International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 05 – Issue 06 || June 2020 || PP. 35-48

Assessment of the Reliability Program (RCM) for Maintenance & Operation in the Cement Manufacturing Industry: A Case Study at Ghacem-Tema

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Abstract: Infrastructural development is an integral part of developing a country, and this is causing a significant growth of the construction industry, of which its key substance is cement. This research assesses the reliability program (reliability centered maintenance) for maintenance and operation at Ghacem, Tema from 2014 to 2018 to ascertain its effectiveness and performance. The study was conducted for the technical section of the plant and using the mixed method methodology, 50 employees were subjected to survey questionnaires, an interview with a technical manager and extraction of technical report and data for analysis. Out of the 50 employees, 40 responded of which 4 were managers and head of sections, 13 were engineers and supervisors, and 23 were technicians.

Findings from the study indicated that the performance of the reliability program in terms of equipment performance data, the plant was 76.99% reliable for the years under review. And the performance of the reliability program in terms of questionnaire and interview, an average performance between 50% and 80% performance was realized. These performances were based on several factors of which the key factor was associated to poor but ok practices performed under the various components of the reliability program (RCM).In response to these findings, practices for the various components of the reliability program must be improved. And this can be done by increasing staff trainings and a periodic (annual or bi-annual) review of the reliability program.

I. Introduction

The 21st century advancement, involvement and development in technology tend to put much pressure on many industrial organizations in the world recently. The chances of survival for these industrial organizations in the local and international competitive market increase remotely and is overwhelming. Top management, business owners and stakeholders of these organizations in one way or the other know that they have the responsibility to meet variable needs of customers by competitive prices and high quality product and also make profit for their investment in the competitive global market.

To compete or stay in competition, an organization or a firm must optimize production; hence never allow production to stop. The uninterrupted operation of a production system is either by constant supply of power or components and equipment of the production system must be very reliable; thus always operating if possible and at the highest efficiency level. The power issue is an area where most industrial organization don't have the full power to control but ensuring continuous operation of production system component for availability, reliability and safety is now a central power drive for many industries to survive in the competitive market. This is obtainable if the system components are maintained through the life cycle the production system.

The life span of machinery of production system can be extended and may be made constantly available through adequate maintenance. Inversely, poor or lack of maintenance of machinery can lead to frequent breakdowns of equipment leading to delay or low productivity. A study conducted in 1993 by the Department of Trade and Industry in the UK accounted that, the annual cost of poor maintenance had amounted to about £1.3 billion in UK industry (Al-Najjar,2006). Other research studies have proven to most industry players that improving maintenance will reduce the high cost of failures in the production system. Many organizations management have nowreviewed their old or non-maintenance strategies and tend to apply new strategies such as Reliability Centered Maintenance (RCM) which optimize the reliability of production system (Albarkoly, 2015).

This write up is a case study of a cement manufacturing industry (Ghacem, Tema) in Ghana and it assess and evaluate the reliability program (RCM) for maintenance and operation for its production system of which reliability in its production system is highly achieved.

Ghacem has two cement grinding plants situated at the main harbor areas of Tema in the Greater Accra region and Takoradi in the Western region of Ghana. The organization's acreages are 108,730m^2 and 34,875m^2 in Tema and Takoradi respectively. Ghacem has a total installed production capacity of 4.4 mtpa, with 2.2 mtpa plant capacity in Tema and 2.2 mtpa in Takoradi.

Tema operation has five (5) grinding horizontal ball mills, three (3) of these are closed circuit with air separators. Takoradi also has 5 grinding horizontal ball mills with two closed circuit. The raw materials for the production of cement are; Clinker, Gypsum, Limestone and Granite dust. Currently, Clinker and Gypsum are imported whilst a local source supplies Limestone and Granite dust. Clinker indoor storage (sheds) capacity is 75,000tons for Tema and 82,000tons for Takoradi. The finished cement storage (silos) capacity for Tema is 17000tons and Takoradi is 15,700tons. The factories have facilities to dispatch cement in bags of 50kg size and bulk cement.

The study was much concerned about the technical section of the Tema plant of the organization and their processes which are in line with the production system

II. Problem Specification

The recent immense infrastructural development in Ghana has seen the invasion of other cement companies in the country, creating a highly competitive market.

To survive in this competitive market, cement produced must be of quality, at affordable price and available always on demand.

There are factors associated with the cost of producing cement. Variable cost such as cost of raw materials, energy etc. and fixed cost such as maintenance cost, operational cost etc., tend to have a high impact on the cost of a bag of cement produced.

High and untimely breakdowns of plant equipment's and its associated high cost (maintenance cost) of repairs is an issue confronting the technical section of Ghacem, Tema. These issues tend to reduce the availability or uptime of the plant machinery hence the high cost of producing a bag of cement.

A more preventive, predictive and proactive way in maintenance and operation in production system known as Reliability Centered Maintenance (a Reliability Program) was introduce to improve the efficiency of machinery, reduce untimely breakdowns and its associated cost, improve processes and service to achieve optimum availability and reliability of the plant at all times.

Nevertheless, the high downtime and its associated maintenance cost has become a worry to management leading to a high operational cost. This has resulted in the high cost of producing a bag of cement, thus making us less competitive on the market.

The need to assess or evaluate why the reliability program introduced is not serving its purpose and the relevant issues confronting the program is reviewed by the study.

The aim of the study is to assess or evaluate the reliability program (RCM) of the organization from 2014 to 2018 to ascertain the effectiveness of the program based on available data.

III. Objectives

The objectives of the study are to:

a) Evaluate the reliability program to determine whether it creates awareness of the causes of failure of equipment's.
b) Assess the consequences of equipment failure anticipated by the reliability program
c) Develop a cost-effective plan to prevent costly breakdown using the reliability program.

IV. Research Questions

a) What kind of failures are associated with equipment failure in the cement industry?
b) What is the most significant effect of low availability of plant machinery in the Cement industry?
c) What are the factors that drive high maintenance cost and how can these factors be addressed to reduce cost?

V. Significance Of Study

The completion of the study will identify issues confronting the Reliability program of Ghacem and also help management and the entire work force of the company to appreciate the reliability program which is intended to optimize the efficiency of plant equipment and process for high productivity at low cost and safe

working environment. This will help the organization in achieving its stated strategic goals; thus, producing good and quality cement at affordable price.

VI. Literature Review

A. Maintenance and Operation

According to Brown and Sondalini (2015), 'maintenance' is defined as "the control, management, quality and the execution of all activities that will ensure the optimum performance and availability of assets are achieved in accordance to their design levels to meet business objectives" (Brown, 2015).

According to Khan and Darrab's report (2010), the upkeep of plant machinery, prevention of equipment failure and breakdowns, increasing reliability, maintainability and the availability of operating system for maximum production is not the only purpose of maintenance, but also improving quality, optimizing productivity through capacity improvement, faster and more dependable throughput, inventory reduction and lowering operating cost is also another purpose of maintenance (Khan, 2010).

In a case study carried out by Alsyouf, at least 14% of potential improvement in return on investment (ROI) are directed to the contribution of maintenance function to lost profit. This was because of unplanned stoppages from maintenance related problems (Alsyouf, 2006).

Many industries have tried to use standard production methods to control maintenance cost but are not successful. Because maintenance costs make up a percentage of production costs, much attention is being turned to maintenance. Maintenance costs are generally classified into two main categories namely, labor costs and material costs. By achieving maximum availability (minimum downtime), reliability and efficiency from plant assets, the manager of the sector ensures that an industry does not need to invest in excess assets to produce its products. Nevertheless, maintenance can increase profits and they are in two main ways; thus, decreasing expenses and increasing capacity (Shafeek, 2015).

B. Reliability Centered Maintenance (RCM)

As the adage goes; "the room of improvement is the biggest of all" advocates cement industry and other manufacturing industries the need to improve the reliability of assets (production system) which tends to promote uptime and availability (Albarkoly, 2015).

According to Albarkoly (2015), the RCM strategy emerged in the 1960's and it is a technique to develop Preventive Maintenance (PM) (Albarkoly, 2015).

The reliability centered maintenance strategy application originated in the aviation industry as a replacement of Preventive maintenance. The theory of the strategy is to prevent potential failures that pose serious consequences and could have resulted in response to heavy increase in maintenance cost, which could render the aviation industry uneconomical after the introduction of wide body jets (National Aeronautics and Space Administration (NASA), 2008).

RCM is believed to have been next introduced to the armed forces, then later considered by the nuclear energy sector and then its application in the oil and gas industry. Many other industries started applying RCM when over time and experience, the strategy made very significant saving in maintenance cost and also the availability of production system for high productivity and equipment efficiency ensured (Albarkoly, 2015).

According to B. Devaraj Naik and Pradeep Kumar Soni (2016) in IJIREST journal, the optimum mixture of reactive, condition based, time or interval based and preventive maintenance practices is Reliability Centered Maintenance (RCM). The figured below illustrates the basic application of each maintenance strategy or practice (Naik, 2016).

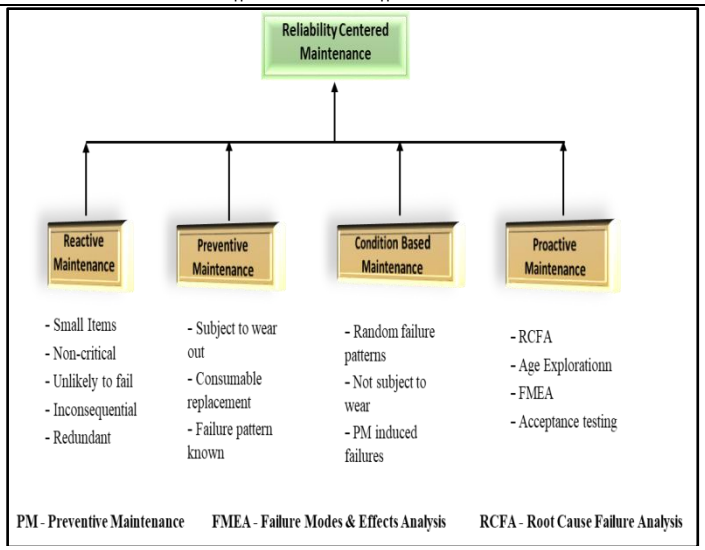

Figure1 Component of Reliability Centered Maintenance (RCM)

In order to optimize facility and equipment reliability whiles reducing lifecycle cost, the key maintenance strategies (i.e. Reactive, Preventive, Condition Based, and Proactive Maintenance) are integrated to utilize their respective strength, rather than being applied independently (Naik, 2016).

Utilization of Reliability Centered Maintenance (RCM) in industries

Álvares, A. J and de Queiroz Souza, R (2008) in a research study, evaluated the impact of the Reliability Centered Maintenance program on a power generating system. Findings from the research according to Álvares showed that reliability centered maintenance guarantee's remarkable improvement in the maintenance functions activities and performance, and also an increase in the reliability and availability of plant equipment. The research revealed that the RCM program permit the definition of a maintenance plan in a structured form (Álvares, 2008).

A research paper which reviews the application of reliability centered maintenance strategy to develop a maintenance plan for a steam-process plant was published by Afefy. According to Afefy (2010), the steam-process plant system consists of several component such as; steam distributor, fire-tubes boiler, dryer, water feed pump and a process heater. The application of the RCM strategy for the maintenance program showed that, the Mean Time between Failure (MTBF) for the plant system and the probability of sudden equipment failures decreased (Afefy, 2010).

Sheetalnath Mahalungkar and Mike Ingram (2004) described in an article that lost or low production due to equipment failure is not acceptable, especially during peak demand times in the cement industry. According to Mahalungkar and Ingram, keeping equipment running in the cement industry is essential, hence the advocacy of the reliability centered maintenance approach which focuses on providing advance or early warning signs of problems to prevent sudden failure is the strategy the industry is now shifting to. The researchers further reviewed that maintenance is expensive, but its cost can be controlled using RCM program (Ingram, 2004).

As the industry evolves with better and more advanced and efficient technology, preventive or scheduled maintenance replaced the reactive maintenance which resulted in better equipment availability (Moubray, 1999).

Sheetalnath Mahalungkar and Mike Ingram (2004) however, reviewed that even with scheduled or prevent maintenance, unpredictable failures do or can occur, hence the industries approach of shifting from preventive maintenance to reliability centered maintenance which is an optimum mixture of Reactive Maintenance (RM), schedule or Prevent Maintenance (PM), Predictive Maintenance (PdM) and Condition Based Maintenance (CBM), where the use of new techniques and technologies are used to constantly observe and monitor conditions of equipment to measure failure degradation and predict failure before incident occur is the latest strategy for achieving higher equipment availability whiles controlling cost associated to maintenance activities (Ingram, 2004).

B. Devaraj Naik and Pradeep Kumar Soni (2016) research paper also outlines the critiques and review the reliability centered maintenance program for a hydraulic system. The findings based on reviewed literature by Son and Naik showed the essence of reliability centered maintenance in terms of cost effectiveness. The

research described that the RCM program does not only improve on the systems functional responsibilities but also significantly reduces the needed maintenance in today's highly competitive world, reduction on concerned cost, equipment failure and rework (Naik, 2016).

Naik and Soni further reviewed that the reliability centered maintenance program emphasis on the safety of systems by allocating criticality index to the various sub-systems and additionally, select maintenance activities based on the risk of failure involved. Naik and Soni (2016) concluded that reliability centered maintenance presents a maintenance plan which is designed for maximizing safety in an economical way and makes production systems more reliable and always available (Naik, 2016).

VII. Research Methodology

As the title of this chapter states, this part of the research describes the research methodology for this dissertation. The early part of this chapter outlines the research strategy and the approach to the research. It continues to describe the method used for the research, followed by the tools or instrument used for data collection. The chapter further states the procedure of data collection, the ethical consideration and final closes with the research limitations.

C. Research Approach

A comprehensive literature review was conducted to obtain information about maintenance in general (its evolution and practices or strategies), reliability centered maintenance which is the current approach of maintenance adopted in Ghacem, Tema (thus its principles and benefits) in this competitive industry.
The research methodology was built upon an extensive literature review of the current situation of the cement manufacturing industry in Ghana (Ghacem) in terms of maintenance and its practices. The study was undertaken to assess and evaluate the reliability program (Reliability Centered Maintenance) of Ghacem, Tema plant to ascertain the effectiveness and optimum functioning of the program over a four-year period.

D. Data Collection Instrument

The methodology used primary and secondary methods to obtain information for the study. Primary data according to Surbhi (2018) is a data a research obtains directly from efforts and experience from people. Data are obtained through methods like questionnaires, interviews etc. Secondary data according to Surbhi (2018) is a secondhand information obtained from various sources such as reports, articles, system data base etc. (Surbhi, 2018).

A survey questionnaire was formulated and conducted for the technical section (maintenance department, technical support department i.e. planning/reliability section, and production department) of the plant, to gain insight and opinion on the factors which most affects the functioning of the reliability program in the plant.

The objective of the survey questionnaire were:

- To collect respondents views on whether the reliability program (RCM) creates awareness of the causes of equipment failures and anticipates the consequences of the failures.
- To gather respondents' views and insight of the reliability programs performance over the years.

A closed ended questions were adopted in the survey questionnaire which consisted about 30 questions comprising of general maintenance knowledge questions to identify profile of respondents in relation to maintenance practices, the interest and knowledge of reliability centered maintenance and the need to improve the maintenance strategy to aid the organization achieve its strategic objectives and goals. The survey questionnaire and samples of three different respondents are attached in the Appendix of this paper.

For the purpose of this research also, a semi-structured interview was conducted for the technical managers and head of section of which one technical manager responded to the request for more information and views of the functioning of the reliability program in the plant. The interview guide questions are attached in the Appendix of this paper.

In addition, historical data and reports from the Computer Maintenance Management System (CMMS-Infor EAM) and other technical reports were extracted for more in-depth analysis on the reliability program (Reliability Centered Maintenance-RCM) performance over the years of review.

E. Data Collection Procedure

In the survey, 50 employees who are working at various department under the technical section of the plant were targeted to respond to a paper question. This target was sampled out of about 80 workers made up of permanent staff, contract staff and student who have been engaged due to national service or industrial

internship working under the maintenance department, technical support department and the production department.

The response rate was about 80% (40 respondents) in total. The figure obtained was an indication that most employees were eager to participate in the study and to help improve system performance in terms of maintenance practices and strategies in the plant.

From the total response rate, 4 respondents signifying 8% were managers and head of section of the various department mentioned earlier. Also, 13 respondents representing 26% of the total response rate were engineers and supervisors. The other respondents who were 23 technicians, indicating 48% of the total response rate, all took part of the study by answering the survey questionnaire.

In addition, one technical manger out of the four technical mangers and head of section granted the request for a semi- structured interview to be conducted in his office.

Other technical report such as the daily availability maintenance report and the reliability report from 2014 to 2018 were extracted from the computerized maintenance management system (CMMS) software known as Infor EAM were also used for the analysis and assessment of the reliability program in Ghacem, Tema.

VIII. Discussion of Results

From the various technical reports such as the daily availability maintenance and reliability report, the plant performance (milling plant and packing plant) with regards to the reliability program (RCM) from 2014 to 2018 has been monitored by some key performance indicators (KPI) to aid technical management help achieve the company's strategic goals and objective.

In relation to plant performance (availability of plant equipment's) for the years under review, in year 2014, the milling plant achieved 91.28% plant availability, which exceeded the annual plant availability target (90%). The packing plant also achieved 91.01% plant availability for the same year which also exceeded the annual plant availability target (90%).

The milling plant failed to achieve the annual plant availability target for the year 2015 to 2018; 2015 recorded 84.30%, 2016 recorded 81.71%, 2017 recorded 88.60% and 2018 recorded 86.34%, as shown in figure 4.1.1

Figure 4.1.1-Plant Performance (Availability Trend for Milling Plant-2014 to 2018 YTD)

However, the packing plant exceeded the annual target from 2015 to 2018. Thus; 96.50%, 98.44%, 97.01% and 96.47% respectively as shown in figure 4.1.2.

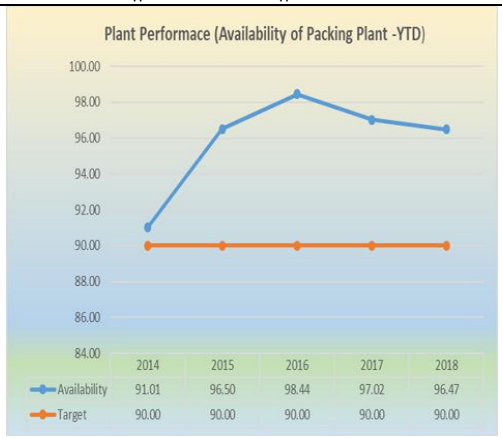

Figure 4.1.2-Plant Performance (Availability Trend for Packing Plant, 2014-2018 YTD)

The run factor (RF) of plant machinery is an indication of how well the equipment are being utilized in relation to run hours in terms of production. The total average run factor (RF) for the milling plant for the years under review was 58.76%. And that of the packing plant was 66.85%. Figure 4.1.3 and figure 4.1.4 depict the various run factors (RF) for the years under review for the research study.

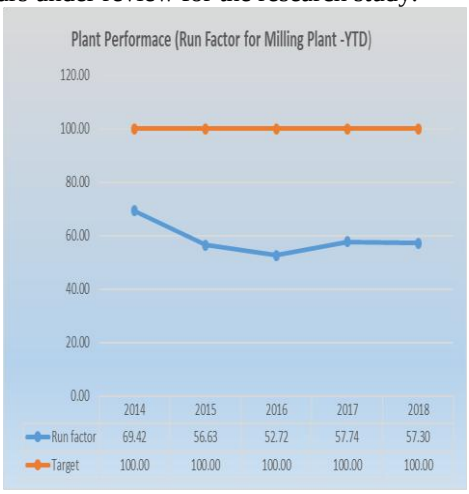

Figure 4.1.3-Plant Performance (Run Factor Trend for Milling Plant, 2014-2018 YTD)

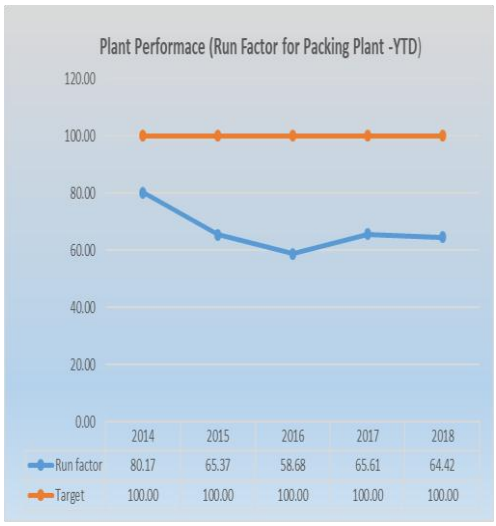

Figure 4.1.4-Plant Performance (Run Factor Trend for Packing Plant, 2014-2018 YTD)

Both the milling and the packing plant had low run factors (RF) against the annual target (100%) over the years under review of this study.

The cost of maintenance per ton from 2014 to 2018 as shown in figure 4.1.5 had an impact on the reliability program (RCM) in relation to production cost. For 2014, the maintenance cost per ton was 3.19% which exceeded the budgeted maintenance cost per ton (3.35%). 2015 maintenance cost per ton which was 4.70% also went above the budgeted maintenance cost (4.60%). 2016 maintenance cost per ton did not differ from the previous years; thus 4.87% against 4.80% (budget). However, subsequent years after 2016 realized low maintenance cost per ton against budgeted maintenance cost per ton; thus, 2017 was 3.60% against 5.25% and 2018 was 3.10% against 5.25%. This indicating that the maintenance cost related to maintenance activities can be controlled and managed for the next years to come.

Figure-Plant Performance (Maintenance cost /Ton for Total Plant, 2014-2018 YTD)

Equipment downtimes or stoppages are categorized in two parts: thus maintenance downtimes and non-maintenance downtimes in Ghacem, Tema plant. The non-maintenance downtimes of equipment are the various stoppages of equipment that occur as a result of production processes. Examples of such stoppages are; shortage of material, power outages or surges, holidays, production miscellaneous such as staff meetings, rain interruptions etc.

The maintenance downtimes are the various stoppages of equipment as a result of functional failure of machines or planned stops to carry out certain maintenance activities of plant machinery. The maintenance activities performed on functional failures of equipment's in the plant are termed as breakdown maintenance and that of scheduled or planned stops are known as planned maintenance of which all falls under reliability centered maintenance.

In relation to breakdown maintenance downtime hours for packing plant for the years under review for the study, year 2014 recorded the highest breakdown maintenance downtime of 27% (1327.80 Hrs) followed by year 2015, which recorded 25% (1232.35 Hrs) breakdown maintenance downtime. Year 2016 and 2017 recorded low breakdown maintenance downtime in comparison with the subsequent years; thus 15% (725.83 Hrs) and 14% (650.42 Hrs) breakdown maintenance downtime respectively. However, this trend of low breakdown maintenance downtime changed in year 2018, as the year recorded 19% (932.32 Hrs)breakdown maintenance downtime as shown in figure 4.1.6.

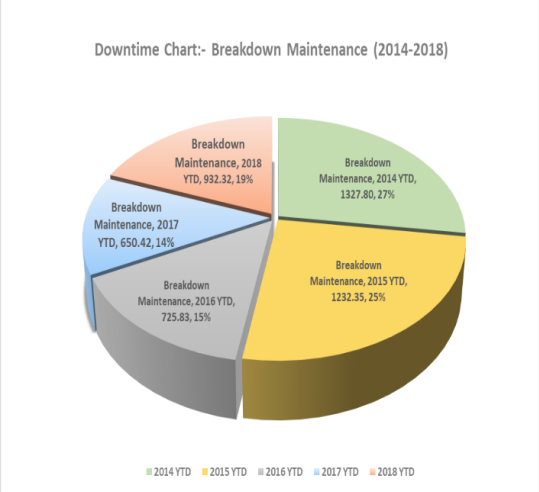

Figure -Plant Performance (Breakdown Maintenance Downtime Chart for Packing Plant, 2014-2018 YTD)

With regards to planned maintenance downtime hours for packing plant, year 2014 recorded 26% (1101.22 Hrs) maintenance downtime which was the highest compared to the other years under review for the study. 2015 year recorded 16% (677.82 Hrs) whiles 2017 year recorded 17% (744.12 Hrs) planned maintenance downtime. 2017 and 2018 years recorded 20% (830.94 Hrs) and 21% (900.19 Hrs) planned maintenance downtimes respectively as shown in figure 4.1.7.

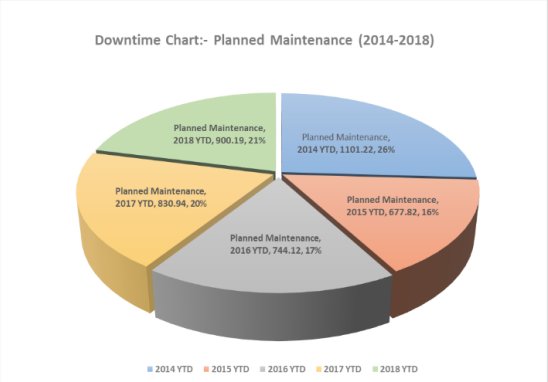

Figure 4.1.7-Plant Performance (Planned Maintenance Downtime Chart for Packing Plant, 2014-2018 YTD)

For the milling plant, breakdown maintenance downtimes recorded for the years under review for this study are shown in figure 4.1.8. Year 2014 recorded 24% (2502.05 Hrs), year 2015 and 2016 recorded low breakdown maintenance downtimes; thus 6% (596.13 Hrs) and 7% (725.83 Hrs) respectively. 2017 year recorded the highest breakdown maintenance downtime of 39% (4148.78 Hrs) and 2018 year recorded 24% (2547.27 Hrs) of breakdown maintenance downtime.

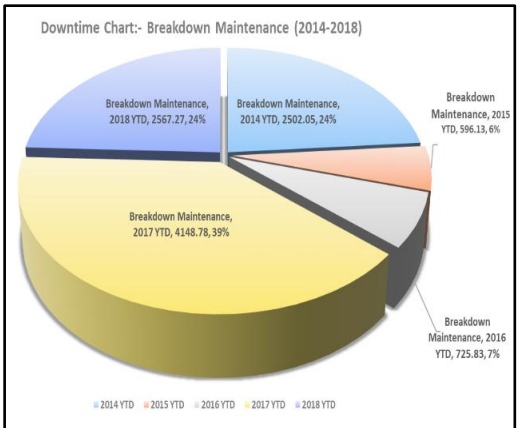

Figure 4.1.8-Plant Performance (Breakdown Maintenance Downtime Chart for Milling Plant, 2014-2018 YTD)

With regards to planned maintenance downtimes for the milling plant, 29% (2208.82 Hrs) downtime was recorded in year 2014. 14% (1085.82 Hrs) in year 2015 and 10% (744.12 Hrs) in year 2016 which was low compared to the other years for the years under review for this study. However, year 2017 and 2018 recorded an increased downtimes; thus 21% (1571.42 Hrs) and 26% (2022.54 Hrs) as shown in figure 4.1.9 respectively.

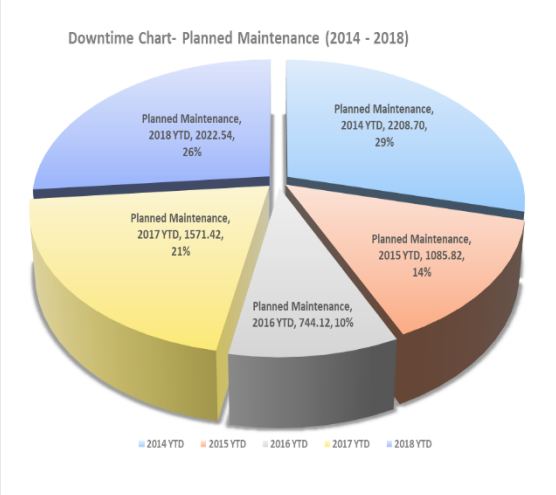

Figure -Plant Performance (Planned Maintenance Downtime Chart for Milling Plant, 2014-2018 YTD)

According to the survey questionnaire results, 40 respondents which represent 80% of the sample employees, clearly had a clear understanding of maintenance as shown in Table 4.2.1. This is evidenced that maintenance are done according to specific schedules and all 40 respondents (80%) testified to that effect.

From table 4.2.1 results, staff of the technical section had various qualification in relation to maintenance work; 48% of sampled employees (24 respondents) have professional qualification. 20% of the sampled employees (10 respondents) qualification is based on technical know-how and 6 respondents (12% of sampled employees) used experience in maintenance to work as their qualification.

The knowledge about the cost of maintenance activities in the plant is known by few people in the technical section. This is confirmed by the response from the survey questionnaire; 9 respondents representing 18% of the sampled employees out of the 40 respondents (80%) know the monthly, quarterly or annual maintenance cost in the plant. 62% of the sampled employees (39 respondents) do not have any knowledge or information of the cost associated to maintenance activities in the plant.

With regards to modern maintenance strategies such as reliability centered maintenance, 36 respondents (72% of sampled employees) know of the strategy. Out of this 72% (36 respondents), 8% (4 respondents) are managers and head of sections, 20% (10 respondents) are engineers and supervisors and 44% of the sampled employees (22 respondent) are technicians. Only 4 respondent (8% of sampled employees) don't know about the reliability centered maintenance (RCM) as a modern strategy of maintenance as shown in table 4.2.2.

Improving maintenance is a believed that could increase the reliability of the production system was strongly agreed by 21 respondents (42% of sampled employees). 18 respondents (36% of sampled workers) also agreed to this believe and only 1 respondent (2% of sampled workers) was uncertain about this believe, as shown in table 4.2.2

Thirty-five respondents (70% of sampled workers) made up of 4 managers/head of sections, 12 engineers/supervisors and 19 technicians testified through the survey questionnaires that the reliability program (RCM) have effect on the performance of the plant equipment lie cycle. 4% of sampled staff (2 respondents) and 6% (3 respondents) said the program had no effect on the performance of the plant equipment's life cycle, respectively.

In relation to the reliability program, 20 respondents (40% of sampled staff) said the effect of condition monitoring (Condition Based Maintenance) in identifying or predicting failures of the plant equipment ranged between 50% and 80% of program performance. 8 respondents (16 % of sampled employees) also ranged the effect of condition monitoring between 20% and 50% of program performance. 12% of sample staff (6 respondents) on the other hand ranged the effect of practice in the reliability program less than 20% of the program performance and 6 respondents (12%) said the effect of condition monitoring in the reliability program ranged above 80% of the program performance on plant equipment, as shown in table 4.2.2 above. This is evidence by the data analysis; thus, annual breakdown maintenance downtimes from 2014 to 2018 from the Daily Availability Maintenance report and the Reliability Report in figure 4.1.6 and figure 4.1.8.

In addition, 17 respondents (34%) mentioned that the effect of planned maintenance in the reliability program (RCM) done to improve the performance and the life cycle of plant equipment and machinery ranged from 50% to 80% of the programs performance. Whiles 15 respondents (30%) ranged the effect of the practice done above 80% of program performance as shown in table 2. This is an indication that planned maintenance is having an impact on the performance and life cycle of plant equipment and machinery under the reliability program (RCM). However, 7 respondents (14%) said the effect of planned maintenance done to improve the performance and the life cycle of plant equipment's and machinery ranged between 20% and 50%. And only 1 respondent (2%) said the effect of the practice on the performance of plant equipment's is less than 20% of program performance. These response evidence that maintenance are done or performed according to specific schedule of which all 40 respondents (80%) out of the total sample staff (50 employees) attests to.

With regards to spares availability's effect in the reduction of maintenance downtime hours of plant equipment's and machinery, 19 respondents (38%) ranged the effect of this component of the reliability program between 50% and 80% of program performance. Also, 15 respondents (30% of sampled staff) ranged the effect of spares availability in the reduction of maintenance downtime hours above 80%. And the remaining 13 respondents of which 7 respondents (14%) said spares availability's effect ranged between 20% and 50% and 6 respondents (12%) indicated that the effect of spares availability in the reduction of maintenance downtime is less than 20% of the reliability program performance.

In relation to some reliability centered maintenance practices or activities performed under condition-based maintenance, 46% of the sampled size (23 respondents) strongly agree to the reporting of critical issues for prompt maintenance to be carried out. 17 respondents (34%) also agree to this practice as shown in table 4.2.3.

The increase in the frequency of inspection of plant equipment with signs of potential failure to measure the degradation of failure and predict the time of functional failure of equipment's is strongly agreed by 13 respondents (26% of sample staff) . In addition, 25 respondents (50% of samples employees) also agree to this practice. However, 2 respondents (4%) were uncertain about this practice performed under condition abased maintenance of the reliability program (RCM).

48% (24 respondents) of sampled employees agree that the use of reliability tools and instrument for condition monitoring should be optimized. 32 % (16 respondent) also strongly agree the practice (thus, the use of reliability tools and instruments) should be optimized.

Analyzing collected data and triggering prevent or planned maintenance when necessary is a practice that 21 respondents (42%) strongly agree in the reliability program. 32% (16 respondents) of the sampled employees also agree to this practice performed under the condition-based maintenance of the reliability program (RCM). However, 3 respondents (6%) are uncertain about this practice performed. This can be related to the point that 8% of sampled staff do not have knowledge about this modern strategy (reliability centered maintenance).

With regards to practices performed under planned maintenance of the reliability program, 22 respondents (44%) agree to the optimum use of time during scheduled maintenance to reduce maintenance downtime hours. 18 respondents (36%) also strongly agree to this practice performed. This can be related to doing work right the first-time practice of which 22 respondents (44%) agree and 17 respondents (34%) strongly agree allowing high wrench time on plant equipment's.

42% (21 respondents) of the sampled employees agree to the practice of following task instructions and safety procedures when executing work, whiles 36% (18 respondents) also strongly agree to the practice. However, 1 respondent is uncertain about the practice. The practice of making spares available as to when it's needed is an essential area for this program and is strongly agreed by 12 respondents (24% of the sampled staff). 23 respondents, representing 46% of sampled staff agree to the practice of making spares available during maintenance periods when needed. However, 1 respondent (2%) disagree to the practice, whiles 4 respondents (4%) are uncertain about the practice performed under planned maintenance of the reliability program.

The practice of making sure spares are available as to when is needed was strongly agreed by 24% (12 respondents) of sampled size. 23 respondents (46%) agree to the practice of making spares available during maintenance when needed. However, 1 respondent (2%) to this practice, whiles 4 respondent (8%) are uncertain about the practices performed under planned maintenance of the reliability program.

In relation to work environment and management issues, 58% (29 respondents) of sampled employees described the relationship between managers/head of sections, engineers/supervisors and technicians with regards to the reliability program (RCM) as ok. 20% (10 respondents) also share in the same idea that, the relationship existing between managers/head of sections, engineers/supervisors and technicians is strong with regards to the reliability program (RCM). Nonetheless, 1 respondent (2%) indicated that there is a weak or poor relationship existing between managers/head of sections, engineers/supervisors and technicians with regards to the reliability program (RCM).

Communication and feedback of information in relation to the reliability program between various sections of the technical unit is ok as indicated by 27 respondents (54% of sampled employees). 22% (11 respondents) said communication and feedback of information is strong between the various sections of the technical unit with regards to the reliability program (RCM). However, 2 respondents (4%) said poor or weak communication of information and feedback exists between the various sections of the technical unit in relation to the reliability program (RCM).

IX. Discussion of Results/Findings

Assessing the reliability program (Reliability Centered Maintenance), the evidence presented from the survey questionnaire, interview and extracted technical data of plant performance for the years under review for the study depict an average functioning of the reliability program for the technical unit of Ghacem, Tema.

Findings from the study indicated that the performance of the reliability program in terms of equipment performance data, of the plant was 76.99% reliable (thus;62.81% of Run factor and 91.17% of availability for both the milling plant and packing plant equipment's) for the years under review. And the performance of the reliability program in terms of questionnaire and interview conducted, was an average performance between 50% and 80% performance was realized.

The effect of this average functioning of the program over the years of review on productivity can be changed and improved since the full functioning of the reliability program (reliability centered maintenance) is not practiced. Thus, low reliability of plant equipment resulting in high cost of producing a bag of cement. Which contradicts the strategic goals and objectives of the company. This can be seen from the inconsistency in the availability and run factor actual percentage compared to the target percentage for each year at the various section of the production line (milling plant and packing plant).

However, the maintenance cost per ton for the years under review, experienced a low, high and low percentages of maintenance cost; thus from low maintenance cost per ton (2014) to high maintenance cost per ton (2015 and 2016) and to low maintenance cost per ton (2017 and 2018).

From a general perspective and confirmation from the interviewee, the average performance of the reliability program (reliability centered maintenance) can be associated to the poor practices performed under the various components of the program; thus condition monitoring, planned or prevent maintenance schedules and spares availability. The effect of these components on the program, on the average was ranged between 50% and 80% of performance. This can be seen in the low run factors and an ok availability for the milling plant and packing plant equipment's for the years under review for the study.

In addition, staff lack of awareness of the maintenance cost per ton for every month, quarterly or annually is also a contributing factor to the average performance of the reliability program. Since that information can give them some sense of belongingness; thus they having a contributing factor of the cost associated to the maintenance of plant equipment (practices performed during maintenance activities).

X. Conclusion

The research study assesses the reliability program (reliability centered maintenance, RCM) which is a modern maintenance strategy practiced in Ghacem, Tema plant. The study explores reliability centered maintenance as a modern strategy in maintenance for which production systems can be improved from its current state to the highest state in terms of reliability and continuous productivity.

The reliability program (reliability centered maintenance), a modern strategy of maintenance comprises of various components as described in the literature review of this paper whose failure can results in adverse consequences, which have direct effect on the continuity of production in the plant.

Based on the analysis done from the from the research study, it was realized that the reliability program (reliability centered maintenance) had an average function in terms of performance Tema plant of Ghacem, from 2014 to 2018 due to some certain practices done with regards to maintenance activities.

From observation and analysis, the effect of the poor performance of the various components of the reliability program (RCM) ranged between 50% and 80% of performance. This was evidenced by the low run factors and averagely ok availability of both milling and packing plant of the plant, recorded over the years under review for the study.

Finally, the study showed that, there is the need to improve on the labor utilization capacity in terms of short interval control from supervisors and proper planning scheduling, and also training of staff to improve on maintenance practices to ensure the reliability of the production system.

XI. Recommendation

With the evidence from the findings, analysis and discussion of this research paper, an average performance of the reliability program (reliability centered maintenance) for the years under review for this

research study have been identified. And the following are some recommendation to improve the reliability program for a reliable plant and continuous production with safety at its heart of operation.

- Periodic (annual or bi-annual) review of the performance of the reliability program against organization set targets.
- Increase staff training to enhance their ability to perform maintenance activities with high sense to ownership and professionalism. Also, to improve on their maintenance practices in the technical unit and the company at large.
- Improve the communication, feedbacks and updates of maintenance and operational process and activities, not neglecting other non-technical department such as procurement etc. that has influence on maintenance activities and operations.
- Implement a continuous improvement program (CIP) which involves all staff; from management to the shop floor employee to mitigate or reduce wastes generated in the system.

XII. References

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