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IMPLEMENTATION OF SIX SIGMA AND QUALITY CONTROL TOOLS IN A FLY ASH BRICK MANUFACTURING PLANT

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Abstract - ***This paper describes the implementation of Six Sigma and quality control tools in a Fly ash brick (FAB) manufacturing plant to meet the quality standards of bricks and customer satisfaction. Due to ever increasing demand of bricks in the construction industry from the infrastructure as well as the real estate sector, it has become necessary to have quality control on the manufacturing process. The critical objective of manufacturing industries nowadays is to deliver a product to the customers as per the required standards and specifications within a stipulated time and cost, minimization of waste and efficient use of resources. Six Sigma principles with an effective DMAIC methodology in construction industry emphasizes on reducing variations in processes and eliminating the root causes of defects. In this statistical analysis using excels software and cause-and-effect analysis using Minitab was done. The variables which were affecting the production quality of bricks were measured and suggestions for reducing the defect level were recommended by using DMAIC principles of six sigma. The results showed that with the proper application of this methodology, and support from the team and staff of the organization, a positive impact on the quality and other features critical to customer satisfaction can be achieved for the organization.***

Keywords— Six Sigma, DMAIC, FAB, DPMO, Quality Improvement

I. INTRODUCTION

In today's competitive world, an organization's success is completely based on its ability to produce products and services faster, superior and cheaper than their competitors. A product having strong competitive advantages over other similar products can only survive today, this competitive advantage is primarily aimed at product quality and product cost. Global competition and demand from the customer for good quality product with low cost is forcing the organizations to search for the means and new techniques to improve their product quality and processes. The Six Sigma methodology is a customer focused continuous improvement strategy that minimizes defects and variation towards an achievement of 3.4 defects per million opportunities (DPMO) in product manufacturing, design and administrative process.
Fly ash bricks are obtained from pulverized fuel ash in major quantity from thermal power stations, lime and an accelerator acting as a catalyst, these are generally manufactured by inter grinding or blending all the raw materials which are then moulded into bricks in a standard size and subjected to curing at different temperature and pressures.

II. METHODOLOGY

This section will present the research methodology used in this project. The methodology used to analyse the quality of Fly ash brick (FAB) during manufacturing processes, it further explains how the problem was investigated and describes the tools which were used to undertake the investigation.

a) *VOC survey*
A questionnaire was prepared to obtain information about factors like quality of Fly ash bricks, order-to-delivery lead time, product cost and owner's response to customer feedback. It was asked to rate those factors of quality evaluation and operation according to their severity level on the given scale, an approach has been done at Fly ash brick plant in Indore and ranking of these factors was done by using RII (Relative importance index).
A scale ranging from 1-5 was adopted to assess the impact of each factor where 1 means Poor, 2 for average, 3 means good; 4 means very good and 5 for excellent. This five-point scale was converted to a Relative Importance Index (RII) for each individual factor, using the following formula, as adopted by Chan and Kumara swamy (1997) and Assaf et al (1995).

$$RII = \frac{\Sigma W}{(A \times N)} \qquad \dots (i)$$

Where ΣW is the total weight given to each factor by the respondents, which ranges from 1 to 5 and is calculated by an addition of the various weightings given to a factor by the entire respondent, A is the highest ranking available (i.e. 5 in this case) and N is the total number of respondents that have answered the questions in the survey. The RII value range from 0 to 1 (0 as not inclusive), the higher the RII, the more will be the impact of a variable.

b) *The SIX SIGMA process*

To maintain the Six Sigma quality, a process must not produce more than 3.4 defects per million opportunities (DPMO) which means 99.9966% defect free. Opportunities can be defined as the total number of chances per unit to exhibit a defect. Each opportunity must be independent of other opportunities and must be measurable and observable. The DPMO can also be thought of as the capability of the process, the more capable the process the less the DPMO will be. Finally, this can be converted into a Sigma or standard deviation, the higher the standard deviation the lower the DPMO, which indicates a more capable process. Defects per Million Opportunities (DPMO) can be defined as

$$DPMO = \frac{Number\ of\ Defective\ Units \times 1000000}{Total\ No.Of\ opportinities} \quad ...(ii)$$

c) Six Sigma DMAIC approach

The methodology used DMAIC, is a five-step improvement process like Define, Measure, Analyze, Improve and Control (DMAIC).

DEFINE - In this step customer requirements are defined and anything that do not meet those requirements known as defect, define the project scope and goals, identify the factors which are CTQ (Critical to Quality) for the product and processes.

MEASURE - Identify and collect an appropriate data which are relevant to the defects and process that needs to be improved. The objective of this measurement is to get enough data or information from the processes. Identify the performance which is required for the processes with respect to their CTQ (Critical to Quality) characteristics.

ANALYZE - To study and analyze the data collected in the previous step and to find out the root causes of the defects and unsatisfactory performance of the processes. Once all the deviations are measured the problem causing these deviations are identified.

IMPROVE - Improve the processes by reducing their defects. Identify the ways to eliminate the existing problem for the processes. Verify those inputs which are creating problem by causing variations and control them. Develop potential solution for the problems.

CONTROL - It helps to ensure that the problems that are creating variations in the desired outputs are resolved. The new process is implemented under a proper control plan to achieve the desired results. Measure the performance of the new process under control plan and continually monitor the process to maintain the quality level of the process.

III. DATA COLLECTION

A. Define

In the Define Phase, Six Sigma methodology offers various tools and methods that can be used to ease the process implementation. In this stage, we define the goals for the improvement of processes, its inputs and outputs and the purpose of the process improvement. We also specify who the customers are – be they external or internal – and ask them about their expectations and requirements with the product. Here we systematically write these requirements down and set measurable targets (Critical to Quality – CTQ) to better meet these requirements.

TABLE I
SIPOC ANALYSIS FOR FAB

Supplier	Inputs	Process	Outputs	Customer
Thermal power plants, Cement factories, Stone crushers	• Fly ash • Stone dust • Lime • Gypsum • Cement	• Mixing of raw materials homogeneously in the pan mixer • Conveying the mix through conveyor belt to the press machine • Pressing of mix in standard shape and size • Formation of fly ash bricks at high pressure • Drying for 1- 2 days • Curing for 15-21 days	Fly Ash Bricks	Builder, Govt. bodies, Owners

B. Measure

This is the second phase of DMAIC process. In this phase, the flow, feedbacks, measurement-control points, and hand-offs across organisational groups are mapped for the different processes.

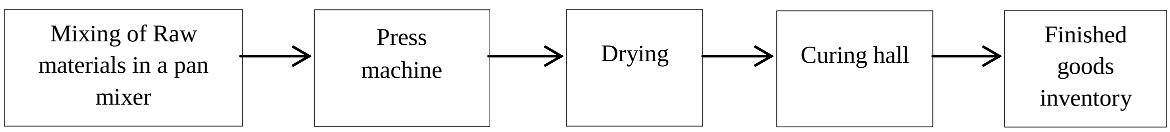

Fig.1 FAB manufacturing process

IV. RESULT AND ANALYSIS

Many defects in manufactured FAB due to the raw material test and compressive strength test on bricks such as fineness of fly ash, deleterious material, water absorption, soundness, proportion of ingredients, handling and stacking, curing and compressive strength of bricks. FAB inspected for these defects for different lots at plant out of these 23 defects were encountered in raw material samples and manufacturing process in the survey, defects in the raw materials and manufacturing process of FAB are shown in the fig. below

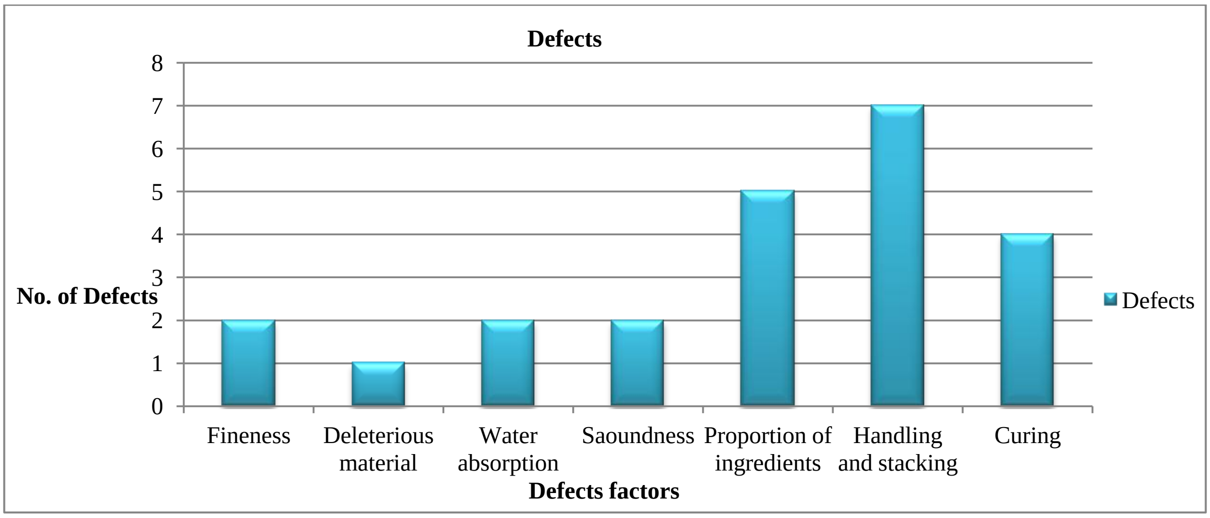

Fig. 2 Graph showing defects calculation

A. Analyze

In this phase, a thorough diagnosis of the current situation is made to identify the main factors that may influence the CTQs for the product quality and manufacturing process. We analyse hypotheses on the sources of wastes and poor quality which we set in the previous phase, we can analyse the process stability and process capability and determine the defects root causes of the current process status.

TABLE II
ANALYSIS OF COMPRESSIVE STRENGTH OF CLASS-10 FAB

Lot No.	Date of Manufacturing	Area (mm^2)	Load (KN)	28 Days Strength (N/ mm^2)
1	24- Sep.	17867	221	12.36
2	24-Sep.	17848	220	12.32
3	26-Sep.	17846	176	9.86
4	26-Sep.	17853	178	9.97
5	26-Sep.	17856	179	9.96
6	29-Sep.	17854	219	12.26
7	29-Sep.	17850	221	12.38
8	29-Sep.	17860	218	12.20
9	4-Oct.	17856	220	12.32
10	4-Oct.	17860	219	12.26
11	4-Oct.	17858	217	12.15
12	5-Oct.	17867	208	11.64
13	5-Oct.	17866	178	9.96
14	5-Oct.	17856	213	11.92
15	6-Oct.	17854	177	9.91
16	6-Oct.	17856	218	12.20
17	6-Oct.	17860	174	9.74
18	8-Oct.	17860	218	12.20
19	8-Oct.	17856	221	12.37
20	8-Oct.	17860	219	12.26

A. Pareto Chart

A Pareto chart is the one which depicts the frequency with which certain event occurs. It is a bar graph where each frequency (or frequency range) is shown in a descending order of their importance from left to right. Using a Pareto chart, helps us to concentrate or focus on those factors which have greatest impact.

A Pareto chart can answer us the following questions,

- What are the largest issues, our project team is facing?
- What 20% of the sources causing 80% of the problems?
- Where should we focus our efforts to achieve the greatest improvements for organisation?

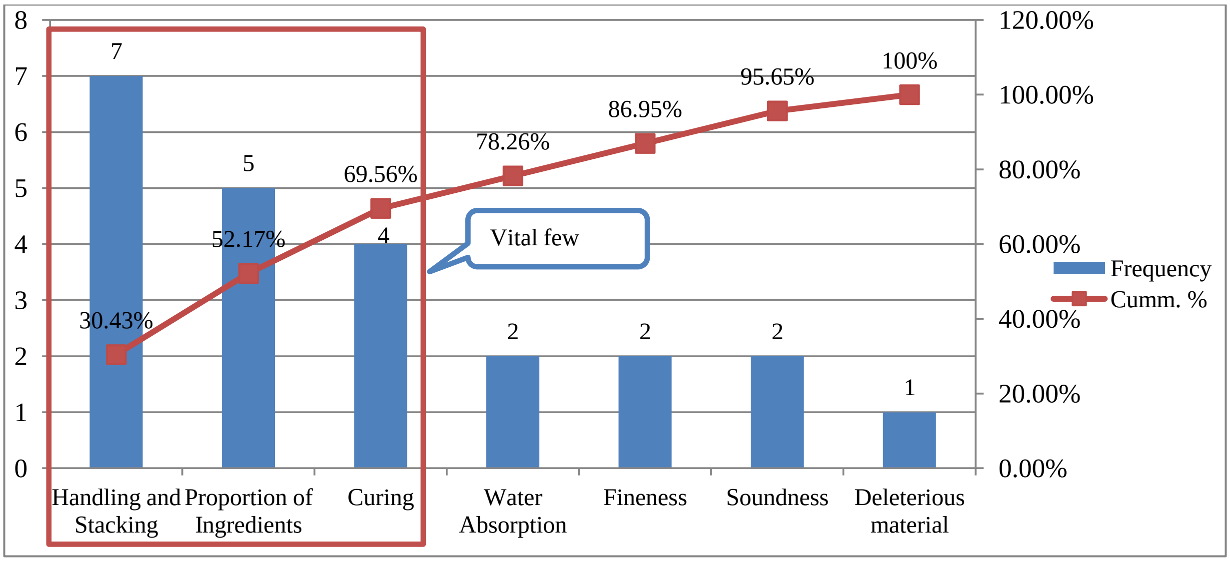

Fig. 3 Pareto Chart for defects factors frequency and Cumulative %

B. Customer satisfaction and relative importance index (RII) report

The customer satisfaction survey gives the information about the satisfaction level of some factors such as quality of product (bricks), Order-to-Delivery time, Product cost and owner's response to the customer feedback.

$$RELATIVE\ IMPORTANCE\ INDEX\ (RII) = \frac{\Sigma W}{(A \times N)} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5 \times N}$$

TABLE III
CUSTOMER SATISFACTION SURVEY AND RII REPORT

Sr. No.	Factors	Excellent (n_5)	Very Good (n_4)	Good (n_3)	Average (n_2)	Poor (n_1)	RII
1	Quality of Product	0	0	30	20	0	0.52
2	Order-to-Delivery time	0	0	16	28	6	0.44
3	Product Cost	0	0	32	18	0	0.528
4	Response to Feedback	0	0	12	26	12	0.4

C. Improve

In this phase actions that are needed to modify the process or settings of influence factors are designed in such a way that the CTQs are optimised.

a) Defects measurement Outcomes and Suggested action plan

TABLE IV
DEFECTS FREQUENCY AND THEIR CUMULATIVE PERCENTAGE

Defect Factors	Occurrence Frequency	Cumulative %
Handling and Stacking	7	30.43%
Proportion of ingredients	5	52.17%
Curing	4	69.56%
Water absorption	2	78.26%
Fineness	2	86.95%
Soundness	2	95.65%
Deleterious material	1	100%
Total Frequency	**23**	**-**

The specimens have been tested for five different mix proportions. The properties such as compressive strength were studied for different mix proportions and at different curing ages. From the results it was inferred that, among the five mix proportions, the maximum optimized compressive strength is obtained for optimal mix percentage of Flyash-30% Lime-20% Gypsum-2% Quarry dust-48% as 10.36 N/mm². From the results obtained water absorption for optimal mix percentage is 14.21%. It is lesser than the standard value of 15% and also it was observed that for maximum strength only minimum water absorption obtained.

TABLE V
VARIOUS MIX PROPORTIONS

Proportions	Fly ash (%)	Lime (%)	Gypsum (%)	Quarry dust (%)
I	30	20	2	48
II	35	15	2	48
III	40	18	2	40
IV	45	20	2	33
V	50	10	2	38

TABLE VI
COMPRESSIVE STRENGTH RESULTS FOR VARIOUS MIX PROPORTIONS

Mix Proportion	Area (mm^2)	Load (KN)	Compressive Strength (N/mm^2)
I	18486	192	10.38
II	18486	187	10.12
III	18486	183	9.89
IV	18486	169	9.14
V	18486	157	8.49

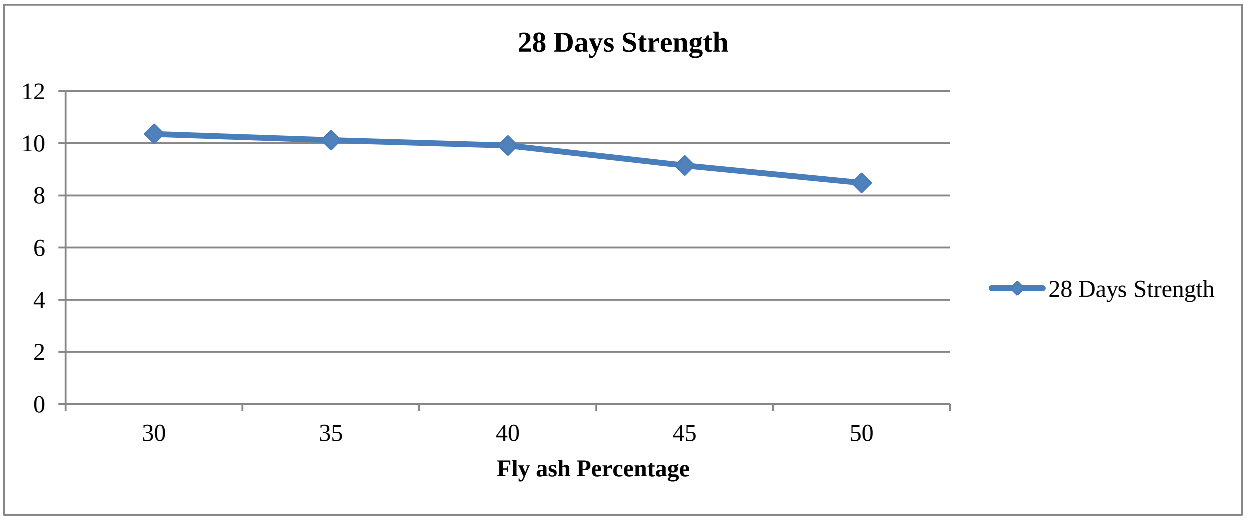

Fig. 6 Compressive strength graph

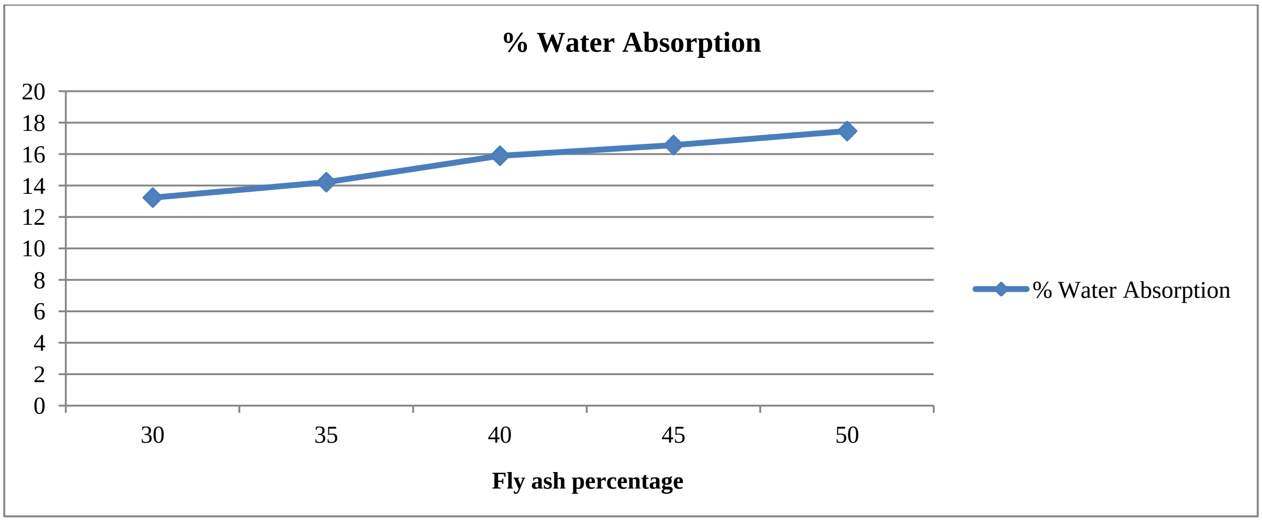

Fig. 7 Percentage Water Absorption Graph

TABLE VII
COMPRESSIVE STRENGTH DEFECT CAUSES AND SUGGESTED ACTION PLAN

Type of Cause	Suggested Action Plan
Men (labour, operator)	• Provide sufficient training to the worker • Provide every machine work instruction to worker to avoid mistake
Machine (Equipment)	• Preventive Maintenance of every machine to ensure machine is in good working condition and avoid breakdowns

Material	• The Fly ash content should be minimized to improve strength of bricks. • High calcium (CaO) Fly ash should be used for greater pozzolanic activity leading to greater strength • Fineness of Fly ash should be more for more pozzolanic activity contributing more strength
Method	• Mixing of raw materials should be done uniformly • Curing should be done properly for a period of 15- 20 days • Setting time can be minimized during winter by reducing Gypsum content
Environment	• Avoid storage of material in an open space too long

TABLE VIII
WATER ABSORPTION DEFECT CAUSES AND SUGGESTED ACTION PLAN

Type of Cause	Suggested Action Plan
Men (labour, operator)	• Provide sufficient training to the workers • Provide every machine work instruction to worker to avoid mistake
Machine (Equipment)	• Preventive Maintenance of every machine to ensure machine is in good working condition and avoid breakdowns
Material	• More is the strength of brick lesser is the water absorption, hence the proportion of mix with greater strength should be achieved for lesser water absorption • More is the unit weight lesser is the water absorption
Method	• Mixing of raw materials should be done uniformly and proportion of ingredients should be maintained • Air drying should be done for a period of 24- 48 hours
Environment	• Avoid storage of material in an open space too long • Workstations should be properly organised

With the implementation of Six Sigma DMAIC process, the Sigma level of the company was found to 2.7 σ which shows the poor quality level. After application of various control tools the defect level of the company has come down and sigma level has improved. It is now 3.67σ which has increased process yield and reduced the defect level percent from 30% to 10-15%. Finally the success was achieved in reducing the defect level of the company to such an extent, we could have achieved even more but that required changes in the whole processes, organising workstations leading to reduced process cycle time, placing bricks side by side for drying and curing.

D. CONTROL

In the Improve Phase we enhanced the system by reducing defects and eliminating variations so that it became capable and in line with the customer's requirements. In the Control Phase, we develop a control system to ensure that the improvements are maintained and the newly improved process can be executed in day-to-day operations of the FAB manufacturing plant. The aim of the control plan is to show that the appropriate level of control exists in relation to those aspects of the product those are critical to its continued acquiescence. It is use to monitor overall manufacturing and delivery process cycle, so the company will use the recommended checklist as a control plan.

V. CONCLUSIONS

The main causes for the defects in quality are quality of raw materials, unskilled labour's, manufacturing techniques, and improper supervision in manufacturing and delivery processes. The factors like more time of manufacturing were identified due to less utilization of equipment's, manpower, material- related problems, owner's financial constraints, delivery system, unqualified/inexperienced labour, shortage of labour and low productivity of labour. The six sigma DMAIC method noticed after arranging defects in an ascending order that are handling and stacking, proportion of ingredients, curing, water absorption, fineness, percentage deleterious material and soundness.

REFERENCES

[1] G. Watson, *Design for Six Sigma*, First Edition. GOAL/QPC. Salem. ISBN 157681-078-X. 396p. 2005.

[2] A. Khajuria, K. Singh, K. Sheikh, *Applying six sigma methodology in a brick kiln industry thereby reducing defect level*, Proceedings of the National Conference on Trends and Advances in Mechanical Engineering. Oct. 2012.

[3] Amer, A., M. Hasan Karakhan, H. M., and Angham, E. A., *Quality Evaluation of Al-Rasheed Ready Concrete Mixture Plant By Using Six Sigma Approach Journal of Engineering*, Journal of Engineering Vol. 18. Sep. 2012.

[4] V. S. Desale and S. V. Deodhar, *Lean Six Sigma Principal in Construction: A Literature Review Related to Conclusions*, International Journal of Emerging Technology and Advanced Engineering. Oct. 2013.

[5] G. Kumar, C. S. Jawalkar, R. O. Vaishya, *Six Sigma-An Innovative Approach for Improving Sigma Level: A Case Study of a Brick Company*, International Journal of Engineering and Innovative Technology (IJEIT), Volume 3. Feb. 2014.

[6] P. S. Sawant and V. S. Pataskar, *Applying Six Sigma Principles in Construction Industry for Quality Improvement*, Intl. Conf. on Advances In Engineering And Technology. 2014.

[7] Y. B. Kurata, E. F. Gala, G. R. Joshua and O. S. Gerald, *Process Improvement and Cycle Time Reduction in the Checking and Loading Process of the Outbound Department of Company*, Proceedings of the Asia Pacific Industrial Engineering & Management Systems Conference. 2015.

[8] B. Swethaa and L. C. Anto, *Quality Control in Construction using Six Sigma Technique*, Journal of Civil Engineering and Environmental Technology 436-439, Volume 3. June 2016.

[9] S. Sriram and A. Revathi, *Implementation of Six Sigma Concepts in Construction Project for Ensuring Quality Improvements*, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5. April 2016.

[10] S. Sathe and B. S. Allampallewar, *Application of Six Sigma in Construction*, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6. Nov. 2017.

[11] R. Sinaga, *The Quality Of Brick Products In Brick Production Process Using Six-Sigma Method At A Brick Factory*, American Journal of Engineering Research (AJER), Vol. 6. Dec. 2017.

[12] J. M. Shariq, G. Gangha and B. Indhu, *Lean Six Sigma Methodology for the Improvement of the road construction projects*, International Journal of Civil Engineering and Technology (IJCIET). May 2017.