Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2020, 7(11):66-78**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Reliability Analysis of Asphalt Plant Components of Bearing and Hot Conveyor Belt

Beke, W. V.[1], Ukpaka, C. P.[2], Nkoi, B.[3]

[1]Postgraduate Researcher, Department of Mechanical Engineering, Rivers State University Port Harcourt, Nigeria
[2]Professor, Department of Chemical/Petrochemical Engineering, Rivers State University Port Harcourt, Nigeria, E-mail:chukwuemeka24@yahoo.com
[3]Senior Lecturer, Department of Mechanical Engineering, Rivers State University Port Harcourt, Nigeria

Abstract The aim of this study was to carry out the reliability analysis of Asphalt Plant components of bearing and hot conveyor in a Construction Company located in Port Harcourt as a case study. The reliability analysis research work carried out on asphalt plant failure components for a period of five years from January 2014 to December 2018. The type of Asphalt plant in which investigation was carried out was a drum mix asphalt plant which is the most commonly used asphalt plant in Nigeria. From this research, it was observed that the components with frequent failures during production are; the bearing and hot conveyor components. This research was carried out successfully using the Monte Carlo reliability model for which the parameters such as meantime between failure (MTBF), Failure Rate (FR), Lost Time to repair also known as Downtime (DT), reliability (R), unreliability (UR), availability (A) and Unavailability (UA) were evaluated using data obtained from Asphalt plant over a five years period (January 2014 to December 2018) such as failure per year (FPy), operating time per year also known as uptime (UT) and repair time per year (RTy). The research showed that the reliability of some of the asphalt plant components such as bearing was at 74% in the first year and then decreased to 11% after the fifth year and hot conveyor for the first year was at 55% and the fifth year 5.8%, This research work recommends that the hot conveyor and bearing should be readily available for replacement in the storeroom to reduce the downtime in a year as well as to enhance productivity. The production capacity was also evaluated successfully for a five year period and it was observed that the production rate was on the decrease as the year progresses from 120 Tonnes / hour for the first year (2014) to 60 Tonnes / hour in the fifth year (2018) a drop in 50% production.

Keywords Reliability, analysis, asphalt plant, components, unreliability, downtime

Introduction

In this study, reliability models are derived from asphalt plant components considering different dependent patterns within and among component failure processes, and different maintenance policies are defined and optimized to minimize maintenance cost per unit time [1]. However, the terms reliability as well as cost are two critical parameters that need to be analyzed and optimized. Reliability of asphalt plant components subject to multiple dependent competing failure processes, and associated maintenance policies and optimization is the focus of this investigation [2].

The technological improvement requires that the analysis of the machine and equipment components should maintain high reliability with low cost in terms of unreliability. Traditional approaches of reliability analysis are sometimes inappropriate or inefficient for some new devices because either they are too reliable to observe failure time data in a reasonable time period [3-4].

For an existing asphalt plant component reliability analysis: planning of operation and maintenance activities taking into account information from e.g. condition monitoring and inspections [5]. Complex systems, reliability modeling can be a very complicated research topic involving a number of intricacies and difficulties [5]. There are different factors that can influence reliability of engineering devices and systems [6]. Environmental factors are some examples, e.g., temperature, humidity, wind speed, mechanical shocks etc [6]. Also, aging, wearing, corrosion, mechanical fatigue and other physical changes can occur due to the regular operational and environmental exposure [7-8]. For many engineering applications, it is difficult to assess system reliability because traditional estimation methods, such as those based on observing failure times (even with accelerated life testing) are not appropriate or efficient or has other limitations. However, system reliability is a very important issue and to fully investigate system reliability, possible failure mechanisms of each component should be identified to further study their effects on the components and system functions [9].

System reliability should be analyzed combining different failure mechanisms, which contributes to major effects on equipment malfunction [10]. For example, aging, unused equipment and overuse influence performances as well as increase the potential degradation and deterioration, which in turn impacts the reliability [11]. Considering liquefied natural gas asphalt plant components and the reliability of natural gas asphalt plant components have been studied [12]. Research on asphalt plant components suddenly revealed the cause incremental damage to the degradation process [13]. System reliability is a critical design characteristic that designers and manufacturers must aggressively address before introducing a new product [14].

In traditional reliability analyses, the tools of modeling in failure are used for many engineering applications. They are straight forward but have limitations. In this research, new system was considered to view the reliability models and the concepts of the model in terms of application in the useful areas of engineering [15]. Without loss of generality, both degradation processes, random shock processes, considering that they are competing and dependent, and implement appropriate maintenance policies [16].

Modern studies have been carried out on asphalt plants and the degradation on the individual components as related to reliability [17]. Studies on the failures of components and the approach of equipment handling influence the aging as well as the performance. However, quality and adequate tool used during maintains help in the standard of the plant utilization [17].

The impact of equipment aging on the environmental has been studied, however, another failure process or when asphalt plant components are simultaneously affected by some shared external stresses, the assumption of independence among asphalt plant components may not be traditional not accurately predict system reliability [18]. Therefore, new reliability models are needed to enhance the tools used in this investigation. The aim of this study is to carry out the reliability analysis of some asphalt plant components of Construction Company located in Port Harcourt as a case study.

Materials and Methods

Sampled Area

The Construction Company where samples are collected is located in Port Harcourt. The company has asphalt plant that produces a minimum of 400 tons of asphalt weekly in dry season and a minimum of 150 to 200 tons of asphalt, weekly in rain season. The company has 38 staff. The company has both atlas asphalt plant and moon asphalt plant, 11 pieces of Mack double axel truck, 2 pieces of Mack lowbed truck, 4 pieces of caterpillar, pay loader, 2 pieces of pieces of caterpillar swamp-buggy, 2 pieces of caterpillar grader, D7h caterpillar, dozzer, 4 pieces of asphalt paver machine, 1 asphalt combination roller, 2 pieces of steel to steel asphalt roller, 1 piece of 320 cat excavator, 1 piece of caterpillar back-hole, concrete mixer truck, 2 pieces of steel to tyre compactor and asphalt cutting machine.

Reliability Test

Reliability means the consistency of a measure. A measure is said to be reliable if it is consistently reproducible. Reliability, therefore, refers to whether a test that is repeated on or about a study would give the same results or not.

Methods of Data Collection

Data collection is the process of gathering data from either the primary or secondary sources for the purpose of the study analysis. The primary sources consist of first-hand information or raw data obtained by the researcher himself through the records and data collected from the company as regard to as asphalt plant. The secondary sources are existing data obtained from relevant materials such; books, journals, magazines and so on an unpublished work of others as well as valuable documents available to the researcher.

Definition of Terms

Asphalt: Asphalt is a mixture of aggregates, binder and filler, used for constructing and maintaining all kind of roads parking areas but also play and sport areas. Aggregates used for asphalt; mixtures could be crushed rocks, sand gravel or slaps.

Types of Asphalt

There are two types of asphalt they are binding and wearing cause asphalt. The difference is as a result of the stone mixture used.

Materials Used in Asphalt Production

The following materials are used such as: Stone dust also called 0-5mm, coarse aggregate 5 – 15mm called ½ inch for wearing, coarse aggregate 15 – 22mm or ¾ inch for binding, sharp sand and bitumen

Asphalt Plant

Asphalt plant refers to as the machine or equipment which is used in the production of asphalt. There are basically two types of asphalt plant, they include the batch mix asphalt plant and drum mix asphalt plant.

In this research work, the study was done on the drum mix asphalt plant used by Construction Company and it is commonly used by many asphalt production companies in Nigeria because of its low cost of maintenance. This asphalt plant ie produced by Moon Engineering works Ltd in India and has a production capacity between 80 - 120 Tons/Hour (TPH).

The components for this drum mix asphalt plant include: Dryer drum, four bin feeder, conveyor belts both inlet and outlet, electric motors, bearings, fan belt, bitumen tank, control panel, gear box, exhaust and vibrating screen. In course of carrying out this study, it was observed that there are few components that usually fail during production over a period of time and those components are the ones we carried out reliability analysis to ascertain failure rate and other parameters.

The Materials Components to be Analyzed Includes

The following asphalt components are to be analyzed in this study: Bearing, hot conveyer belt, fan belt and electric motors

Reliability Tools and Techniques

There are reliability tools and techniques methodologies available for failure of plant components. We have the Monte Carlo reliability model which can realistically assess plant condition when combined with cost, repair times and statistical events. Monte Carlo simulation model is very helpful for considering approximate operating conditions in a plant including cost effectiveness and sizing to provide protection for short duration failures.

Reliability model stimulate correctives ideas for solving costly problems and present, replication of old problems. Reliability model offer a scientific method of studying actions, responses and cost in the virtual laboratory of the computer using actual failure data from existing plants. It is noted that either Monte Carlo model is never better than the data supplied or obtained as a failure that occurs.

Model Formulation and Development

The mathematical model for this research was established by considering five (5) year study interval (S.I) as well as the number of failures (NF) and the repair time per failure (CTPF) for each of the components to be analyzed.

Mean Time between Failures (MTBF)

Mena time between failure (MTBF) for each asphalt plant components was evaluated using the mathematically expression given in equation (1), we have

$$(\text{MTBF}) = \frac{SI}{NF} \quad (1)$$

Total Mean Time between Failure (TMTBF)

To determine the total mean time between failures for each of the asphalt plant components for each year for five year period, we must first establish total failure per year.

Thus,

$$(\text{TFPy}) = \left[(\frac{1}{MTBF})_{y1} + (\frac{1}{MTBF})_{y2} + (\frac{1}{MTBF})_{y3} + (\frac{1}{MTBF})_{y4} + (\frac{1}{MTBF})_{y5}\right] x\ annual\ hr/\ yr \quad (2)$$

Therefore, the total time between failures (TMTBF) for one component of the asphalt plant for 5 years is expressed as

$$\text{TMTBF} = \frac{annual\ \ hours\ per\ year}{Total\ failure\ per\ year} = \frac{AHPY}{TFPY} \quad (3)$$

Failure Rate (FR)

To determine the failure rate for each asphalt plant component, the mathematical expression stated below can be applied,

$$\text{FR} = \frac{1}{MTBF} = \frac{1}{SI/_{NF}} = \frac{NF}{SI} \quad (4)$$

$$\text{FR} = \left[\frac{1}{MTBF}\right] = \left[\frac{NF}{SI}\right] \quad (5)$$

Total Failure Rate (TFR)

The total rate (TFR) is determined by the summation of each failure rate of each asphalt plant component investigate and is expressed mathematically as

$$TFR = [(TFR)_1 + (TFR)_2 + (TFR)_3 + (TFR)_4 + (TFR)_5] \quad (6)$$

Failure Per Year (FPY)

To determine the failure per year (FPY) for each asphalt plant to be investigated, the mathematical expression is the:

Fpy = (failure rate for each product) x (annual hour per year)

$$= (\text{FR})\ (\text{AHP}_1) \quad (7)$$

$$= \left(\frac{NF}{SI}\right)(ANPY) \quad (8)$$

$$\text{FPY} \left[\frac{1}{MTBF}\right] (\text{AHPY}) \quad (9)$$

Total Failure Per Year (TFPY)

Therefore the failure per year (TFPY) is the summation of failure per year (FPY) for each of the asphalt plant component for 5 year include

$$TFP_Y = \sum\left[(FP_y)_1 + (FP_y)_2 + (FP_y)_3 + (FP_y)_4 + (FP_y)_5\right] \quad (10)$$

Total Repair Time Per Failure (TRTPF)

The total repair time per failure (TRTPF) is determined using the mathematically expression as shown below:

$$(\text{TRTPF}) = \frac{Repair\ \ time\ \ per\ \ failure\ \ of\ \ each\ component\ \ \ x\ failure\ \ per\ \ year\ \ of\ \ each\ component}{Total\ \ failure\ \ per\ \ year} \quad (11)$$

$$= \frac{(CTPF)_1\ (FPY)_1 + (CTPF)_2\ (FPY)_2 + (CTPF)_3\ (FPY)_3 + (CTPF)_4\ (FPY)_4 + (CTPF)_5\ (FPY)_5}{TFPY} \quad (12)$$

Reliability Model

To determine the reliability of each asphalt plant component, the mathematically expression is giving as

$$R = e^{-}(\frac{1}{MTBF})^t \quad = e^{-\lambda t} \quad (13)$$

Where,

$$\lambda = \frac{1}{MTBF}$$

When as the reliability for each asphalt component for five year study is give as

$$R = e^{-}\left[(\frac{1}{MTBF})_1 + (\frac{1}{MTBF})_2 + (\frac{1}{MTBF})_3 + (\frac{1}{MTBF})_4 + (\frac{1}{MTBF})_5\right]^{t} \quad (14)$$

Unreliability model

To determine unreliability for each asphalt plant component, the mathematical expression is given by,

$$U_R = 1 - R = e^{-}(\frac{1}{MTBF})_t = 1 - e^{-\lambda t} \quad (15)$$

Availability Model

To determine availability (A) of each asphalt plant component per year.

$$A = \frac{uptime}{uptime + down\ time} \quad (16)$$

Unavailability

The unavailability (UA) for each component is determined by using the expression below

$$UA = 1 - A = 1 - \left[\frac{uptime}{uptime + down\ time}\right] \quad (17)$$

Computational Data and Reliability Analysis for Bearing Component

The bearing component of an Asphalt plant was observed to be one of the equipment with regular breakdown. Table 1 shows the data collected for the bearing for a period of 5 years (study interval) which included the failure rate per year, operating time per week and repair time to repair each breakdown per year.

Table 1: Data Collected from Asphalt Plant for Bearing Component

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	1	2	54 (2,592)
2	3	2	50 (2400)
3	5	2	46 (2208)
4	7	2	43 (2064)
5	10	2	40 (1920)

Results and Discussion

The results obtained from the investigation of an asphalt plant component for a period to 5years are represented in the table and figures respectively.

Bearing (B)

Table 1a shows the data evaluated from the bearing component using the Monte Carlo model of reliability analysis.

Table 1a: Results of Reliability Parameters for the Bearing (B).

Parameters	Period (Year)				
	1	2	3	4	5
Uptime (UT)	2592	2400	2208	2064	1920
Study Interval (SI)	8760	8760	8760	8760	8760
Meantime Between Failure (MTBF)	2592	800	441.6	294.9	192
Failure Rate (FR)	0.000114	0.000342	0.000571	0.000799	0.001140
Downtime (DT)	2	6	10	14	20
Reliability (R)	0.7442	0.4401	0.2834	0.1922	0.1121
Unreliability (UR)	0.2558	0.5599	0.7166	0.8078	0.8879
Availability (A)	0.9991	0.9975	0.9955	0.9933	0.9892
Unavailability (UA)	0.0008	0.0025	0.0045	0.0067	0.0103

Looking at the Table 1a, from the computational bearing values, it is observed that there is a decrease in the uptime (operating time) from the 1st year to the 5th year. Also decreasing yearly is the mean time between failures, while the down time (DT) increases from the 1st year to the 5th year. There was also an increase in the failure rate form their 1st year to the 5th year. Subsequently, from the investigation a bar chart was used to show the relationship between the number of years against the number of failure and downtime obtained.

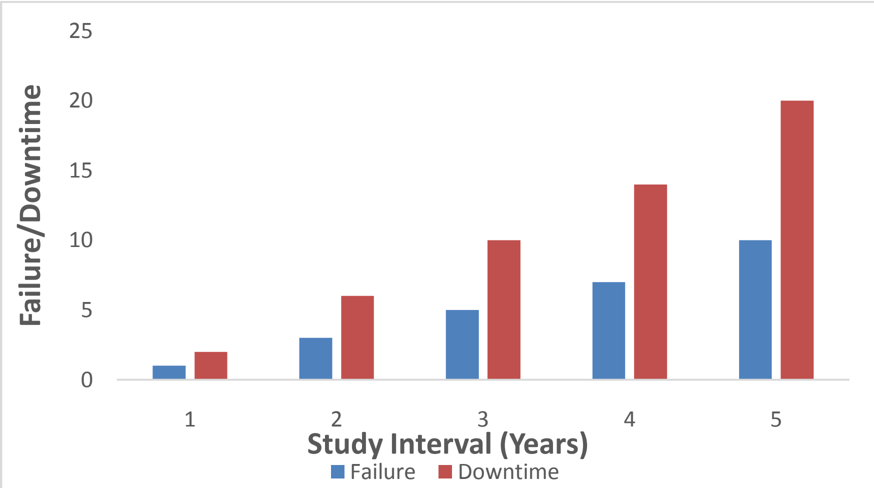

Figure 1: Number of Failure/Year and Downtime (DT) against the year

The analysis of the research on Figure 1 shows that during production as the year increases, the number of failures for the bearing component was observed to be steadily increasing from the 1st year (2014) until 5th year (2018). Figure 1 the down time was also increasing with the failure rate at from the 1st year and then steadily increasing until the 5th year. The breakdown as a result of this same component also affected the production capacity for these 5 years.

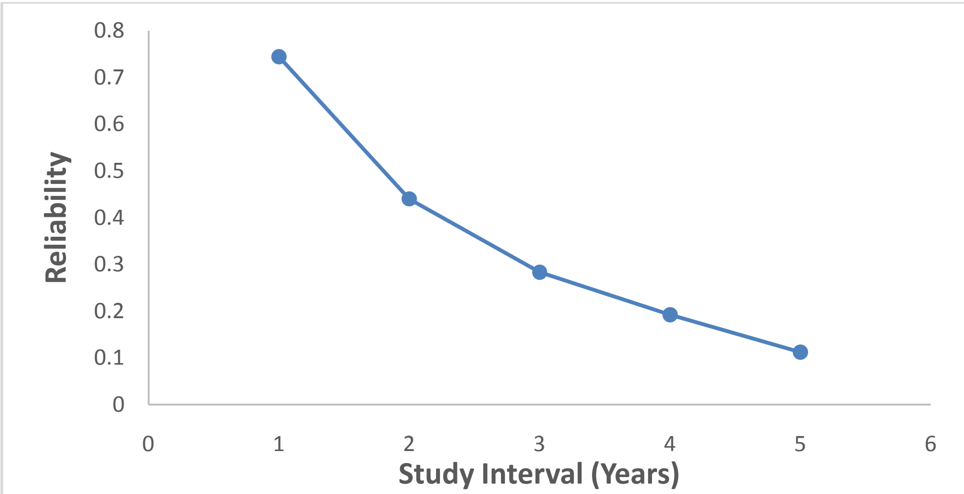

Figure 2: Reliability against the Study Interval (5 years)

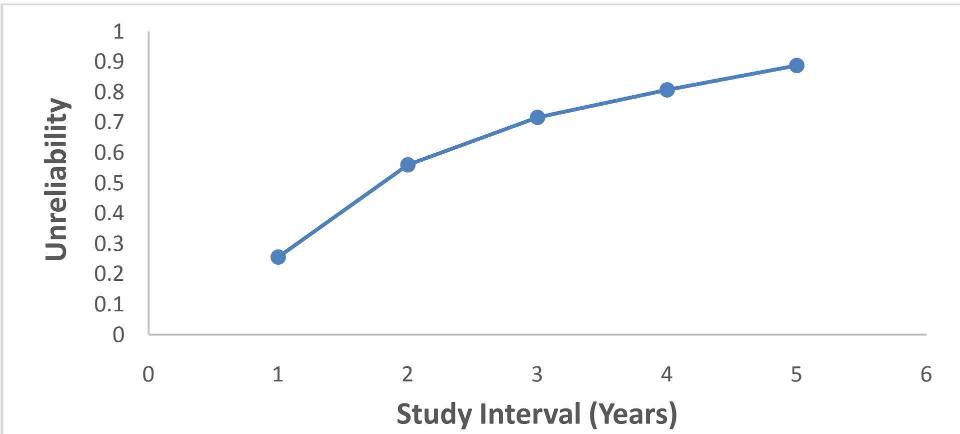

Figure 3: Unreliability against the Study Interval (5 years)

The investigation of the reliability from Figure 2 of the bearing component in the asphalt plant as graphically represented shows that the reliability is decreasing sharply. This is observed as from between the 1^{st} year and 2^{nd} year, there was a sharp drop in the reliability curve and then it continued throughout the 5 year period. The unreliability graph shows a reverse effect from the reliability graph as can be seen on Figure 3. This shows that as the year increases, the bearing component in the asphalt plant became less reliable due to regular breakdown and maintenance.

Hot Conveyor Belt

The hot conveyor belt upon investigation showed that for the 5 year period, there was a significant rise in the downtime and failure rate yearly as can be found on Table 2. The computational values for the reliability analysis were obtained using Monte Carlo method for the Hot Conveyor belt.

Table 2: Results of Reliability Parameters for the Hot Conveyor Belt (H).

Parameters	**Period (Year)**				
	1	**2**	**3**	**4**	**5**
Uptime (UT)	2592	2400	2208	2064	1920
Study Interval (SI)	8760	8760	8760	8760	8760
Mean Time Between Failure (MTBF)	2596	480	276	206.4	147.7
Failure Rate (FR)	0.000228	0.000571	0.00913	0.00114	0.00148
Downtime (DT)	24	50	72	80	104
Reliability (R)	0.5534	0.2540	0.1332	0.0931	0.0583
Unreliability (UR)	0.4466	0.7460	0.8668	0.9049	0.9417
Availability (A)	0.9910	0.9796	0.9684	0.9627	0.9481
Unreliability (UA)	0.0090	0.0204	0.0316	0.0373	0.0514

However, the meantime between failure was observed to be reducing as the operating time (uptime) is reduced yearly as found on Table 2.

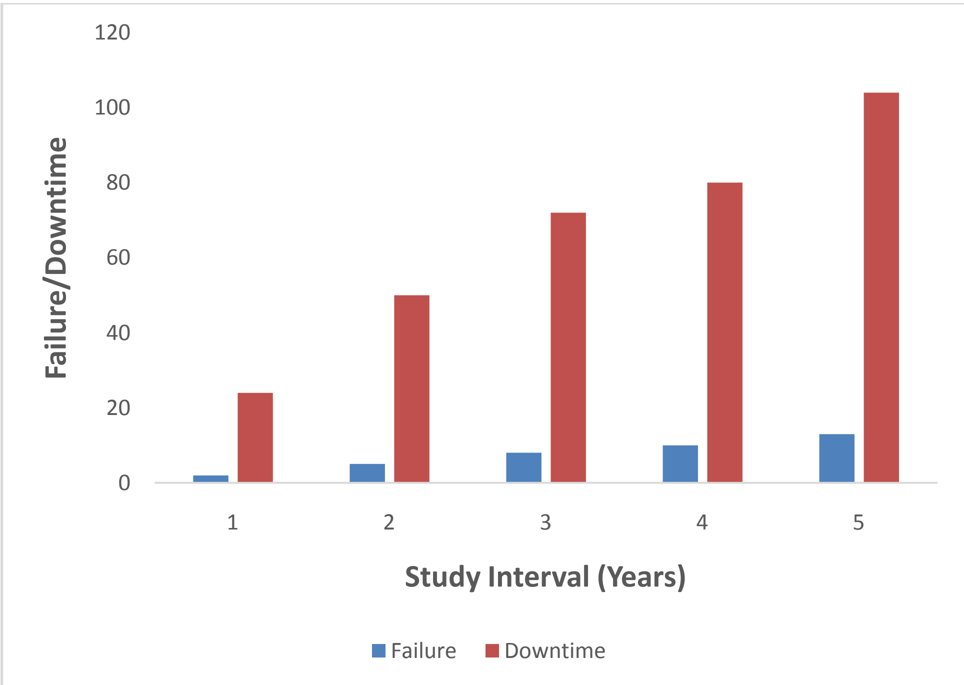

Figure 4: Number of Failure/Downtime against Study Intervals (years)

From Figure 4 it is observed that there is an increase in the failure rate and downtime over the period of 5 years same as was observed in the bearing component. This hot conveyor has more downtime than the bearing because it takes at least 24 hours to repair a broken conveyor; hence the downtime time gradually increases for the entire 5 year period.

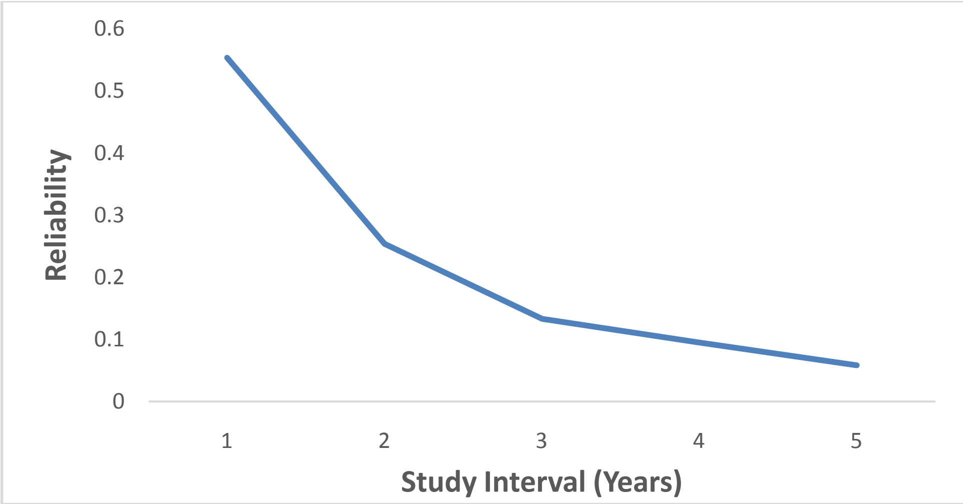

Figure 5: Reliability Analysis of the Asphalt Plant Hot Conveyor Belt for a 5 Year Period

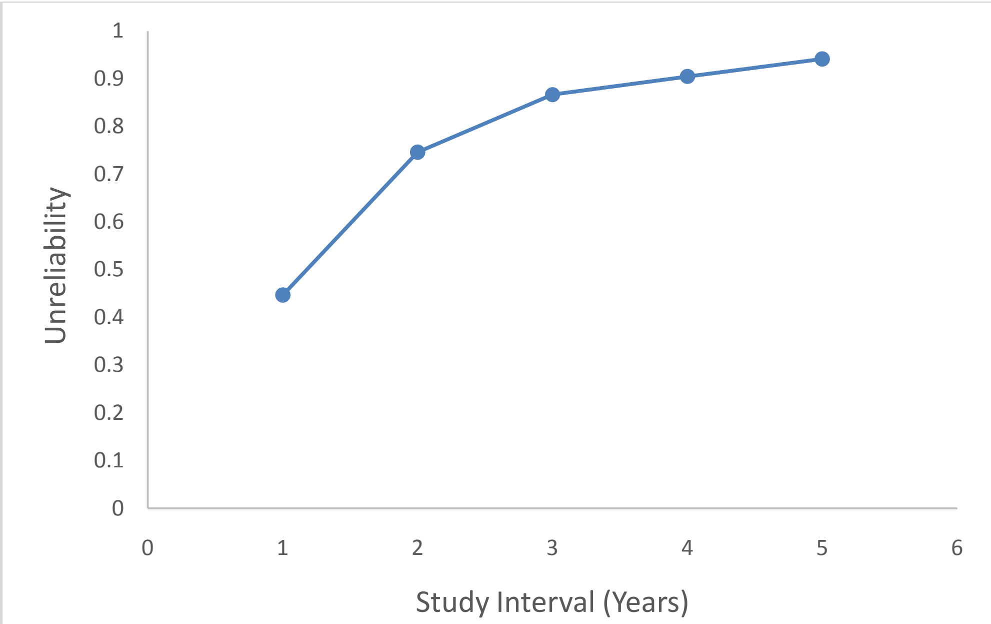

Figure 6: Unreliability Analysis of the Asphalt Plant Hot Conveyor Belt for a 5 Year Period

There is a sharp decrease in reliability in Figure 5 and an increase in Figure 6 (unreliability) as in case of the bearing component. The reliability was decreasing as the failure rate was increasing, while the unreliability was increasing. This shows that the hot conveyor belt was becoming less reliable yearly due to regular breakdown and repairs.

Production Capacity of Plant for 5 year Period

The production capacity from the company records are shown in the Table 3. The production capacity, quantity of asphalt produced and the production time for a 5 year period.

Table 3: Production Capacity of Asphalt Plant for a 5 year Period

Year	Capacity (Tonnes/Hour)	Production Time (Hours)	Quantity Produced (Tonnes)
1	120	2592	311,040
2	110	2400	264,000
3	93	2208	205,344
4	85	2064	175,440
5	60	1920	115,200

From the Table 3 it observed that the steady downtime obtained by these various asphalt plant components over the years has affected the production rate of the plant. From the first year, the production capacity has its maximum operating time which produced about 311,040 Tons of asphalt. The decrease started to occur as a result of the downtime experienced by the plant which led to 115,200 tons of asphalt produced in the 5th year as shown in Table 5.

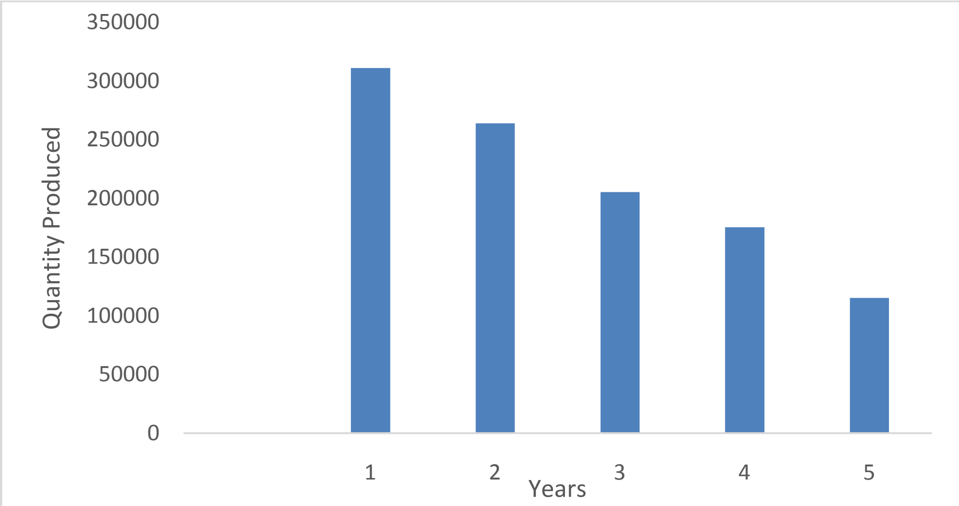

Figure 7: Production Capacity of Plant from 2014 to 2018

From Figure 7 the consequences of the frequent breakdown of bearing and hot conveyor has caused the asphalt plant to drop to less than 50% production capacity within a 5 year period from 2014 to 2018.

To Evaluate the Operating Time Per Year

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1st year = 54 x 4 x 12 = 2592 hrs/y, for 2nd year = 50 x 4 x 12 =2400 hrs/y, for 3rd year = 46 x 4 x 12 = 2208 hrs/y, for 4th year = 43 x 4 x 12 = 2064 hrs/y and for 5th year = 40 x 4 x 12 =1920 hrs/y

Total operating times = 2592 + 2400 + 220 + 2064 + 1920 = 11184 hrs/y

Mean Time between Failures (MTBF) for the Bearing (B)

MTBF = $\frac{Operating\ \ times}{no\ of\ failure}$

For 1st year = $\frac{2592}{1}$= 2592 hrs, for 2nd year =$\frac{2400}{3}$ = 800 hrs, for 3rd year = $\frac{2208}{5}$ = 441.6 hrs, for 4th year = $\frac{2064}{7}$ = 294.9 hrs and for 5th year = $\frac{1920}{10}$ = 192 hrs

Total mean time between failures for the bearing for (B) for 5 year

= TMTBF = $\frac{Annual\ \ hours\ per\ year}{Total\ failure\ \ per\ year} = \frac{(Y1+Y2+Y3+Y4+Y5)}{1+3+5+7+10}$

= $\frac{2592+800+441.6+294.9+192}{1+3+5+7+10}$

TMTBF = $\frac{4320.5}{26} = 166.17 hrs/failure$

Failure Rate for the Bearing (B) per year

Failure rate = $\frac{Number\ \ of\ failure\ \ per\ \ year}{study\ \ intrval\ \ (hours\ )}$

Study interval = 1 year x 24 hours $\tilde{-}$ 365 x 24 = 8760 hours/year

For 1st year = $\frac{1}{8760}$= 0.000114, for 2nd year = $\frac{3}{8760}$ = 0.000342, for 3rd year = $\frac{5}{8760}$ = 0.000571, for 4th year = $\frac{7}{8760}$ = 0.000799 and for 5th year = $\frac{10}{8760}$= 0.00114

Total failure rate for 5 years = $\sum$ failure rate/year

= 0.00114 + 0.000342 + 0.000571 + 0.000799 + 0.00114 = 0.002966 /year

Lost Time per year for the Bearing (B)

Lost time per years = failure of each component per year x Repair Time

For 1st year = 2 x 1 = 2, for 2nd year = 2 x 3 = 6, for 3rd year = 5 x 2 = 10, for 4th year = 7 x 2 = 14 and for 5th year = 10 x 2 = 20

Reliability Analysis (R) for Bearing (B)

Reliability, $R = e^{-\lambda t}$

Where, λ = failure rate/year, t = operating time/year

For 1st year = $e^{0.000114\ x\ 2592}$ = 0.7442 = 74.42%, for 2nd year = $e^{0.000342\ x\ 2400}$ = 0.4401 = 44.01%, for 3rd year = $e^{0.000571\ x\ 2208}$ = 0.2834 = 28.34%, for 4th year = $e^{0.000799\ x\ 1920}$ = 0.1922 = 19.22% and for 5th year = $e^{0.00114\ x\ 1920}$ = 0.1121 = 11.21%

Unreliability (UR) for Bearing

Unreliability = 1 – R

Where, R = Reliability, for 1st year = 1 – 0.7442 = 0.2558, for 2nd year = 1– 0.4401 = 0.5599, for 3rd year = 1 – 0.2834 = 0.7166, for 4th year = 1 – 0.1922 = 0.8078 and for 5th year = 1 – 0.1121 = 0.8879

Availability (A) for the Bearing (B)

Availability (A)=$\frac{uptime}{uptime\ +downtime}$

For 1st year = $\frac{2592}{2592+2}$ = 0.9992, for 2nd year = $\frac{2400}{2400+6}$ = 0.9975, for 3rd year = $\frac{2208}{2208+10}$ = 0.9955, for 4th year = $\frac{2064}{2064+14}$ = 0.9933 and for 5th year = $\frac{1920}{1920+20}$= 0.9897

Unavailability (UA) for Bearing (B)

Unavailability = 1 – A

Where, A = Availability, for 1st year = 1- 0.9992 = 0.0008 ≃0.8%, for 2nd year = 1- 0.9975 = 0.0025 ≃0.25%, for 3rd year = 1- 0.9955 = 0.0045 ≃0.45%, for 4th year = 1- 0.9933 = 0.0067 ≃0.67% and for 5th year = 1- 0.9897 = 0.0103 ≃1.03%

Computational Data and Reliability Analysis forHot conveyor Belt

The hot conveyor belt component of Asphalt plant was analyzed from the data obtained from the Asphalt Plant. Table 4 shows the data collected for the hot conveyor belt for a period of 5 years (study interval) which included the failure rate per year, operating time per week and repair time to repair each breakdown per year.

Table 4: Data Collected from Asphalt Plant for Hot Conveyor Belt Component

Yrs	Failures/y	Repair Time/Year	Operating Hours /week
1	2	12	54hrs/w
2	5	10	50hrs/w
3	8	9	46hrs/w
4	10	8	43hrs/w
5	13	8	40hrs/w

To Evaluate the Operating Time Per Year

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1styear = 54 x 4 x 12 = 2592h/y, for 2nd year = 50 x 4 x 12 = 2400h/y, for 3rd year = 46 x 4 x 12 = 2208h/y, for 4th year = 43 x 4 x 12 = 2064h/y, for 5th year = 40 x 4 x 12 = 1920h/y

Mean Time between Failure for Hot Conveyor Belt

MTBF = $\frac{Operating\ \ time}{no\ of\ failure}$

For 1st year = $\frac{2592}{2}$ = 1296h, for 2nd year = $\frac{2400}{5}$= 480h, for 3rd year = $\frac{2208}{8}$ = 276h, for 4th year = $\frac{2064}{10}$ = 206.4h and for 5th year = $\frac{1920}{13}$ = 147.7h

(ii) Total mean time between failures for hot conveyor belt for 5yrs

TMTBF = $\frac{total\ \ annual\ \ hour\ \ per\ \ year}{Total\ \ failure\ \ per\ \ yera}$

$= \frac{1296+480+276+206.4+147.7}{38} = \frac{3036.1}{38}$ = 79.90

Failure Rate for the Hot Conveyor Belt Per Year

Failure rate = $\frac{number\ \ of\ failure}{study\ \ interval} = \frac{NF}{SI}$

Study interval (hours) = 1 year x 24 hours = 365 x 24 = 8760 hours/year

For 1st year = $\frac{2}{8760}$= 0.0002283, for 2nd year = $\frac{5}{8760}$ = 0.000571, for 3rd year = $\frac{8}{8760}$ = 0.000913, for 4th year = $\frac{10}{8760}$= 0.00114 and for 5th year = $\frac{13}{8760}$ = 0.00148

Total failure rate for 5 years = $\sum failures/year$

= 0.0002283 + 0.000571 + 0.000913 + 0.00114 + 0.00148 = 0.00433

Lost time per year for Hot Conveyor Belt

Lost time year = failure of each component per year x repair time

For 1st year = 2 x 12 = 24 hours, for 2nd year = 5 x 10 = 50 hours, for 3rd year = 8 x 9 = 72 hours, for 4th year = 10 x 8 = 80 hours and for 5th year = 13 x 8 = 104 hours

Reliability (R) for Hot Conveyor Belt

$R = e^{-\lambda t}$

Where, λ = failure rate/year, t = operating time/year, for 1st year = $e^{-0.0002283\ x\ 2592}$ = 0.5534 ≃55.34%, for 2nd year = $e^{-0.000571\ x\ 2400}$ = 0.2540 ≃25.40%, for 3rd year = $e^{-0.000913\ x\ 2208}$ = 0.1332 ≃13.32%, for 4th year = $e^{-0.000114\ x\ 2064}$ = 0.0951 ≃9.51% and for 5th year $e^{-0.000148\ x\ 1920}$ = 0.0583≃5.83%

Unreliability (UR) for Hot Conveyor Belt

Unreliability (UR) = 1 –R

Where, R = Reliability

Therefore, for 1st year = 1- 0.5534 = 0.4466 ≃44.66%, for 2nd year = 1- 0.2540 =0.746 ≃74.6%, for 3rd year = 1- 0.1332 = 0.8668 ≃86.68%, for 4th year = 1- 0.0951 = 0.9049 ≃90.49% and for 5th year = 1- 0.0583 = 0.9417 ≃94.17%

Availability (A) for Hot Conveyor Belt

Availability (A) = $\frac{uptime}{Uptime\ +downtime}$

For 1st year = $\frac{2592}{2592+24}$ = 0.9910 ≃99.1%, for 2nd year = $\frac{2400}{2400+50}$ = 0.9796 ≃97.96%, for 3rd year = $\frac{2592}{2208+72}$ = 0.9684 ≃96.84%, for 4th year = $\frac{2064}{2064+80}$ = 0.9627 ≃96.27% and for 5th year = $\frac{1920}{1920+104}$ = 0.9486 ≃ 94.86%

Unavailability (UA) for Hot Conveyor Belt

Unavailability = 1- A

Where, A = Availability, for 1st year =1- 0.9910 = 0.009 ≃ 0.9%, for 2nd year = 1- 0.9796 = 0.0204 ≃2.04%, for 3rd year = 1- 0.9684 = 0.0316 ≃3.16%, for 4th year =1- 0.09627 = 0.0373 ≃3.73% and for 5th year = 1- 0.9486 = 0.0514 ≃5.14%

Production Capacity of Asphalt Plant Studied

The yearly production capacity for the Asphalt Plant was obtained from company records as found on Table 5 below.

Table 5: Production Time and Capacity of Asphalt Plant From 2014-2018

Year	Capacity (Tons/Hour)	Production Time per year (Hours)
1	120	2592
2	110	2400
3	93	2208
4	85	2064
5	60	1920

To calculate the Quantity of Asphalt produced (Tons) by Asphalt plant for the period of 5 years.

Quantity Produced = Production Capacity X Production Time

For 1st year = 120 Tons/ hour X 2592 hours = 311,040 Tons, 2nd year = 110 Tons/ hour X 2400 hours = 264,000 Tons, 3rd year = 93 Tons/hour X 2208 hours = 205,344 Tons, 4th year = 85 Tons/hour X 2064 hours = 175,440 Tons and 5th year = 60 Tons/hour X 1920 hours = 115,200 Tons

Conclusion

This research was carried out mainly on asphalt plant failure component of bearing and hot conveyor belt during production for a 5 year period. This investigation shows that these failures of the components either breakdown or fails during production after operating for several hoursover a period of time running into years, if components of bearing and hot conveyor beltare not properly maintained or changed, the tendency of influencing the production capacity negatively can occur. These components include the hot conveyor belt and the bearing as considered in this study. The Monte Carlo method was used for the successful evaluation of the reliability analysis of the Asphalt Plant components. The method was successfully used to evaluate the reliability of the asphalt plant failure components during production. The Monte Carlo analysis was used to evaluate parameters such as the mean time between failure, failure rate, reliability, unreliability, availability and unavailability for each component as shown in Tables 1a and 2.

From the research work, it was also observed that the failure and break down of these components affected the production capacity over these 5 year period at which the capacity decreases as the year increases and the components become less reliable. In all these, we can conclude that the reliability of asphalt plant component was carried out successfully and that the failure components are determinant factors to production capacity which must be critically looked into to enhance productivity.

In evaluating the reliability of asphalt plant components such as the bearing, hot conveyor belt,some functional parameters such as the uptime, study interval, downtime, meantime between failure, reliability and unreliability were determined. It shows that the reliability of these components was decreasing as the year increases giving rise to decrease in production of asphalt for the five year study interval.

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