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Comparative Cost Analysis between Asphalt Pavement and Concrete Pavement in Road Construction: A Case study using Concrete grade 35

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Abstract

Roads and Highways are vital lifelines. Roads are needed for accessibility and for transporting of people, goods and services. Roads are therefore needed for socio-economic purposes. This research aims at assessing the suitability of concrete grade 35 as an alternative pavement to as asphalt pavement in road construction. The objective of the research is to carry out investment appraisal on road project undertaken using concrete pavement and asphalt pavement and to compare their lifecycle costs and their initial cost of construction. The findings were as follows; the initial cost of the asphalt pavement was cheaper than concrete pavement. In terms of lifecycle costs, concrete pavement is cheaper than asphalt pavement. Investment appraisal methods were in favour of the asphalt pavement, however the present worth was in favour of concrete pavement. This was due to the high maintenance costs of asphalt pavement.

Keywords: Road, Highway, Investment Appraisal, Pavement.

1. Introduction

Road is a hard surface built for vehicles to travel on (Oxford Advance Learner's Dictionary, 2001). Road is also defined as a specially designed hard surface for cars, buses, bicycles, etc to travel on. The new Encyclopaedia Britannica (2003), defined the term street, road and highway as those travelled ways on which people, animals and wheeled vehicles have moved throughout recorded history.

The World book Encyclopaedia (1988), defined a road as a strip of land that provides routes for travel by automobiles and other wheeled vehicles.

World books Encyclopaedia (1988), roads usually connect urban areas with each other and rural areas. Roads are needed for accessibility. Farmers use them to ship their products to the markets. Trucks can carry manufactured products from one area to another. Good roads carry millions of automobiles that travel on business and pleasure.

Robinson et al (2004), most roads are built to facilitate the transport of people and goods, and so as to promote development. Road forms an important part of the social safety net facilitating the distribution of wealth through trade and employment opportunities in both rural and urban communities. Road also facilitates the movement of people, goods and services in all sectors for the economy, including tourism, mining, health, trade, education and agriculture. Roads are needed for socio-economic purposes. Economies and society depend heavily on efficient roads.

In the European Union, 44% of all goods are moved by trucks over roads and 85% of all people are transported by cars, buses or coaches on roads according to the European Commission (2007). Road transport remains one of the strategic sectors of Ghana's economy (Ghanaweb, 2013). Emmit and Gorse (2003), Stated that the principal requirements of a facility includes; shelter, safety and comfort, ease of use and operation, ease of maintenance, periodic repair and replacement, adaptability and durability, ability to recycle materials and components.

The overall goal is to achieve these goals in an economic, safe and timely fashion using he most appropriate resources available.

Most roads are constructed by Government. Government include Central government, Local government and Government agencies. Most roads are constructed and cared for by the state. Government helps the states and agencies pay the cost of building and improving the roads. In Ghana, the Ministry of Road and Highway is the Government of Ghana ministry responsible for road construction and maintenance. The vision of the ministry is

to provide and maintain and integrate, cost effective, safe and sustainable road network responsive to the need of users, supporting growth and poverty reduction.

In Ghana, roads are classified as national roads, regional roads and inter-regional roads. The roads are also classified based on the department managing them. These are Highways, Urban roads and feeder roads. Roads can also be classified as first class roads, second class roads and third class roads.

World book Encyclopaedia (1988), classified roads as surfaced and unsurfaced roads based on the type of surface. Roads are also classified as local and secondary roads and primary highways. Local roads carry traffic within a local area.

Secondary roads link small communities and connect local roads to main highways leading to distant places. Primary highways are the most important roads. Generally, primary highways are the main roads and connect the larger communities. Other classifications of roads are free ways (super highways) and express ways. Roads within towns and cities are called streets.

Road surface or pavement is the durable surface materials laid down as an area intended to sustain vehicular or foot traffic, such as a road or walkway (Wikipedia, 2015).

Pavement is the surface of a road, or a flat part at the side of a road for people to walk or any area of flat stones on the ground (Oxford Advanced Learner's Dictionary, 2001). Pavement materials include concrete, asphalt, stone such as flagstone, cobblestone, and sett, artificial stone, bricks, tile and wood (Seeley, 1993).

Seeley (1993) classified pavement into two categories, flexible pavement and rigid pavement. Paquette and Wright (1987) categorised pavements into rigid, flexible and composite.

Roads are constructed of either Bitumen (asphalt) or Concrete. In Ghana most roads are constructed with Bitumen, with the exception of the Accra-Tema motorway which is constructed with concrete. The cost of constructing asphalt roads continues to rise and this calls for alternative products which will serve the same purpose and function but will be less expensive and concrete has been suggested.

Concrete pavement is a durable road material comparable to asphalt pavement in performance and physical properties as well as in lifecycle costs. This research aims at analysing the comparative cost between asphalt pavement and concrete pavement in road construction.

1.1 Aim

The research aims at assessing the suitability of using concrete grade 35 as a pavement as an alternative to asphalt pavement in road construction.

1.2 Objectives

i. To compare the initial cost of concrete grade 35 pavement and asphalt pavement in roads.
ii. To compare the lifecycle of cost of concrete grade 35 pavement and asphalt pavement in road.
iii. To carry out investment appraisal on road project undertaken using concrete grade 35 asphalt pavement in roads.

2. Methodology

Primary and secondary sources of data were employed. This was achieved through informal interviews with professionals at Ghana Highways Authority, Department of Feeder Roads, and Urban Roads, Literature review of previous theses, journals and textbooks.

As part of the data collection to determine the cost of rigid pavement (concrete grade 35 pavement), a road of length one kilometre (1km) and width 10 meters was used as basis for the analysis. The profile of the road was based on a design. Measurement of the road was done and bill of quantities produced. The cost of the road project is then determined from the Bill of Quantities.

A similar exercise was done for the road constructed with asphalt and a Bill of quantities prepared for the asphalt road. The study compared the initial cost of concrete pavement and asphalt pavement as well as their lifecycle costs.

2.1 Construction of Rigid Pavement Using Grade 35 Concrete

Length of road = 1km = 1,000m

Width of road = 10m

2.2 Order of Taking Off

1. Oversite Excavations disposal
2. Compacting bottom of foundation
3. Crushed stone base and compacting
4. Blinding layer 50mm thick
5. Polythene sheet
6. Concrete Grade 35 – 150mm thick
7. Dowel bars (20mm diameter High Tensile Steel bars)
8. Fabric Reinforcement
9. Toppings 25mm thick mortar (optional)
10. Power Floating (optional)
11. Wood for expansion Joint
12. Sealing of expansion Joint
13. Formwork for concrete bed

2.3 Quantities for Concrete Road

These quantities were obtained from measurement.

1(a) over site excavation – 3,000m^3
(b) Disposal of excavated material offsite – 3,000m^3
2. Compacting bottoms of excavation - 10,000m^2
3. (a) Crushed stone base 150mm thick - 1,500m^3
(b) Compacting of crushed stone - 10,000m^2
4. Blinding layer 50mm - 10,000m^2
5. Polythene layer - 10,000m^2
6. Concrete Grade 35 - 1,500m^3
7. Dowel bars - 4,465kg
8. Fabric Reinforcement - 10,000m^2
9. Toppings 25mm thick - 10,000m^2
10. Power float - 10,000m^2
11. Wood for Expansion Joint - 6,350m
12. Sealant for expansion Joint - 6m^3
13. Formwork - 303m^2

2.4 Cost of Rigid Pavement Using Concrete Grade 35

The cost is obtained by multiplying the various quantities by their by their respective rates and summing them

AMOUNT GH¢

1(a) Oversite excavation – 3,000m^3 @ GH¢4.00/ m^2- 12,000.00
(b) Disposal of excavated material offsite – 3,000m^3 30,000.00
2. Compacting bottoms of excavated – 10,000m^3 @ GH¢2.00 – 20,000.00
3. Crushed stone base, 150mm thick – 10,000m2 @ GH¢10.50 105,000.00
4. Blinding layer 50mm – 10,000m^2 @ GH¢6.00 60,000.0
5. Polythene sheet 10,000m^2 @ GH¢3.00/m^2 30,000.00
6. Concrete Grade 35, 1,500m^3 @ GH¢425/m^3 673,500.00
7. Dowel bars (20mm bar) 4,465kg @ GH¢3.80/m^2 16,967.00

8. Fabric Reinforcement 10,000m^2 @ GH¢ 16/m^2	160,000.00
9. Toppings 25mm thick mortar 10,000m^2 @ GH¢19/m^2	190,000.00
10. Power floating of concrete bed 10,000m^2 @ GH¢2/m^2	20,000.00
11. Wood for expansion Joint 6350m @ GH¢3/m	19,050.00
12. Sealant for expansion Joint 6m^3 @ GH¢120/m^3	720.00
13. Formwork 303m^2 @ GH¢35/m^2	10,605.00
Sub Total	1,311,842.00
Add Preliminaries 5%	65,592.10
Total Cost	**1,377,434.10**

(i) Cost per kilometre = $\frac{\text{Total Cost}}{\text{Total length}} = \frac{\text{GH¢1,377,434.10}}{\text{1km}}$

Cost per kilometre = GH¢1,377,434.10/km

(ii) Cost per metre = $\frac{\text{Total Cost}}{\text{Total length in metres}} = \frac{\text{GH¢1,377,434.10}}{\text{1,000m}}$

Cost per metre = GH¢1,377.43/m

(iii) Cost per square metre = $\frac{\text{Total Cost}}{\text{Total area in metres square}}$

Cost per square metre = $\frac{\text{GH¢1,377,434.10}}{\text{10m x 1,000m}}$ = GH¢137.74/m^2

2.5 Quantities Obtained From the Measurement of Asphalt Pavement

1. Oversight Excavation – 3,000m^2
2. Compacting bottoms of Excavations - 10,000m^2
3. Crushed Stone base, 150mm thick – 1,500m^3
4. Asphalt pavement, 150mm thick – 10,000m^2
5. Wearing Course (asphalt), 25mm thick – 10,000m^2

Cost of Asphalt Pavement

	Amount in GH₵
1. Oversite Excavation 3000m3 @ GH₵ 4.00/m2	- 12,000.00
2. Disposal of excavated material 3000m^3 @ GH₵ 10.00/m^2	- 30,000.00
3. Compacting bottoms of excavation 10,000m^2 @ GH₵ 2.00/ m^2	– 20,000.00
4. Crushed Rock/Stone base 10,000m^2 @ GH₵ 10.50/m2	– 105,000.00
5. Asphalt pavement 150mm thick, 10,000m^2 @ GH₵58.00/m^2	– 580,000.00
6. Wearing course 10,000m^2@ GH₵30.00/m^2	– 300,000.00
Sub-Total	GH₵1,047,000.00
Add 5% of Preliminaries	GH₵ 52,350.00
Total Cost	**GH₵1,099,350.00**

Cost per Kilometer = $\frac{\text{Total Cost}}{\text{Total Length}}$

Cost per Kilometer = $\frac{\text{GH₵1,099,350}}{}$ = GH₵1,099,350.00/km

1km

2.6 Lifecycle Cost of Concrete Grade 35 Pavement (Per Kilometer)

Lifecycle cost is the ultimate cost of the pavement.

Analysis

Concrete Pavement (per kilometre) using grade 35 concrete

Data

i. Initial cost = GH¢1,377,434.10
ii. Lifespan = 40 years
iii. Interest rate = 30% per annum
iv. Maintenance cost per kilometre = 2% of initial cost $\frac{2}{100}$ x GH¢1,377,434.10
= GH¢27,548.68

v Summation of all Present values (ΣPV)

$$\Sigma PV = \frac{1}{1.30^1} + \frac{1}{1.30^2} + \frac{1}{1.30^3} + \frac{1}{1.30^4} + \ldots\ldots\ldots\ldots\ldots\ldots + \frac{1}{1.30^{40}}$$

ΣPV = 3.33075

vi. Lifecycle cost = annual maintenance cost x ΣPV lifecycle cost (per kilometre)
Lifecycle cost per kilometre = GH¢27,548.68 x 3.33075 per kilometre
lifecycle cost per kilometre = GH¢91,757.77

vii Total Lifecycle cost = initial cost + lifecycle cost (per kilometre)
Total lifecycle cost (per kilometre) = GH¢1,377,434.10 + GH¢91,757.77
Total lifecycle cost (per kilometre) = GH¢1,469,191.87

2.7 To Determine the Lifecycle Cost of Asphalt Pavement (Per Kilometer)

Data

(i) Initial cost – GH₵1,099.350/km
(ii) Lifespan - 20 years (with replacement)
(iii) Interest rate - 30% per annum
(iv) Maintenance cost per kilometer = 15% of initial cost per annum.

Maintenance cost per kilometer = 15/100 x GH₵1,099,350.00 per annum.

Maintenance cost per kilometer per annum = GH₵164,902.50

(v) Present value of the reconstruction cost

$$PV = \frac{\text{Cost of reconstruction}}{1.30^{20}} = \frac{GH₵1,099,350}{1.30^{20}} = GH₵\ 5,784.54$$

(vi) Summation of all Present values $\sum$ PV = 3.33075

(vi) Lifecycle cost = annual maintenance cost x $\sum$PV per kilometer
Lifecycle cost = GH₵164,902.50 x 3.33075
Lifecycle cost = GH₵549,249.00.

(vii) Total lifecycle cost = initial cost + reconstruction cost + lifecycle cost per km
(Per Kilometer)

Total lifecycle cost = GH₵ 1,099,350.00 + GH 5,784.54 + GH₵549,249.00 (per km)

Total lifecycle cost = GH₵1, 654,383.54 (per kilometre)

(i) *Cost of constructing the Highway (motorway) Using Concrete*

The Highway is 20km long, Dual carriageway and in both directions.

Cost of constructing the Road = 2 x 20km x GH¢1,377,434.10/km

Cost of constructing the Road = GH¢55,097,364.00

(ii) Maintenance cost per annum = 2% of Total Cost

$$\text{Maintenance cost per annum} = \frac{2}{100} \times \text{GH¢55,097,364.00}$$

Maintenance cost per annum = GH¢1,101,947.28

(iv) Return on Investment

Annual revenue (income) = Number of vehicles x charge per vehicle x number of days

Annual revenue (income) = 50,000 x GH¢1.00 x 365

Annual revenue = GH¢18,250,000.00

Investment Appraisal of Concrete Pavement

(i) Using the simple payback method

$$\text{Number of years} = \frac{\text{Initial Investment}}{\text{Annual returns}}$$

$$\text{Number of years} = \frac{\text{GH¢55,097,364.00}}{\text{GH¢18,250,000.00}} = 3.02 \text{ years}$$

(ii) Using Discounted Payback method (i =30% p.a.) See Table 1 at appendix

$$\text{Payback Period (Time)} = 8 \text{ years} + \left(\frac{1.720915}{1.720975} \times 12 \text{ months}\right)$$

= 8 years, 11.99 months = 9 years

(iii) Net Present Values

For a period of 40 years, the summation of all the present values is 3.33075. Given that interest rate is 30% p.a.

Total NPV = Gross Present values – Initial Investment

Total NPV = [(3.33075)(GH¢18.25m) – GH¢55.097m]

Total NPV = [GH¢60.786m – GH¢ 55.097m]

Total NPV = GH¢5.689 million

(iv) Average Rate of Return (A.R.R.)

$$\text{A.R.R.} = \frac{\text{Average returns}}{\text{Initial Investment}} \times 100\%$$

ARR = GH¢18.25m x 100% = 33.123%
GH¢55.097m

(v) Profitability Index = Σ Benefits
Σ initial investment

Profitability Index = GH¢60.78 million = 1.10325
GH¢55.097 million

(vi) Present Worth (PW)

Present Worth = initial cost + Present values of all maintenance cost over 40 years

PW = GH¢55.097m + (GH¢1.102m) (3.33075)

PW = GH¢55.097m + GH¢3.6705m = GH¢58.7675m

2.8 Investment Appraisal Of Asphalt Pavement

2.8.1 Cost of Constructing the Highway (Motorway) Using Asphalt

(i) Length of road = 20 kilometer, Dual carried way

Cost of motorway = 2 x length x cost per kilometer

Cost of motorway = 2 x 20 kilometer x GH₵ 1,099,350.00

Cost of motorway = GH₵43,974,000.00

(ii) Maintenance cost per annum = 15% of Total cost

Maintenance cost per annum = 15/100 x GH₵43,974,000

Maintenance cost per annum = GH₵6,638,543.10

(iii) Return on Investment

Annual revenue = Number of Vehicles x Charge per Vehicles x Number of Days

Annual revenue = 50,000 x GH₵1.00 x 365

Annual revenue GH₵18,250,000 = GH₵18.25 million

(i) Using the simple pay back method

Number of years = Initial investment = GH₵ 43,974.000.00
Annual returns GH₵18,250,000

Number of years = 2.4095 years = 2 years 5 months

(iii) Using Disconnected Payback method. (i = 30% per annum) See Table 2 at appendix

Payback Period = 4 years + (4.4399 x 12 months)
4.912527

Payback Period = 4 years + 10.84 months

Payback Period = 4 years 11 months.

(iv) Net Present Values

For a period of 40 years, the summation of all present values is 3.33075. Given that 2 = 30% per annum.

Total NPV = Gross Present values – Total investments.

The Asphalt pavement has a life of 20 years, therefore in 20 years time, the pavement must be reconstructed. Hence the present values of GH₵43.974 million given an interest rate 30% per annum is GH₵231,381.66.

Total NPV = Gross Present values – Total investments.

Total NPV = (3.33075) (GH₵18.25million) – (GH₵43.974million + 0.23138million)

Total NPV = GH60.7861875 – GH44.20538

Total NPV = GH 16.581 million.

(v) Average Rate of Return (ARR)

ARR = Average returns x 100% = GH₵18.25 x 100%

Initial investment GH₵43.994

A.R.R. = 41.502%.

(v) Profitability index = ∑ Benefits

∑ initial investment

Probability index = GH₵60.7861875million = 1.375

GH₵44.20538million

Present Worth (P W)

(i) Present worth for first 20 years

P W 1 = GH₵ 43. 974 million + GH₵6. 639 (3.3158)

P W 1 = GH₵ 65.9876 million

(ii) Present worth of asphalt pavement and replacement (PW2) = GH₵ 65.9876 million (0.005261783)

P W 2 = GH₵0.34721 million

Total P W = P W1 + P W2 = GH₵65.08776 million + GH₵0.3472/ million

Total P W = GH₵66.3348 million

3.0 Comments and Analysis

Construction of Rigid Pavement Using Grade 35 Concrete : See Table 3 on appendix

The analysis of breakdown of works is given in Table 3 above. The major constituents are concrete works, toppings, fabric reinforcement, crushed stone base, preliminaries and blinding layer. These constitute 46.28%, 13.79%, 11.60%, 7.61%, 4.80%, and 4.36% respectively.

Table 4 in the appendix shows the Cost of Asphalt Pavement in Ghana cedis.

The analyses of the breakdown of the cost of construction are given in table 4 above. The major components are asphalt pavement, weaning course, sub-base material and preliminaries. These constitute 52.76%, 27.29%, 9.55% and 4.78% of the total cost of constructing the pavement respectively.

4.0 Findings

(i) Using Grade 35 concrete, the initial cost of one kilometre length of road is GH¢1,377,434.10 whilst that of asphalt road is GH¢1,099,350.00 per Kilometer. Hence in term of initial cost, asphalt pavement than concrete grade 35 pavement. Hence asphalt pavement is cheaper by GH¢278,084.10 per Kilometer.

(ii) The lifecycle costs of concrete grade 35 pavement is GH¢1,469,191.87 whereas that of asphalt is GH₵1,654,383.54/km. Hence in terms of lifecycle costs, Concrete grade 35 is cheaper than asphalt pavement. Hence concrete is a cheaper pavement material. Using Concrete grade 35 as a pavement material will result in savings over the lifespan of the road.

(iii) The investment appraisal for the road project gave the following results:

(a) Using the simple payback method, the payback period for Concrete pavement is 3.02 years whilst that of Asphalt pavement is 2 years 5 months.

(b) Using the Discounted payback method, the payback period for Concrete pavement is 9 years whilst that of asphalt pavement is 4 years 11 months.
(c) The total Net Present value for the Concrete road project is GH¢5.689 million whilst that for the asphalt road project is GH₵16.581 million.
(d) Using the average rate of return, the average rate of return for the Concrete road project is 33.123% whilst that for the asphalt road project is 41.502%.
(e) The Present Worth (PW) for the Concrete road project is GH¢58.7675 million whilst that for the asphalt road project is GH₵66.3348 million. Hence Concrete pavement is cheaper than asphalt pavement in terms of present worth.

5.0 Conclusion

.In view of the findings, concrete grade 35 pavement can be used as an alternative pavement material since it is better than asphalt pavement in terms of Present Worth.

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LIST OF TABLES

Table1: Using Discounted Payback method (i = 30%)

Year	Returns (GH¢ millions)	D.C.F.	NPV (GH¢ millions)	Cumulative NPV (GH¢ millions)
0	(55.097)	1.000	((55.097)	(55.097)
1	18.25	0.76923	14.0384	(41.0586)
2	18.25	0.59172	10.79889	(30.25971)
3	18.25	0.45517	8.30685	(21.95286)
4	18.25	0.35013	6.38987	(15.56299)
5	18.25	0.26933	4.91527	(10.64772)
6	18.25	0.20718	3.78103	(6.86669)
7	18.25	0.15931	2.9085025	(3.9581875)
8	18.25	12259	2.23727	(1.7209175)
9	18.25	0.09430	1.720975	0.000575
10	18.25	0.72538	1.3238185	1.323876
11	18.25	0.05580	1.01835	2.342226
12	18.25	0.042922	0.7833265	3.1255525
13	18.25	0.033017	0.60256025	3.72811275

Table 2: Using Disconnected Payback method. (i = 30% per annum)

YEARS	RETURNS (GH₵ MILLION)	D.C.F	NPV (GH₵ MILLION)	CUMULATIVE NPV (GH MILLION
0	(43.974)	1.0000	(43.974)	(43.974)
1	18.25	0.78923	14.0384	(29.9356)
2	18.25	0.59172	10.79889	(19.13671)
3	18.25	0.45517	8.30685	(10.82986)
4	18.25	0.35013	6.38987	(4.43999)
5	18.25	0.26933	4.91527	(0.4758)
6	18.25	0.20718	3.78103	4.25631
7	18.25	0.15937	2.9085025	7.16481
8	18.25	0.12259	2.23727	9.40208

Table 3: Construction of Rigid Pavement Using Grade 35 Concrete

ITEM	DESCRIPTION OF WORKS	AMOUNT GH₵	PERCENTAGE OF TOTAL (%)
1	Oversite Excavation	12,000.00	0.87
2	Disposal of Excavated material	30,000.00	2.18
3	Compaction of bottoms of Excavations	20,000.00	1.45
4	Crushed Stone base	105,000.00	7.61
5	Blinding layer	60,000.00	4.36
6	Polythene Sheeting	30,000	2.18
7	Concrete Grade 35	637,500.00	46.28
8	Dowel bars	16,967.00	1.23
9	Fabric Reinforcement	160,000.00	11.60
10	Toppings 25mm thick mortar	190,000.00	13.79
11	Power Floating	20,000.00	1.45
12	Wood for expansion Joint	19,050.00	1.38
13	Sealant for expansion Joint	720.00	0.05
14	Formwork	10,605.00	0.77
15	Preliminaries (5%)	65,592.10	4.80
16	TOTAL	1,377,434.10	100

Table 4: Cost of Asphalt Pavement

ITEM	DESCRIPTION OF WORKS	AMOUNT (GH)	PERCENTAGE OF TOTAL (%)
1	Over site Excavation	12,000.00	1.09
2	Disposal of Excavation material	30,000.00	2.73
3	Compaction of bottoms of excavation	20,000.00	1.85
4	Sub-base of crushed stones	105,000.00	9.55
5	Asphalt Pavement	580,000.00	52.76
6	Wearing Course	300,000.00	27.29
7	Preliminaries	52,000.00	4.73
8	Total	1,099,350.00	100.00