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Evaluation of Optimum Asphalt Yield of a Process

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Abstract
This study is on evaluation of optimum asphalt yield of a process. The data used is a secondary data collected from the records department of Consolidated Contractors Company Nigeria Ltd (C.C.C) between years 2008-2010. A fitted trend equation was obtained which enables prediction of the production yield at any point in time. The trend line estimated from a 12 point centered moving average showed a sharp fall in the production yield of asphalt and a slight rise in the month of August for the three years period. The seasonal analysis showed from the result of the seasonal indices that the month of July has the least production of asphalt and this can be attributed to the presence of heavy rain fall which primarily affects the production of asphalt. Also, regression analysis was used to develop two models that expresses the nature of relationship between the production yield and factors such as Temperature, Humidity, Rainfall, Efficiency(environmental factors), Stone-dust/sand mixture, chippings of various sizes C5, C10, and Bitumen(material factors). Finally, it was established from analysis that the best regression model for predicting the production yield of asphalt is the material factor fitted equation.
Key words: Trend, Seasonal index, Environmental factors, Time series

1. Introduction

The primary use of asphalt is in road construction, where it is used as the glue or binder mixed with aggregate particles. Asphalt is a heavy, dark brown to black mineral substance, one of several mixtures of hydrocarbons called bitumen. Asphalt is a strong, versatile weather and chemical-resistant binding material which adapts itself to a variety of uses. Asphalt binds crushed stone and gravel (commonly known as aggregate) into firm, tough surface for roads, streets, and airport run-ways. Asphalt, also known as mineral pitch, is obtained from either natural deposit such as native asphalt or Brea or as a byproduct of the petroleum asphalt. The use by early civilizations occurred naturally and were found in geologic strata as either soft, workable motars or as hard brittle black veins of rock formations (also known as asphaltic coal). Natural asphalt was extensively used until the early 1900s when the discovery of refining asphalt from crude petroleum came in place.

Modern petroleum asphalt has the same durable qualities as naturally occurring asphalt. However, the mix design ratio of asphalt produced by construction companies varies and this invariably determines the life span of any road built with it before it shows signs of cracking. In other words, the higher the durability of the asphalt, the longer the life span of the road design asphalt, the smoother the road made with such quality of asphalt. Consequently, many factors are responsible for the yield of asphalt produced by many established asphalt producing companies in Nigeria.

These factors include poor operational processes in asphalt making, the type of machine (man power) used, sand-stone-dust-chippings ratio, sand-stone-dust-bitumen ratio, Bitumen-stone-dust absorption rate, the type of stone dust, quality of material/bitumen used in mixing operations, quality of bitumen used in producing the asphalt, the use of Bitumen that is not heated up to (150 - 170^{0}C) depending on where the asphalt is to be conveyed to, poor mixing of sand and stone dust adopted before processing, among others. These factors have adversely affected the desired yield of the asphalt for road construction and sometimes lead to collapsing of roads in various states in Nigeria. In road building asphalt itself is a mixture of elements depending on the road specification, which could be for weary courts, binder courts, athletic courts etc. The constituents are namely Gravel, Sharp Sand, Quarry Dust (Crushed Stone) and Bitumen. However, the flow chart of Figure 1 clearly depicts the Asphalt production process of Consolidated Construction Company Nigeria Limited (CCC).

2. Background Of Study

Hot Mix Asphalt (HMA) production is generally subcontracted to the HMA producers by state ministries of works, Federal Road Maintenance Agency, etc. As a control procedure, these government institutions investigate the performance of the final asphalt product and determine the pay factor (Russell et al. 2001), which ultimately determines the amount of payment to the subcontractor. Not surprisingly, one of the main elements of the pay factor determination is the quality of the asphalt.

Schmitt et al. (1997) report that quality control costs of a typical asphalt manufacturer are approximately

2% of total HMA construction costs. Nevertheless, as inferior quality asphalt products may lead to repaving of a road, the actual quality costs would be higher where mixing, trucking, and paving costs correspond to 38% of total HMA construction costs.

Kuo et al. (1996) proposed a method to improve the accuracy of gradation estimation by image analysis in HMA production. However, their research is very limited to the size of the particles; fine particles cannot be easily detected (especially #200 sieve, the finest aggregates).

West (2005) proposed state-of-the-art equipment that can be used in monitoring HMA production such as, microwave probes (for moisture). In his study, video imaging techniques are mentioned as near future technology.

3. Material and Methods

Data on the daily production yield of asphalt with the daily weather conditions for month over three years was collected from the Consolidated Contractors Company Ltd; oral interview, library books, and report write ups from different periodicals were utilized judiciously, see Table 1 for details.

3.1. Source of Data

The source of data used for this study is;

- Secondary data

The secondary data source of information includes;

- Data, from the records department.
- Data, from the laboratory department
- Data, from the machine operator

3.2. Time Series

A time series describes the variation in the value of a variable through time. Such variations or movement are result of systematic, as well as random behavior of the variables. The aim of the series analysis is to break down the time series into distinct components representing the effect of their various movements.

3.3. Multiple Regressions

Multiple regression measures the nature of relationship between more than two variables. When more than one independent variable explains the variations in the response variable, the model will be called a *multiple regression* model expressed as:

$$y = b + b_1x_1 + b_2x_2 + \cdots b_ix_i + b_mx_m \quad (1)$$

In this work the dependent variable is the production yield of asphalt while the independent variables are temperature, humidity, rainfall, efficiency, S, C5, C10 and B.

4. Analysis of Data and Discussion

The flow chart that aids minitab15 software analysis of data is as presented in Figure 2.

4.1. Time Series Analysis

Through the application of the Time Series analysis a graphical behavior of the monthly production yield of Asphalt of company under study is represented by Figure 3.

4.2. Estimation of Trend Using a 12 Monthly Centered Moving Average

Table 3 will be used to find the trend line for the monthly number of production yield of CCC Nig. Ltd. Since, the data exhibit a natural 12-monthly cycle, the method of moving average is used. Table 2 is the summary of the moving average analysis using the Minitab.

4.2.1. Trend Analysis

The fitted Trend Equation is obtained as in equation (2) and graphically represented by Figure 4.

$$Y_t = 85.6671 + 2.00808^{*}t \quad (2)$$

4.3. Seasonal Analysis in the Production Yield of Asphalt

Estimation of the seasonal influence on the production yield of asphalt, table 3 shows the seasonal analysis summary result using the Minitab package, which is graphically represented by Figure 5.

5. Regression Analysis

Using table1, where interest is on a model that expresses the nature of relationship between the production of asphalt yield and other factors of interest. Here the yield is the dependent variable and Temperatures (degree), Humility (%), Rainfall (mm), and Efficiency (%) are the independent variables. The proposed model is

$$Yield = \beta_0 + \beta_1 Temperature + \beta_2 Humidity + \beta_3 Rianfall + \beta_4 Efficiency + \varepsilon \quad (3)$$

We can also model another regression fitted equation where the yield still remains the dependent variable and the various asphalt material such as S, C5, C10 and B are the independent variables. The propose model is

$$Yield = \beta_0 + \beta_1 S + \beta_2 C5 + \beta_3 C10 + \beta_4 B + \varepsilon \quad (4)$$

The aim of the regression analysis is to build a mathematical model that will help make predictions about the impact of variable variations. The result of the multiple linear regression analysis is as presented below;

5.1. Minitab output and Environmental factor Regression Analysis

The regression equation is obtained as

$$Yield = 23310 + 15.5Temperature + 1.07Humidity + 0.017Rainfall - 267Efficiency \quad (5)$$

$R^2 = 16.1\%$; $R^2(adj) = 5.3\%$; *and* $Analysis\ of\ Variance, p = 0.23$

5.2. Material factor model Regression Analysis

The regression equation is

$$Yield = 0.449 + 0.9915 + 1.03C5 + 1.01C10 + 0.964B \quad (6)$$

$R^2 = 100.0\%$; $R^2(adj) = 100.0\%$; *and* $Analysis\ of\ Variance, p = 0.0000$

6. Discussion Of Results

Observe that the Table 2 shows the detailed summary of the 12 months centered moving average and the trend analysis. Equally a trend fitted equation was obtained, where Y_t is the yield at time ”t”, note that time here is generic for this research month. The fitted equation will help us to predict the production yield of asphalt at CCC given any time.

Note that from figure 4 graph one can observe that there is always a sharp fall in production of asphalt during the month of June, July and a slight rise in the month of August.

From the table 3 we can observe that there exist a sharp fall in the seasonal index for the period 6 (June), 7 (July) and a slight rise in period 8(August). Where the period 7(July) has the least index. The fall in production of asphalt can be attributed to the presence of heavy rain fall which affects the production of asphalt. This was expressed graphically in figure5.

Also, the coefficient of determination for the model of (5) obtained as r^2= 16.1% means that 16.1% of variation in the dependent variable (yield) is explained by the variation in the independent variable (environmental factors), with analysis of variance p value of 0.23 showing that the model is not significant and that the factors are not mainly responsible for the variation in the yield of asphalt.

Also, the coefficient of determination for the model of (6) obtained as r^2= 100% and p value 0.00; means that the model is best for predicting the production yield of asphalt, since the coefficient of determination shows a very strong relationship.

7. Conclusion

A fitted trend equation was obtained as to predict the monthly production yield at any point in time.

From the seasonal analysis, it is observed that the influence of the season on the production yield of asphalt is least in the month of July. This could be attributed to the presence of heavy down pour (rain) in the month of July which primarily affects the production of asphalt.

A predictive model for the production of asphalt is established.

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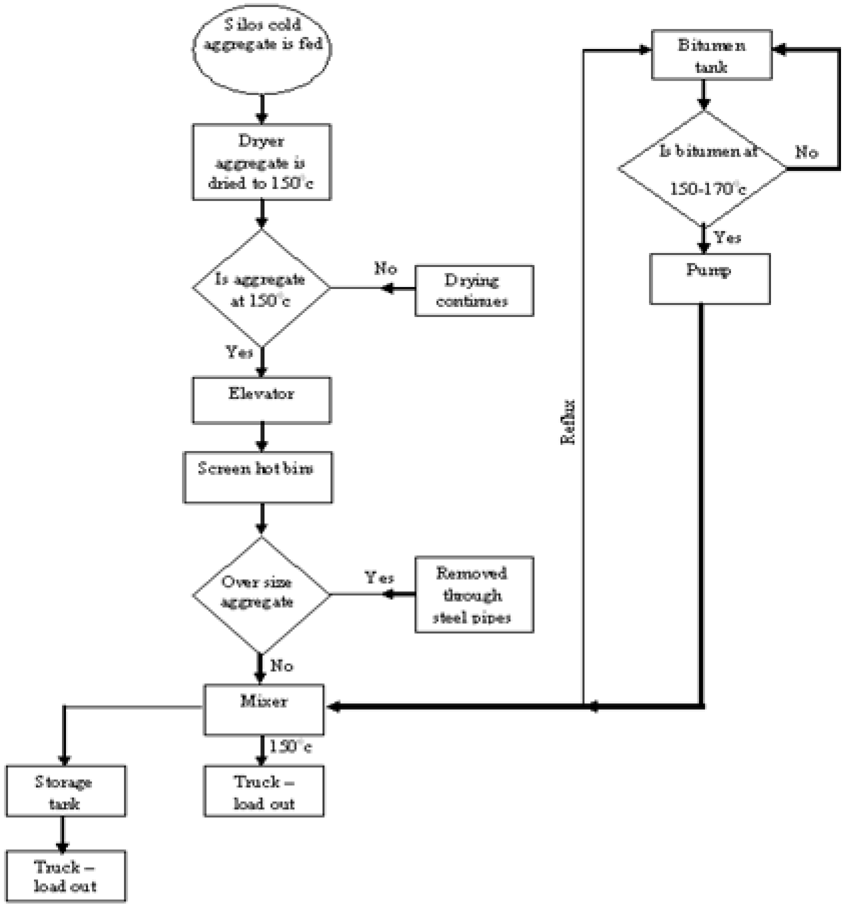

Figure 1: Asphalt Production Process Flow Chart of CCC

Table 1: Presentation of Monthly Data Collected from CCC (Nig) Ltd (2008-2010)

Year	Month	Yield	Temperature	Humidity	Rainfall	Efficiency	S	C5	C10	B
2008	Jan	146.3	28.4	76	11.2	88.9	90.7	20.7	26.3	8.7
	Feb.	87	30	80	0.7	88.9	54.3	12	15.8	5
	mar	86.3	30.7	76	50.6	88.9	53.6	12.1	15.4	5.1
	Apr	181.1	29.2	81	121.1	88.9	112.4	25.3	32.6	10.9
	may	180	28.3	81	233.1	88.9	111.4	25.2	32.6	10.8
	Jun	105.5	27.6	85	248.3	88.9	65.5	14.8	19	6.3
	Jul	55.3	26.7	89	386.6	88.9	34.5	7.5	10	3.3
	Aug	53.6	26.7	87	283.3	88.7	33.1	7.4	9.9	3.3
	Sep	79.9	26.9	86	249.4	88.7	49.4	11.3	14.3	4.9
	Oct	39.2	26.9	85	376	88.8	24.4	5.6	7	2.2
	Nov	65.8	27.6	73	96.3	88.8	40.8	9.5	11.7	3.8
	Dec	120.3	28.8	76	0	88.7	74.8	16.8	21.5	7.3
2009	Jan	100.4	29	72	0.2	88.9	62	14.1	18.2	6.1
	Feb	46.5	30.4	72	66.8	88.9	28.8	6.6	6.4	2.7
	Mar	98	30.8	73	13.6	88.9	60.8	13.8	17.6	5.8
	Apr	77	29.7	79	203.5	88.9	47.7	10.8	14	4.5
	May	164.5	28.7	81	161.3	88.9	102	23	29.5	10
	Jun	80	27.7	84	191.9	88.9	56	10.2	10	3.8
	Jul	42	27	84	13.2	88.9	28.5	6.1	5.3	2.1
	Aug	104.3	27.2	86	299.9	88.8	64.5	14.8	18.8	6.25
	Sep	259	27	87	306.4	88.8	160.6	36.2	46.6	15.5
	Oct	153.1	27.3	85	166.9	88.7	95.3	21.3	27.4	9.1
	Nov	232.1	28.6	82	412	88.7	144.1	32.4	41.9	13.4
	Dec	160.5	28.3	71	0	88.7	99.5	22.5	28.9	9.6
2010	Jan	52	26.5	53	0	88.8	29.9	7.2	9.4	3.2
	Feb	147.2	29.8	74	18.5	88.8	91.3	20.7	26.5	8.8
	Mar	126.7	30.6	75	59.9	88.8	79	17.7	22.7	7.3
	Apr	164.5	29.3	78	100.7	88.8	102	23	29.5	10
	May	205.6	28.3	83	281.4	88.7	127.7	28.7	37	12.3
	Jun	129	27.6	73	115.1	88.7	80	18	23	8
	Jul	106.2	27	74	256.5	88.7	83	15	6	2.2
	Aug	72	27.6	79	234	88.8	32	11.2	18.8	10
	Sep	120	27.9	76	95	88.8	76	22	10	12
	Oct	150.3	28.1	74	81	88.6	98.7	22.5	20	9.1
	Nov	250	28.6	72	2	88.8	153.3	43.3	40.9	12.5
	Dec	180.2	28.1	70	0	88.7	120	25.6	28.3	6.3

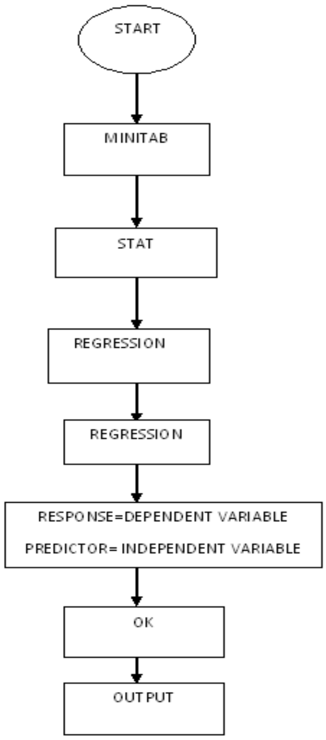

Figure 2: Flow Chart for the Regression Analysis Executed in Minitab Software

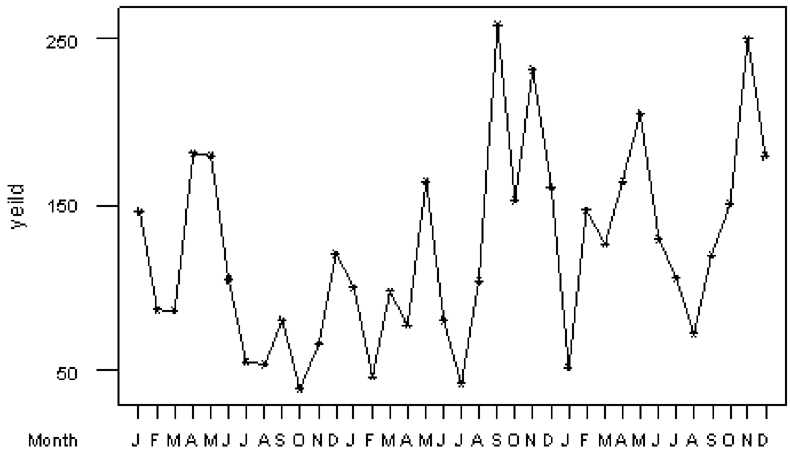

Figure 3: Monthly Production Yield of Asphalt at CCC from 2008-2010

Table 2: Moving Average and Trend Analysis

Row	Period	Yield	AVER1	Predict	Error
1	1	146.3	*	*	*
2	2	87.0	*	*	*
3	3	86.3	*	*	*
4	4	181.1	*	*	*
5	5	180.0	*	*	*
6	6	105.5	*	*	*
7	7	55.3	98.112	*	*
8	8	53.6	94.512	*	*
9	9	79.9	93.313	*	*
10	10	39.2	89.463	*	*
11	11	65.8	84.479	*	*
12	12	120.3	82.771	*	*
13	13	100.4	81.154	*	*
14	14	46.5	82.712	98.112	-51.612
15	15	98.0	92.287	94.512	3.488
16	16	77.0	104.496	93.313	-16.313
17	17	164.5	116.171	89.463	75.037
18	18	80.0	124.775	84.479	-4.479
19	19	42.0	124.433	82.771	-40.771
20	20	104.3	126.613	81.514	23.146
21	21	259.0	132.004	82.712	176.288
22	22	153.1	136.846	92.287	60.813
23	23	232.1	142.204	104.496	127.604
24	24	160..5	145.958	116.171	44.329
25	25	52.0	150,675	124.775	-72.775
26	26	147.2	152.004	124.433	22.767
27	27	126.7	144.867	126.613	0.087
28	28	164.5	138.958	132.004	32.469
29	29	205.6	139.588	136.864	68.754
30	30	129.0	141.154	142.204	-13.204
31	31	106.2	*	145.958	-39.758
32	32	72.0	*	150.675	-78.675
33	33	120.0	*	152.004	-32.004
34	34	150.3	*	144.867	5.433
35	35	250.0	*	138.958	111.042
36	36	180.2	*	139.588	40.612

The accuracy estimates are: MAPE = 41.72 , MAD = 49.63, MSD = 4277.83

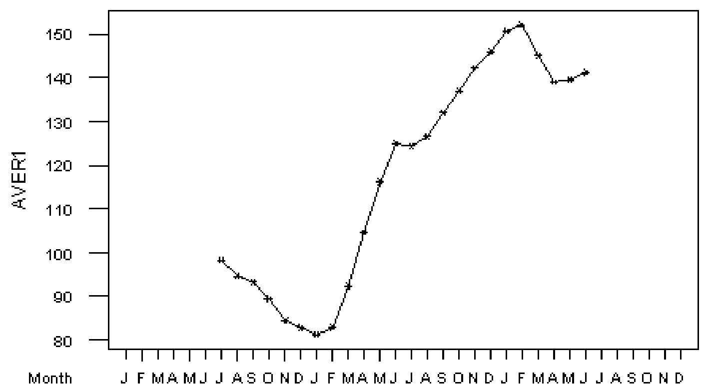

Figure 4: Trend Line of the Monthly Production Yield of CCC

Table 3: Seasonal Indices of Yield of Asphalt

Period	Index
1	0.823902
2	0.796991
3	1.00835
4	1.00012
5	1.50430
6	0.809730
7	0.469248
8	0.724253
9	1.46753
10	0.810720
11	1.25546
12	1.32939

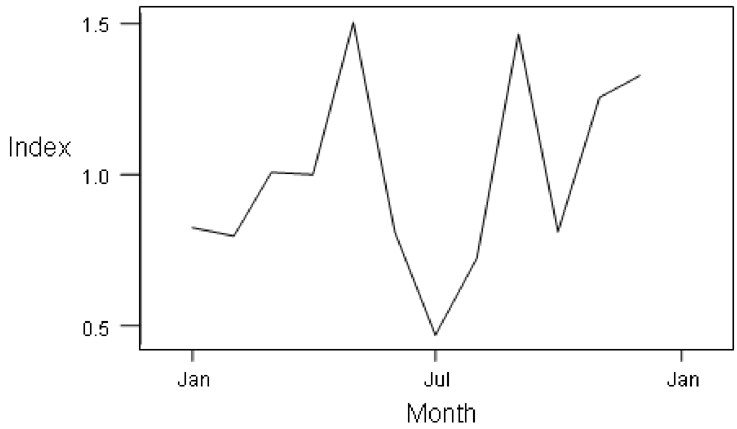

Figure 5: Seasonal Indices Plot of the Monthly Production Yield of CCC