

# Maintenance Practices in Cement Industry

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## Abstract

This paper analyzes an existing maintenance management system in a cement factory in the Kingdom of Saudi Arabia using a modified questionnaire. The analysis shows that there are strong areas such as predictive maintenance and maintenance automation. Other areas are found weak such as training programs and maintenance reporting. Some areas are found mix between strong and weak such as maintenance documentation, and maintenance planning and scheduling. This paper is an assessment initiative for maintenance and productivity continuous improvement and can be integrated as a part of a decision support system for maintenance management.

## Scope

The performance measurement is aimed to determine the missed practices in order to achieve further productivity improvement in cement industry. Furthermore, the research push the management to adopt best practices to remove the waste of the overall process.

*Keywords:* Maintenance practices; Survey; Questionnaire; Cement industry

## 1. Introduction

Because maintenance expenditures make up a percentage of production costs, attention is being turned to maintenance. Many companies have tried to use standard production methods to control maintenance. This is not successful. The maintenance can increase profits in two

main ways: decreasing expenses and increasing capacity. Maintenance costs consist of two main divisions, labor and material. By achieving maximum availability (minimum downtime) and efficiency from plant assets, a manager ensures that a company does not need to invest in excess assets to produce its products. Benchmarking is a continuous improvement tool; it should only be started if the company wants to make changes to maintenance improvement.

Khan and Darrab [1] reported that the purpose of maintenance is not only to upkeep the plant machinery and equipments preventing from failure and breakdowns, increasing reliability, maintainability, and availability of the operating system for maximizing production, but also to improve quality and boost higher productivity through improving capacity, faster and more dependable throughput, reducing inventory, and lowering operating cost. Al-Sultan [2] investigated the there has been some research on maintenance management and practice in Saudi Arabia, but it remains very limited because most of it is written from a practitioner's prospective and very few articles focus on sound scientific solutions to maintenance problems. Ikhwan *et al.* [3] showed that a proper maintenance practice is needed and more university-industry interaction in the field of maintenance in Saudi Arabia becomes necessary. Al-Saggaf [4] investigated the case study of SCECO-EAST's (Saudia Arabia) experts in implementation of TQM to distribution substation (S/S) maintenance [5] and investigated the developing training programs

for machine operation, thereby reduced the operational errors in Saudi Arabia. Bob [6] reported that wasted energy from poorly maintained compressed air systems cost US industry up to \$3.2 billion annually. Alsyouf [7] showed in a case study that at least 14% of potential improvement in return on investment are directed to contribution of maintenance functions to lost profit, which is due to unplanned stoppages and bad quality caused by maintenance related problems. Blanchard [8] demonstrated that a large percentage (e.g. 70% for some systems) of total life cycle cost for a given system is attributed to operating and maintenance activities. De Groot [9] investigated two categories of ratios under

which the performance indicators can be presented:

1. Economic ratios (as that in Table 1), which allow the follow-up of the evolution of internal results and certain comparisons between maintenance services of similar plants.
2. Technical ratios, which give the maintenance manager the means of following the technical performance of the installations.

Some ratios are linked to maintenance costs. Among those are the economic ratios which seem to be the most representative and have been chosen and customized hereafter.

Table 1. Surveys in Europe in cement industry.

Economic Ratio	Value
Direct maintenance cost/Added value of production	12.90
Direct maintenance cost/Replacement value of assets	16.40
Cost of maintenance personnel/Direct maintenance cost	39.75
Cost of subcontracting/Direct maintenance cost	14.00
Cost of spare parts and current maintenance items/Direct maintenance cost	42.64
Average stock value/Replacement value of production equipment	09.80
Maintenance workforce/Total plant workforce	28.40
Downtime/Hours theoretically available for production on yearly basis	05.94
Number of stock-outs/Total items in stock	06.99

Salonen and Deleryd [10] reported that companies often try to optimize their maintenance using the ratio between *preventive and corrective maintenance* (PM/CM) as a key performance indicator. One problem with this approach is that some companies increase the amount of PM haphazardly, regardless of whether the PM has the desired effect or not. Chen [11] reported that once maintenance is performed, the job being processed must be stopped. This will result in some jobs being late or tardy and a relatively larger flow time is generated. It is known that minimizing total flow time leads

to rapid turnover of all jobs, reduces in-process inventory and decreases utilization of resource. Alsyouf [12] investigated the case study the maintenance is no longer a cost centre, but it can be a profit generating function, especially in similar types of industry where the downtime cost is high.

Mostafa [13] reported that although maintenance is one of the oldest jobs in the Egyptian industry, it has not progressed much through the years. In order to examine the state of maintenance practice, we should consider two main factors: the management side of maintenance and the technology used.

Sharma *et al.* [14] investigated the optimal system maintenance policy that may be the one which either minimizes system maintenance cost rate or maximizes the system reliability measures. Chen [15] investigated a developed procedure to find the sequence that minimizes the total setup time and to minimize the completion time with maintenance schedule in a manufacturing system. Chinese and Ghirardo [16] investigated the maintenance performance. An interesting finding is that no direct correlation between firms' size and maintenance performance could be observed. Good results are equivalently reported by smaller and larger firms and therefore seem not a matter of size. Ahuja and Kumar [17] reported that one approach to improve the performance of maintenance activities is to implement a *total productive maintenance* (TPM) system. TPM is considered to be an effective strategic improvement initiative for improving quality in maintenance engineering activities. Reis [18] investigated the aims to promote knowledge on issues related to maintenance, i.e. the behavior of manufacturing companies that consider maintenance as a source of competitive advantage and maintenance managers' perception of planning when they undertake certain practices in this area. Kans [19] investigated the survey of computerized maintenance support which reveals a focus on maintenance management information technology. Vassilakis [20] reported that maintenance is a process in its own right, thus it requires understanding, control and needs improvement. Aoudia *et al.* [21] investigated the recommended necessary improvements to maintenance. They reported that it is not sufficient to demonstrate the negative impact of ineffective maintenance management on a company, but it is also essential to identify its causes. Lamptey *et al.* [22] investigated a case study for optimizing decisions on the best combination of preventive maintenance by using the questionnaire survey. Dowlatshahi [23] investigated the role of industrial maintenance in the maquiladora industry. Maquiladora industry is a system utilizes

Mexican workforce and foreign investment and technology on the border region between the United States and Mexico. Chang and Wang [24] investigated the significant human risk factors in aircraft maintenance technicians in the airline industry. Ahuja and Khamba [25] investigated the effectiveness and implementation of the TPM program for a steel manufacturing unit, and highlight the contributions made by strategic TPM initiatives in a typical Indian manufacturing organization.

It is clear from the previous review and up to the author knowledge that there is a shortage in researches on continuous improvement of maintenance management and practice. A survey of maintenance practices is presented based on maintenance management in cement factories in Saudi Arabia. The study investigates the effect of different parameters on maintenance continuous improvement.

## 2. Measurements and Methodology

Industrial sector is growing and heavy industry remains a driving force in Saudi Arabia. According to Ministry of Commerce & Industry recorded more than 4561 Productive Factories Until 2009 Classified by 22 Industrial Activity, employing about 519788 people and Finance by 399321 Million S.R. Ministry of Commerce & Industry data show that manufacture of refined oil products, which involve 81 firms employing about 24595 people and finance by 153819 Million SR. Saudi Arabia faces a particular human development challenge that involves a gradual shift away from dependence on expatriate labor. The economy has gradually reduced dependence on oil revenues by diversifying into export industries such as metals, plastics, chemicals and cement. Saudi Arabia developmental policies and plans are outlined in a five-year national plan that guides public investments. The eighth five-year development plan (2005-2009) addresses many of the challenges as: supporting private sector investment as the driver of future growth and promoting further diversification

away from heavy reliance on natural resources, particularly oil and natural gas, avoiding negative impacts on the environment, particularly water resources. By reviewing practicing maintenance as a continuous improvement tool for the companies those strive to achieve superior performance in their respective market. It is found that there are limitations with heavy industry, especially the cement industry. Therefore, the study focuses on cement industry. The main objective is the descriptive application of a *maintenance questionnaire* in order to continuously improve the cement factories. The link between maintenance practices and production features of firms is very important. The survey was a result of cooperation with industrial sector. The questionnaire was tested through discussions with maintenance consultants. The survey consists of 150 questions in 15 areas to be answered by maintenance manager in the cement company. A special check list was used to test if the questionnaire covers all necessary maintenance areas in cement industry.

### 2.1. Cement manufacturing process

Cement manufacturing industry is identified by North American Industry Classification System (NAICS) code 32731 (formerly identified as SIC code 3241). The procedure of cement making follows:

1. The cement manufacturing process begins when limestone, the basic raw material used to make cement, is transported by rail to the Edmonton plant from the Cadomin limestone quarry 220 kilometers west of Edmonton.
2. The limestone is combined with clay, ground in a crusher and fed into the additive silos. Sand, iron and bottom ash are then combined with the limestone and clay in a carefully controlled mixture which is ground into a fine powder in a 2000 hp roller mill.
3. Next, the fine powder is heated as it passes through the Pre-Heater Tower into a large

kiln, which is over half the length of a football field and 4.2 meters in diameter. In the kiln, the powder is heated to 1500 degrees Celsius. This creates a new product, called clinker, which resembles pellets about the size of marbles.

4. The clinker is combined with small amounts of gypsum and limestone and finely ground in a finishing mill. The mill is a large revolving cylinder containing 250 tons of steel balls that is driven by a 4000 hp motor. The finished cement is ground so fine that it can pass through a sieve that will hold water.
5. The cement manufacturing process consists of many simultaneous and continuous operations using some of the largest moving machinery in manufacturing. Over 5000 sensors and 50 computers allow the entire operation to be controlled by a single operator from a central control room.

### 2.2. Maintenance in cement industry

High productivity at the modern cement plant is highly dependent on regular, scheduled maintenance. This requires planning, to ensure that company staff always have the knowledge, manpower and parts on hand to give equipment the attention it needs when it's due for scheduled maintenance. The primary maintenance approach is to do what necessary to keep the equipment running with maximum production. Maintenance include elements such as motor and bearing lubrication, motor belt replacement, fan blade cleaning, fan wheel balancing, and compressed air system maintenance.

### 2.3. Data collection

Cement companies are the target of this study. The study included famous (large and known) cement company in Saudi Arabia. To conduct the survey questionnaire was delivered to these companies including field visits, E-Mail and Fax. The purpose of data collection is to obtain information about maintenance in cement industry to keep on

record, to make decisions about important issues in maintenance and to pass conclusions improvement information on to analyses stage. Questionnaire design depends on keeping the questionnaire as short as possible. Use simple and clearly worded questions. Start with demographic questions to help respondents get started comfortably. Use dichotomous (yes/no) and multiple choice questions. Use open-ended questions cautiously. Avoid using leading-questions. The questionnaire was designed with structured questions in which the respondent could choose an answer from a set of list possibilities. Pretest a questionnaire (in Arabic) with maintenance manager in cement, academics and consultant through many draft tests. All their comments were considered in a revised version.

#### **2.4. Data analysis**

Statistical techniques were used to analysis collected data in order obtain answers to questions. Many questions of our survey are based on five point Likert type scales .Achieving accurate data and understanding of maintenance processes and parameters that are being measured. The data analyses help the best practices which lead to superior performance. The best practices are practices are that enable a company to be become a leader in its marketplace. Benchmarking process in maintenance used the following steps. Conduct internal analysis, identify areas for improvement, find partners, make contact, develop questionnaire, perform sit visits, compile results, develop and implement improvements and do it again. The goal of internal analysis is to identify weaknesses and areas that need improvement in company. Goals of maintenance organization are maximum production at lowest cost, highest quality, and within the optimum safety standard.

### **3. Results and Discussion**

Appropriate analysis for the data collection; lead to obtain a general view or different maintenance parameters in the cement

companies. The companies use the preventive maintenance program includes lubrication checklists and inspection checklist. Some diagnostic procedures such as heat, oil and vibration analysis are used. There is a specific personnel execute preventive maintenance on each crew. The preventive maintenance results are checked annually for material cost and time. Corrective action work orders are generate from the inspection plane. The inspections tasks include safety information, material requirements, time and number of labors. The frequency of inspection task interval in all equipment depends on fixed interval chart and equipment run time. More than 90% from important equipments follow up by preventive maintenance. More than 90% of PM program are completed within one week of the required date. More than 90% of an equipment items are checked by PM program. Predictive maintenance program includes vibration analysis and thermograph for criticality only and includes oil analysis for all equipments. Predictive maintenance program utilizes sonic techniques only for criticality. The *computer maintenance management systems* (CMMS) is tied into predicative maintenance system. The data of predictive maintenance is used to build work orders for preventive corrective maintenance and to improve maintenance performance. And it assigns specific technicians to work in the predictive maintenance program. Weekly work schedule includes tasks for predictive maintenance.

The percentage of all maintenance operation utilizes CMMS is more than 80%. More than 75% of maintenance activity are planned and scheduled through a CMMS. More than 75% of the maintenance inventory and purchasing include CMMS. The production scheduling system, the payroll, timekeeping system, financial, accounting system and CMMS are integrated. The financial and accounting system and CMMS are integrated. More than 90% of maintenance personnel are using the system for their job functions with a high level of performance. CMMS data is used to make cost effective

decisions and verify the progressive return of investment. The whole organization focused on asset utilization and optimization. The maintaining function is perceived as value added by management. The maintenance data collection system is utilized by management. Operators are used for first line maintenance functions in some areas. More than 90% of overall equipment availability is calculated on key assets, processes and facilities. More than 90% of operational decisions are made taking into account equipment reliability and availability. More than 75% from the right soft skills training classes (such as leadership) have been conducted for maintenance supervisors. Less than 59% from the right technical training have been conducted for appropriate personnel. The Financial effect of equipment availability is not got by everyone. From 75% to 89% of non-emergency work orders are completed within four weeks of initial request. Work order planning specific job instructions or job plan. From 10% to 20% of planned work orders experiencing delays due to poor or incomplete plans. The maintenance planner is responsible for planning the work orders. Maintenance job schedules are issued biweekly. Maintenance and production/facilities are scheduled for daily meeting. The backlog of maintenance work is available by date needed. After of the job is completed, the actual time, material, downtime and other information is reported by the supervisor of the group. From 75% to 89% of time are actual measure compared to that estimated for monitoring planning effectiveness. Both of planner and supervisor are report to same maintenance manager. From 80% to 95% of time are materials in stores when required by maintenance organization. From 75% to 80% of items in inventory appears in maintenance stores catalog. A person from maintenance staff control stocked as maintenance inventory items. The maintenance store catalog is produced by alphabetic and numeric listing. More than 95% of aisle and bin location is specified for the stores. More than 95% of

maintenance stores items are issued to a work order or account number upon leaving the store. Maximum and minimum levels for the maintenance stores items are specified for more than 95% of the inventory. More than 80% of critical maintenance material is stock in the warehouse or in a location readily accessible when the material is required. More than 95% from maintenance stores inventory level are updated daily upon receipt of materials. More than 90% from items are checked for at least one issue every year.

Maintenance organization chart is current and complete. The job descriptions are available for all maintenance positions including supervisors. The ratio between maintenance supervisors to hourly maintenance employee is between 1:13 to 1:16. The ratio between maintenance planners to hourly maintenance employee is between 1:10 to 1:14. Maintenance organizational assignments responsibility fully documented. Maintenance shop and work area from the point of layout and locations is perfect. Maintenance tools and equipment from the point of quality and quantity is perfect. The maintenance personnel are tied to pay incentive plan based on output. From 75% to 89% of the time are the maintenance reports distributed on timely basis to the appropriate personnel. From 75% to 89% of time are the reports distributed within one day of the end of the time period specified in the report. Equipment reports include the equipment downtime in order of highest to lowest total hours weekly or monthly. Preventive maintenance report include the PM hours verses total maintenance hours per item expressed as a percentage. The personnel reports include the time showing hours worked by employee divided by work order. The planning reports include the backlog report showing the total hours ready to schedule versus the craft capacity per week.

There is a strong support visible management support for continuous improvement effort. The organization strong support continuous improvement effort in maintenance. The spirit of cooperation

between plant management and labor is excellent. On continuous improvement the company focused on management, maintenance, stores and purchasing. Management support training designed to enhance employee skills purchasing. The continuous improvement efforts tied to reliability engineering. From 60% to 89%, competitive forces affect improvement efforts. The site's document management system is electronic and interfaced with other systems. The ratio of maintenance drawings included in the system is between 50 to 79 %. The site's timing for migration to fully functional and utilized document management system is no plan. Document control procedures and associate work process exist for the system. The maintenance personnel are in process of being trained to use the document management process. The document management system has detailed indexing and search capabilities that make document simple and easy to find the quality and level of document version control is excellent. A document management system is used by managers and supervisors only. About 75% of maintenance man-hours are reported to work order and 75% of maintenance materials are charged against a work order number when issued. About 75% of total jobs performed by maintenance are covered by work order. About 75% of total jobs performed by maintenance are covered by work order. About 25% of the work orders are opened under a priority that would be identified as emergency or urgent and 75% of work orders are available for historical data analysis. About 50% of work orders are checked by a qualified individual for work quality and completeness. From 75% to 89% from operations personnel generate work order requests. From 60% to 74% from facilities generate work order requests. Operations work order priority is set for maintenance daily in a joint operation and maintenance meeting. Facility work order priority is set for maintenance daily in a joint facility and maintenance meeting. Operators are involved in the upkeep and asset

performance. Operators are trained and certified to perform equipments inspections. From 40% to 59% of time operators follow up and sign off on completed work order. Maintenance is included in production and process scheduling meetings.

Downtime duration is consistently tracked for all assets. For key areas only the downtime cost is clearly identified. For all assets downtime causes are accurately and consistently tracked. Maintenance costs are clearly and accurately tracked for key assets only. All other maintenance costs such as energy, quality, and contractors are available. Total operation costs are compared when making decisions for all cost factors. Efficiency loss cost is available and accurate for 75% to 89% of time. Personnel are not dedicated to financial costs analysis. The majority is offered and attends supervisory training, which is offered on an infrequent or irregular basis. All maintenance planer receive one on the job training for at least one month. Maintenance planers received scheduling practices training program. General quality and productivity training includes upper management and line supervision. Formal job experience for maintenance craft training is required before hire. Formal maintenance craft employees training is provided in irregular intervals for some employee only. All training program instructors is all on the job training only. Training program instructor is done only supervisors. Quality and skill level of maintenance work force group is good and need to some improvement. Quality and skill level of supervisory group still need some improvement.

The organization has an attitude towards *reliability centered maintenance* (RCM) which is developed as a part of work culture. From 75% to 89% of complete and accurate assets data is available for RCM analysis. RCM is used to adjust and refine the preventive maintenance. From 75% to 89% of the work order history is accurate in tracking the causes of failures. From 75% to 89% of the failures are clearly identified. Failure analysis is conducted using analysis tools such

as why tree, fishbone and Pareto diagram to assure accuracy and consistency of effort. Dedicated personnel are permanently assigned to maintain the RCM program. Management view RCM as value added activity and measure the reliability engineering effectiveness. More than 90% from important equipments follow up by preventive maintenance. More than 90% of an equipment items are checked by a preventive maintenance program. More than 90% of PM is completed within a week of date. Predictive maintenance shows that CMMS tied into predicative maintenance system. Data of predictive maintenance is used to build work orders for preventive and corrective maintenance and to improve the maintenance performance.

Maintenance automation showed that the percentage of all maintenance operation utilizes CMMS is more than 80%. More than 75% of maintenance activity are planned and scheduled through a CMMS. More than 75% of the maintenance Inventory and purchasing include. More than 90% of maintenance personnel are using the system for their job functions with a high level of performance. Maintenance planning and scheduling showing that, more than 90% of overall equipment availability is calculated on key assets, processes and facilities. More than 90% of operational decisions are made taking into account equipment reliability and availability. From 75% to 89% of non-emergency work orders are completed within four weeks of initial request. From 75% to 89% of time is an actual measure compared to the estimate for monitoring planning effectiveness. Maintenance organization showing that,

maintenance organization chart is current and complete. The job descriptions are available for all maintenance positions including supervisors. The ratio between maintenance supervisors to hourly maintenance employee is found between 1:13 to 1:16. The ratio between maintenance planners to hourly maintenance employee is found between 1:10 to 1:14. Maintenance personnel are tied to pay incentive plan based on output. Maintenance inventory and purchasing show that from 80% to 95% of time are stored materials.

More than 95% of aisle and bin location is specified for the stores. More than 95% of maintenance stores items are issued to a work order or account number upon leaving the store. Maximum and minimum levels for the maintenance stores items are specified for more than 95% of the inventory. More than 95% from maintenance stores inventory level are updated daily upon receipt of materials. More than 90% from items are checked for at least one issue every year. Operations and facilities involvement showed that from 75% to 89% from operations personnel generate work order requests.

Fig 1. summarizes the score assigned to each area based on the designed questionnaire. It is evident that the maintenance work orders are the lowest level. Thus, total score of 17 points, indicates the need to improve the training and proposes appropriate solutions. Also it is clear that the work orders come in second level of weakness. Total score of 25 points confirms that there are many activities can be improved in the work orders.



Fig.1. Scores of maintenance areas.

#### 4. Conclusions

The areas those need to improvement such as training programs in maintenance show that the majority is offered and attended supervisory training on an irregular basis. All instructors depend on the job training only. It is not a mix of classroom and lab exercises. Quality and skill level of maintenance work force group is good but need to some improvement. Training is done by supervisors while it must be by an outside contract expert staff. Quality and productivity training includes upper management and line supervision only without workers. Formal job experience for maintenance craft training is required before hire but it is not tied to a pay and progression programs. Operations and facilities involvement show that operators are trained and certified to perform equipments inspections. It must content lubrication, minor maintenance task and assist in maintenance repair task.

Maintenance reporting shows that equipment reports include the equipment downtime in order of highest to lowest total hours weekly or monthly. It is preferable to include also maintenance cost for equipment

in order of highest to lower weekly or monthly. The purchasing reports include price performance, showing the quoted and actual prices, it preferably to include also buyer or purchasing agent performance report. Non stock report showing all direct items not carried in stock for a specified period. Administrative maintenance reports including monthly maintenance costs versus monthly maintenance budget with a year to date total. It is preferable to include also the comparison of labor and material costs as a percentage of total maintenance cost and total costs of outside contractor usage. The finances of maintenance showing that, downtime costs is clearly identified for key area only, it preferably to include all area. Maintenance costs are clearly and accurately tracked for key assets only, it preferably to include all assets. A dedicated individual or team is not assigned to analyze financial costs. Maintenance documents show that maintenance personnel are in process of being trained to use document management.

Although the application is conducted to one company, this application of this work can be extended to more companies.

## Future Work

The application will be extended to different cement companies taking in consideration the impact of maintenance practices on productivity. In addition, it will consider establishing a reference guideline of a standard procedure based on the process of maintenance protocol development for cement companies.

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## ممارسات الصيانة في صناعة الأسمنت

هانى شفيق

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### خلاصة

هذه المقالة تحلل نظام إدارة صيانة لأحد مصانع الأسمنت الكائنة في المملكة العربية السعودية باستخدام إستبيان تم إعداده لهذا الغرض. وقد كشف هذا التحليل عن وجود جوانب قوة في النظام مثل الصيانة التنبؤية وميكنة الصيانة. ومن ناحية أخرى تم الكشف عن جوانب الضعف في النظام مثل برامج التدريب على الصيانة وتقارير الصيانة. كما وُجدت جوانب تجمع بين القوة في عناصر معينة والضعف في عناصر أخرى مثل سجلات الصيانة وتخطيط وجدولة الصيانة. وقام هذا الأسلوب بدور التقييم لجميع جوانب النظام ولذلك يمكن إعتبره مبادرة للتحسين المستمر للصيانة والإنتاجية ويمكن دمجه كجزء من نظام لدعم القرار في إدارة الصيانة.