APPLICATION OF SIX SIGMA FOR QUALITY IMPROVEMENT IN BUILDING CONSTRUCTION

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Abstract: Construction industry is suffering from issue of low productivity of labours and poor performance due to quality issues. Projects are getting delayed due to rejection of constructed components which are not meeting with the specifications. Concept of Six Sigma is a statistical problem solving methodology which is a powerful tool of Lean Construction to reduce defects by ensuring the quality. In this study, DMAIC approach of Six Sigma was applied on three items of construction: Flooring, Brickwork and Plastering. Sigma level was calculated for these items on construction projects and was observed as 2.75 for flooring work, 1.90 for brickwork and 2.60 for plastering work. After applying steps of improve and control stage of Six Sigma, it was observed that average improvement in sigma level was 12.7% for flooring work, 42% for brickwork and 19.2% for plastering work. Construction industry needs to apply the tool of six sigma to improve the quality of construction. This will help the contractor to improve overall quality of the whole structure and will also reduce the problems of maintenance in the future.

Keywords: Six Sigma, Building construction, Flooring, Brickwork, Plastering, DMAIC.

I. INTRODUCTION

India is one of the most developing countries in the world. Construction industry is growing at very fast rate in India. Many Infrastructure projects like Bullet train, Metro rails, Ports and Airports development are coming up in India. Real estate sector is also expanding in our country to meet the demand of houses for increased population in urban and rural areas. Construction industry is suffering from issue of low productivity of labours and poor performance due to quality issues. Projects are getting delayed due to rejection of constructed components which are not meeting with the specifications. Waste generation is also another burning issue of construction industry. In order to improve the performance of construction processes, construction industry seeks help of tools like Lean Technology or Lean Construction. Lean Construction looks into design and operation about the right processes. Main focus of Lean Construction is on elimination of waste generation. One of the tool of Lean Construction is Six Sigma.

Six Sigma is a statistical problem solving methodology which is a powerful lever to reduce defects by ensuring the quality. The term six sigma (6 σ) originated as a performance measure or a measure of quality. Six Sigma process goals are set in parts per million (PPM) in all areas of the building production process. This concept aims at reducing the defects down to 3.4 per million, or in other terms, it aims at achieving 99.99% success. Six Sigma has now evolved as a technology for improving business efficiency and also focusing on productivity, cost reduction and ensures quality. Six sigma uses generally two concepts: DMAIC and DMADV. DMAIC is Define, Measure, Analyze, Improve and Control. DMADV stands for Define, Measure, Analyze, Design and Verify. DMAIC method of Six Sigma is used for the projects which are aimed at improving the existing business processes. DMADV is used for the projects which are still in planning and design stage.

II. LITERATURE REVIEW

Sathe S & Allampallewar S B (2017) applied Six Sigma tool on construction project of a Commercial Building. They applied this tool on internal finishing works like Brickwork, Plastering, Flooring and Painting. They found that it is possible to adopt this tool in construction industry. They emphasized on bringing awareness among stakeholders like Consultants, Engineers and employees regarding benefits of Six Sigma. Bodke S et al (2017) studied the application of Six Sigma in building construction. They applied it for activity of plastering work during construction of 24 flats. Sigma level was worked out and then it was conveyed to the team of construction. After that, DMAIC methodology was applied to improve the quality of plastering work. Sukumar S and Radhika R (2017) studied implementation of Six Sigma as a process improvement method to improve the construction processes by analyzing the factors affecting the formation of construction wastes. Micheal S & Eldhose S (2014) applied Six Sigma to improve quality of construction in multi-storey buildings. DMAIC method was used to reduce the cost for variations and improve the quality of their product. Anitha P and Shanmugrapriya T (2016) implemented Six Sigma tool for elimination of waste and process improvement of construction work. Sree Vidya C (2019) did review of different papers that have done study of application of Six Sigma in

construction industry. Through study of 20 research papers, she found that there is a great scope in future for construction industry to adopt and apply the tool of Six Sigma for process improvement and to achieve goals of quality and time. Manojkumar R (2018) studied to improve the quality of painting work, brickwork, concreting work and welding work using SMAIC method of Six Sigma. Kuo-Liang Lee and Yang Su (2013) demonstrated how a six sigma team can determine and improve the key input variables affecting the cracks in lightweight partition walls. A case study methodology was used in this research.

III. METHODOLOGY

In this research case study approach was used. DMAIC concept of Six Sigma was applied on three ongoing construction projects. Details of construction projects are: [1] Flat construction at Anand, Gujarat [2] Hostel Building Construction project at Vallabh Vidyanagar, Gujarat and [3] Private Bunglows at Karamsad, Di. Anand, Gujarat. Flooring work was taken for study under six sigma on the first project. Brickwork was taken for study on second project and plastering work was studied on third project. Observations for defects were taken for each item under study for various criteria and then after sigma level was calculated. Defect per million opportunities (DPMO) was calculated for each item by following equation.

$$DPMO = \frac{\text{No. of '1' in checklist} * 10,00,000}{\text{No. of opportunities of defects} * \text{No. of units}}$$

Six sigma is found from DPMO value from standard conversion table of Six sigma to DPMO.

IV. DATA COLLECTION & CALCULATION OF SIGMA LEVEL

1. Flooring work

On first site of flat construction, flooring work was studied. Observations for defects were taken for eight different quality aspects like dimensions, leveling, colour variations, strength, thickness, skirting quality, joint work and polishing quality. Observations were taken from ten different locations of three flats. Sample observations are given in table 1 is as given below.

Table 1: Defects observations for Flooring work

	Site name: Flat construction at Anand									
	Parameters	Dimension quality	Leveling	Colour variation	Strength	Thickness	Skirting	Joint work	Polishing	Defects
	Flat no. 602									
Sr No	Location									
1	Bed room 1	0	0	0	0	0	1	0	0	1
2	Toilet 1	0	0	0	0	0	0	0	0	0
3	Drawing room	0	1	0	0	0	0	0	0	1
4	Kitchen	0	0	0	0	0	0	1	0	1
5	Store room	0	0	0	0	0	0	1	0	1
6	Bed room 2	0	0	0	0	0	0	0	0	0
7	Toilet 2	0	0	0	0	0	1	1	0	2
8	Common Toilet	0	0	0	0	0	0	0	0	0
9	Bed room 3	0	0	0	0	0	0	1	0	1
10	Dining room	0	0	0	0	0	0	0	0	0
										7/80

Total observed defects were 35 out of total 320.
DPMO = 35 * 10,00,000/ (8*10*4) = 109375. Hence, Sigma level is 2.75.

2. Brickwork

On second project site of Hostel building construction brickwork was taken for study. Observations for defects were taken for eight different quality aspects like thickness of joints, bond between bricks, dimensions of bricks, strength, leveling, curing, unevenness of joints and edges in bricks. Observations were taken from 34 different locations of Hostel building site. Observations are given in table 2 is as given below.

Table 2: Defects observations for Brickwork

	Site name: Hostel Building site at Vallabh Vidyanagar, Gujarat									
Sr No	Parameters / Wall id.	Thickness of joints	Bond unevenness	Dimensions	Strength	Leveling	Uneven joint gap	Curing	Edges	Defects
	GF									
1	Room 1	1	0	0	1	1	1	1	1	6
2	At 1	1	0	1	1	1	0	1	1	6
3	Room 2	1	1	0	0	1	0	0	0	3
4	At 2	1	0	0	1	1	1	0	1	5
5	Room 3	0	0	0	0	1	1	0	1	3
6	At 3	0	0	1	1	1	0	0	1	4
	SF									
7	Room 1	0	1	0	0	1	0	0	1	3
8	At 1	0	1	0	1	1	1	0	0	4
9	Room 2	0	1	0	1	0	1	0	1	4
10	At 2	0	0	0	0	1	1	0	1	3
11	Room 3	0	0	0	0	1	1	0	0	2
12	At 3	0	0	1	0	1	1	0	0	3
13	Room 4	0	1	0	1	0	1	0	1	4
14	At 4	0	0	0	0	1	1	0	0	2
15	Room 5	1	0	0	0	1	0	0	1	3
16	At 5	0	0	0	1	1	1	0	0	3
17	Room 6	1	0	0	0	1	0	0	0	2
18	At 6	0	0	0	0	1	0	1	0	2
19	Room 7	0	0	0	1	1	0	0	1	3
20	At 7	0	0	0	0	1	0	0	0	1
21	Room 8	0	0	0	0	1	0	0	1	2
22	At 8	0	0	0	0	1	0	0	0	1
23	Room 9	0	0	0	0	1	1	0	1	3
24	At 9	0	0	0	0	1	0	0	0	1
25	Room 10	0	0	0	1	1	0	0	1	3
26	At 10	0	0	0	0	1	0	0	0	1
27	Room 11	0	0	0	0	1	1	0	0	2
28	At 11	0	0	0	0	0	0	0	1	1
29	Room 12	0	0	0	1	1	1	0	1	4
30	At 12	1	0	0	0	0	0	0	0	1
31	Room 13	0	0	0	0	1	0	0	1	2
32	At 13	0	0	0	0	1	0	0	0	1
33	Room 14	0	0	0	1	1	0	0	1	3
34	At 14	0	0	0	0	1	0	0	1	2
	Total									**93/272**

Total observed defects were 93 out of total 272.
DPMO = 93 * 10,00,000/ (272) = 341911 . Hence, Sigma level is 1.9.

3. Plastering

On third project site of private bungalow construction at Karamsad, Anand, plastering was taken for study. Observations for defects were taken for eight different quality aspects like swelling, curing, cracks, falling off, stains on surface, unevenness, finishing, moisture end edges and corners work. Observations were taken from five different locations of five bungalows. Observations are given in Table 3 is as given below.

Table 3: Defects observations for Plastering work

	Site name: Private Bungalows construction at Karamsad, Anand										
	Parameters	Swelling	Curing	Cracks	Falling of plaster	Rust stains	Uneven surface	Finishing	Moisture	Edges	Defects
	House no.										
Sr No	18										
1	Lr	0	0	0	0	1	0	0	1	0	2
2	Kt	0	0	0	0	1	0	0	1	0	2
3	Br 1	1	0	0	0	0	0	0	1	0	2
4	Br 2	0	0	0	0	0	0	1	0	0	1
5	Br 3	1	0	0	0	0	0	0	0	1	2
	19										
6	Lr	0	0	0	0	0	0	0	0	0	0
7	Kt	0	0	0	0	1	0	0	1	0	2
8	Br 1	1	0	0	0	0	0	0	0	0	1
9	Br 2	1	0	0	0	0	0	0	0	0	1
10	Br 3	0	0	0	0	0	0	1	0	0	1
	20										
11	Lr	0	0	0	0	1	0	0	0	0	1
12	Kt	0	0	1	0	0	0	0	0	0	1
13	Br 1	0	0	0	0	0	0	0	0	0	0
14	Br 2	0	0	0	1	0	0	0	0	0	1
15	Br 3	0	0	0	0	0	0	1	0	0	1
	22										
16	Lr	0	0	0	0	0	0	0	0	0	0
17	Kt	0	0	1	0	0	0	0	0	0	1
18	Br 1	0	0	0	0	0	0	1	0	0	1
19	Br 2	0	0	0	0	0	0	0	1	0	1
20	Br 3	0	0	0	0	0	1	1	0	0	2
	02										
21	Lr	0	0	0	0	0	0	0	0	1	1
22	Kt	0	0	0	0	0	0	0	0	1	1
23	Br 1	0	0	0	0	1	1	0	0	1	3
24	Br 2	0	0	0	0	0	0	0	0	0	0
25	Br 3	0	0	0	0	0	1	1	0	0	2
	Total										**30/225**

Total observed defects were 30 out of total 225.
DPMO = 30 * 10,00,000/ (225) = 133333.3. Hence, Sigma level is 2.6.

V. APPLICATION OF ANALYZE, IMPROVE AND CONTROL PHASES

After calculating sigma levels for flooring, brickwork and plastering on three different sites, it was time to apply next phases of Six sigma, that is analyze, improve and control. So, results were prepared and shown to construction team members like engineer in charge and supervisors. They were made aware about defects and possible ways were discussed to improve upon aspects to reduce the defects. Supervisors had further discussion with team of masons and labours to further work in the direction to reduce the defects. Sigma level was again calculated on same construction sites for same items after a gap of certain time period. Same parameters were taken for identification of defects. Results of new sigma level and its comparison with old sigma level are given in Table 4 as given below.

Table 4: Sigma level comparison for 3 construction items

Sr No	Item under study for sigma level	Detail of construction site	Old sigma level	New sigma level	% improvement in sigma level
1	Flooring work	Flat construction at Anand	2.75	3.10	12.7
2	Brick work	Hostel Building site at Vallabh Vidyanagar	1.90	2.70	42
3	Plastering work	Private Bungalows construction at Karamsad, Anand	2.60	3.10	19.2

VI. RESULTS AND DISCUSSION

It is observed that six sigma level of flooring was 2.75, that of brickwork was 1.9 and for plastering it was found as 2.60. After finding these levels, construction team members were made aware to know about defects and their root cause were also discussed. Team members were told to improve the performance in next phase of work. Sigma level was again measured after doing this exercise. It was found that sigma level got improved by 12.7% for flooring work. For brickwork, sigma level was improved by 42%. This is very notable improvement of sigma level. For plastering work, sigma level was improved by 19.2%.

VII. CONCLUSION

This study covers application of Six Sigma on three major construction activities like flooring, brickwork and plastering on three different construction projects. Results are quite good which shows average increase in sigma level for construction items as 24.6%. So, it is concluded that construction industry should apply the tool of Six Sigma to improve the quality of different items of construction. This will help the contractor to improve overall quality of the whole structure and will also reduce problems of maintenance in the future.

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