for both gradation and plasticity index (12-15 percent).

4.5 Field Density results

The field density results of the base layers had a relative density between 80 -85 percent of the maximum dry density. The specification calls for compaction which would achieve 95 percent of the maximum dry density.

Likewise, the field density results of the sub-base layer indicated that the relative density ranged from 65 to 85 percent of maximum dry density. The specification also called for 95 percent compaction.

4.6 Dynamic Cone Penetration Test (DCPT)

The test results from the dynamic cone penetration test revealed that the thickness of the base layer varied from 150 to 180 mm whereas the sub base ranged from 90 to 150 mm. Using empirical relationships, the California bearing Ratio (CBR) values were determined from the DCPT results.

The specification for base layers of the California Bearing Ratio (CBR) should exceed 80 percent but the results for the base layer were below 45 percent indicating a sub standard material or weak base layer. The CBR values for the sub base layer ranged from 25 to 50 percent. The specification calls for 40 percent CBR. The results indicate some of sub base materials met the specifications but a large portion was poor to marginal sub base material.

Analysis on the test results obtained by the DCPT revealed that there was no clear distinction between the quality of base and sub base layer materials since the lateritic gravelly sandy soils with trace of clay were practically dumped on the subgrade soil.

4.7 Construction of the Vegetative Median

The four lane dual carriageway was completed before the vegetative median was constructed. The construction of the median was delayed for four months due to the rainy season. However, the excavated hole was not covered or plated. The open excavated median was exposed to climatic elements such precipitation during the rainy season. The excavated hole had open standing water for months which infiltrated into the base, subbase and the subgrade of the newly constructed road pavement. The shear strength of saturated layers decreased which led to premature pavement failure as soon as the road pavement was open to traffic. The pavement distresses included rutting, shoving, alligator cracking and water seeping into the pavement surfaces especially at the vehicle lanes near the median. The high water table at some sections of the road was also a contributory factor for water entering the road surface from multiple cracks of the bedrock

4.8 Remedial Works

.Maintenance works started three months after the road pavement was open to vehicular traffic to remedy most of the pavement defects to ensure safety on the roadway. The defective sections on the roadway were excavated to the subgrade formation. Geotextile material was installed at CH 880 as shown the figure 3. 100 mm boulders were placed on the geotextiles fabric. It was then compacted with a 10 ton vibratory roller to a depth of 0.5 meters.

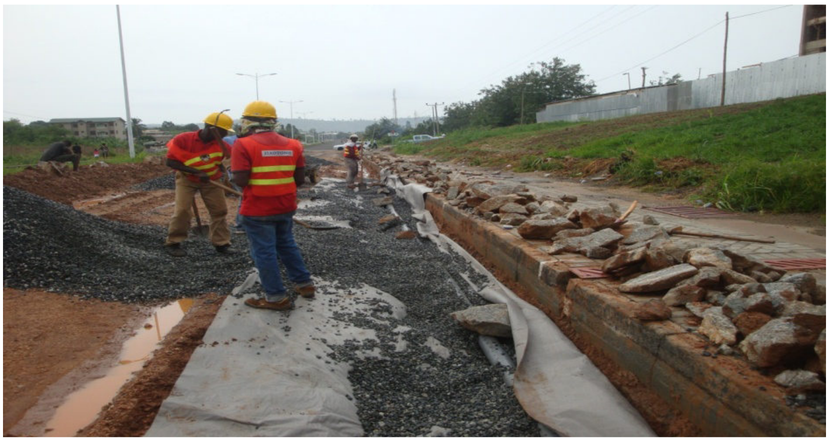


Fig 2: Use of geotextile material at ch 880

Crushed rock aggregates (0 -40 mm size) were placed on the compacted boulder layer and were subsequently compacted. Crushed granite aggregates mixed with natural gravels were used as a sub –base layer and were compacted to a thickness of 200 mm.

The sub-base materials were stabilized with 10 percent cement to increase its CBR and compressive strength values. The 200 mm thick stabilized material was used as a base layer. Unfortunately the wearing course is still surface dressed instead of hot asphaltic cement concrete layer.

The vegetative median was replaced with concrete median to prevent the infiltration of water into the pavement layers (Agbeko et. al., 2012).

Appendix A illustrates the condition of the road before construction of the structured layers and after provision of the pavement system.

5. Conclusion and Recommendations

From the forensic studies, it can be concluded that the causes of the premature failure of the Koforidfua By-Pass road could be attributed to the planning, design and its construction.

During the planning stage, no geotechnical and hydrogeological investigation were performed.

The design should have called for sufficient drainage system and hot asphalt cement concrete wearing course instead of surfaced dressed wearing course.,

The construction phase was poorly managed as manifested by the use of substandard or marginal materials, poor compaction of sub-base and base layers due to inadequate quality control and quality assurance and finally lack of dedicated supervisory/Technical staffs on the project.

It is recommended that subgrade soils should be proof rolled and the poor subgrade soils should be replaced or mechanically / chemically stabilized. Poor to marginal sub-base or base materials should be avoided or stabilized. Proper drainage should be an integral part of any road system. There should not be an open excavation of a median especially during the rainy season. .Finally it is recommended that a comprehensive quality control and quality assurance program with dedicated supervisory team to enforce it.

References

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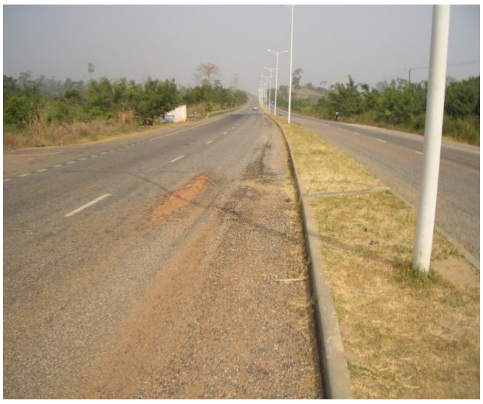
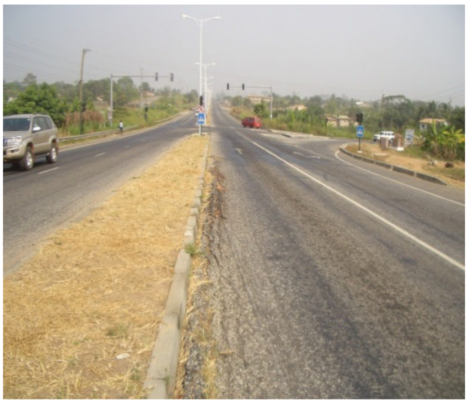
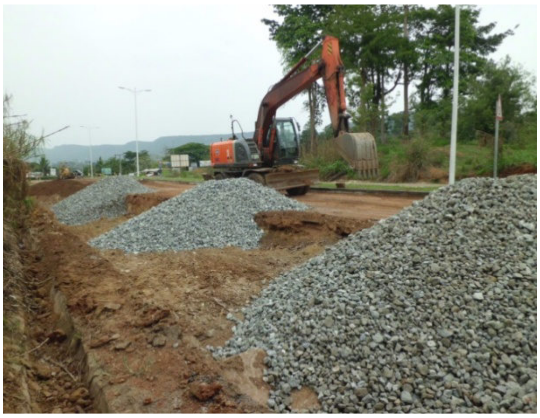
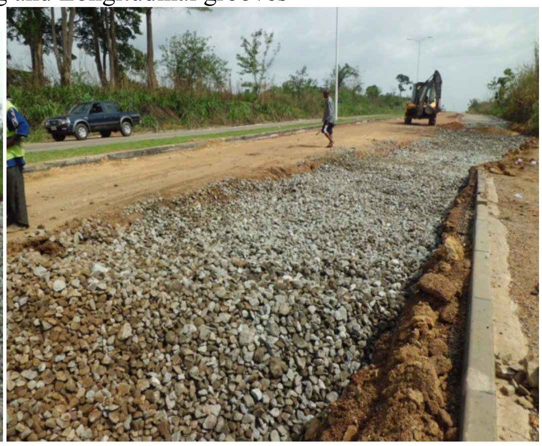
Leonard, Gerald. A. (1983), Investigation of Failures, The 16 th Terzaghi.s lecture, ASCE of Geotechnical Engineering Division, Vol. 108. GT2 pp 185-246

APPENDIX A

Road defect (pothole) Shoving and Longitudinal grooves

During remedial works (Placement of crush rock base material)

Table 1. Field density test

DATE	LOCATION	LAYER	WET DENSITY ($Kg\text{-}m^3$)	DRY DENSITY ($Kg\text{-}m^3$)	MC (%)	CMC (%)	R. COMP. (%)
24-6-12	0+500NB-R	BASE	2315	2188	9.5	5.8	96.0
"	0+500SB-L	"	1939	1824	9.0	6.3	80.1
"	1+400NB-R	"	1999	1875	10.4	6.6	82.3
"	3+375NB-L	"	2064	1931	11.6	6.9	84.8
"	3+850NB-R	"	2015	1876	12.8	7.4	82.4
"	4+300SB-L	"	2047	1938	7.5	5.6	85.1
24-6-12	0+500NB-R	SUBBASE	2113	1946	9.8	8.6	85.5
"	0+500SB-L	"	1603	1505	12.5	6.5	66.1
"	1+400NB-R	"	1752	1584	13.5	10.6	69.6
"	3+375NB-L	"	1781	1622	12.3	9.8	71.2
"	3+850NB-R	"	1783	1599	15.8	11.5	70.2
"	4+300SB-L	"	1570	1478	8.5	6.2	64.9

MDD: 2278 $Kg\text{-}m^3$
OMC: 5.90%
MDD: 2277 $Kg\text{-}m^3$
6.40%

MATERIALS ENGINEER (E/R

Table 3. Grading and plasticity index results

Description	75.0mm	37.5mm	19.0mm	9.5mm	4.75mm	2.0mm	425µm	75µm	LL	PL	PI
0+100	100	99	98	92	81	68	46	36	42	26	16
0+500	99	99	95	90	78	55	29	19	32	19	13
4+250BASE	-	100	95	89	74	51	26	17	32	20	12
4+250 SUB BASE	-	100	100	99	98	95	31	19	32	18	14

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