APPLICATION OF SIX-SIGMA TOOL IN RESIDENTIAL PROJECT AT SURAT

[1]Rujal J. Parmar, [2] Vyom B. Pathak, [3]Hiren A. Rathod, [4]Rushabh shah
[1]Student of Masters of Construction Engineering and Management, [2]Assistant Professor& Research Scholar, [3,4]Assistant Professor
[1]Department of Civil Engineering,
[1]SNPIT & RC, Umrakh, Bardoli, Gujarat, India

Abstract: ***Six-Sigma is a Quality improvement technique that has being implemented in manufacturing and other industries. Six -Sigma is new to construction industry. This paper describes the basic theory of Six Sigma, principles, methodology. A case study of a residential building is taken in which the Six Sigma principles are applied for internal finishing work, the Six Sigma methodology has been adopted to improve the quality and is checked against the sigma level.***

Index Terms - Six-Sigma, Quality Control, Defects, Causes and Recommendations, Construction industry

---

I. INTRODUCTION

For any construction project, Time, Cost and Quality are very vital. Quality can be achieved by applying the Six-Sigma tool that was first found out and implemented by Motorola Corp in early 1980s. Six-Sigma is a highly disciplined process that helps us focus on developing and delivering near-perfect products and services. The word *Sigma* is a statistical term that measures how far a given process deviates from perfection. Six-Sigma is a data driven methodology, and requires accurate data collection for the processes being analysed. Six-Sigma is a business-driven, multi-dimensional structured approach for: improving the processes, lowering the defects, reducing the process variability and the costs, Increasing the customer satisfaction and profits.

II. LITERATURE REVIEW

Devendra G. Pendokhare, Taqui Quazi[1] The objective of this paper is to review and examine the evolution, benefits, and challenges of six sigma practices and its future as a management tool in organizations.

Ganesh U. Borse and Prof. P. M. Attarde [2] have carried out the literature survey and have presented the review of eight literatures in which Six-Sigma is applied in the construction industry.

Low Sui Pheng and Mok Sze Hui [3] carried out the case study at the Housing and Development Board (HDB), Singapore. Six-Sigma was applied to improve the quality of internal finishes where improvement measures taken by Contractor A helped to raise the Sigma from 2.66σ to 3.95σ.

Ruchika S. Patel, Dr. Neeraj D. Shah and Hiren A. Rathod [4], in their paper, gave the review of various papers related to Six-Sigma in Construction Industry.

Sneha P. Sawant and Smita V. Pataskar[5] described the basic theory of Six Sigma, principles, methodology and various tools used. A case study of a residential building is taken in which the Six Sigma principles are applied for internal finishing work, the Six Sigma methodology has been adopted to improve the quality and is checked against the sigma level. The findings suggest that proper training and management support and minor changes in current work procedure can help improve the quality and ultimately customer satisfaction which is of prime importance

III. PROBLEM STATEMENT

Construction management and technology are the two key factors influencing the development of the construction industry. The productivity of the construction industry worldwide has been declining over many past years. In order to achieve high quality level in construction industry and improve the performance, feasibility and suitability of different new philosophies in construction projects have been studied in recent years, but due to the various processes associated with construction projects, their complexity, and lack of specific metrics, this issue is still questionable and demands further studies. One approach for improving the process is using Six Sigma concepts in construction.

IV. OBJECTIVES

- To develop strategy for applying six sigma in onstruction project.
- To investigate the existing sigma level of project undertaken.
- To propose the corrective measure to enhance the sigma level of the project.

V. RESEARCH METHODOLOGY

Six-Sigma tool has two methodologies viz. DMAIC (Define, Measure, Analyze, Improve and Control) and DMADV (Define, Measure, Analyze, Design and Verify). DMAIC is used for projects aimed at improving the existing process whereas DMADV is used for projects aimed at creating new product or process designs. In this case-study, DMADV methodology was used.

Table 1: Framework of DMADV

Steps	Theory	Practical (What I am going to do?)
Define	Define the design goals that are required for quality improvement.	Four elements wall,floor, ceiling, door, window have been chosen for carrying out the research work.

Measure	Measure and identify CTQs (Critical to Quality), measure product capabilities, production process capability and risks that already exist or are in practice.	The specifications, materials & their properties used in these elements will be collected. The processes will be studied and analyzed by using questionnaire survey.
Analysis	Find out the lacuna in the existing product and processes.	From the data collected analyzed by using questionnaire survey, lacuna in the existing processes will be identified.
Design	Design an improved alternative, best suited per analysis in the previous step.	New alternatives will be discovered and recommended.
Verify	Investigate the probable changes**.**	Comparison will be done between the existing and new recommended ideas.

VI. DATA COLLECTION AND ANALYSIS

5.1 Execution of DMADV Framework

5.1.1 Define:

First of all, the permission was taken to carry out the research work by collecting the data from the residential site viz. Green City Gold which is located at pal Bhatha, Adajan, Surat.Four elements wall, floor, ceiling, door, and window have been chosen for carrying out the research work. Finding the defects in floor, wall, ceiling, door and window.

Table 2: Identified Defects

Floor	**Walls**	**Ceiling**	**Door and windows**
Finishing	Finishing	Finishing	Joints and gaps
Cracks and damages	Alignment	Cracks and damages	Material and damages
Roughness	Cracks and damages	Roughness	Functionality
Jointing	Jointing	Jointing	Accessories defects

5.1.2 Measure:

To find out the defects in floor, ceiling, wall, door, window of 52 flats and the site visit was done and observed carefully, checked out if there were any defects. The table below shows the defects identified no. of defects and no. of checks.

Table 3: No. of Defects per Flats

No. of Flat	**No. of Defect**	**No. of Flat**	**No. of Defect**	**No. of Flat**	**No. of Defect**
1	12	**21**	35	**41**	35
2	15	**22**	35	**42**	34
3	32	**23**	27	**43**	31
4	37	**24**	36	**44**	34
5	52	**25**	30	**45**	33
6	39	**26**	23	**46**	30
7	42	**27**	34	**47**	32
8	48	**28**	33	**48**	40
9	20	**29**	33	**49**	29
10	28	**30**	28	**50**	39
11	57	**31**	35	**51**	32
12	32	**32**	29	**52**	36
13	34	**33**	35		
14	26	**34**	30		
15	49	**35**	31	**Total defects=1728**	
16	38	**36**	32	**Avg.=1728/52**	
17	38	**37**	27	**=33.23**	
18	34	**38**	34	**≅ 34**	
19	33	**39**	30		
20	28	**40**	32		

5.1.3 Analysis:

The aim of Six Sigma is to improve the quality near perfection which means 3.4 Defects per Million Opportunities (DPMO), to maximize the customer satisfaction and business benefits. This goal will occur when the sigma level is 6. Table 2 illustrates the rate of defects per million opportunities in different sigma levels.

Table 4: Rate of DPMO in Different Sigma Level

Yield	**DPMO**	**Sigma Level**
30.9	690,000	1
69.2	308,000	2
93.3	66,800	3
99.4	6,210	4

99.98	320	5
99.9997	3.41	6

$$\text{Yield}=\frac{\text{Total no.of perfects}}{\text{Total no. of checks}}\times 100\%$$
$$=\frac{(264-34)}{264}\times 100$$
$$\textbf{Yield=87.121\%}$$
$$\text{DPMO}=\frac{\text{No.of 'X' in the data collection sheet}}{\text{No. of opportunities of defects} \times \text{No of unit}}\times 1000000$$
$$=\frac{34}{264}\times 1000000$$
$$=1{,}28{,}787.87$$
$$\textbf{DPMO}\cong \mathbf{1,28,788}$$

Based on the sigma conversion table 4, the equivalent sigma for 1, 28,788 DPMO was calculated approximately 2.743. It was found out by interpolating the values from table. Thus the current sigma level of the green city gold is 2.743.

5.1.4 Verify:

After finding the current sigma level, find out cause of defects and recommendations were given along with the repair measures. Some of the recommendations were implemented at the site as per the feasibility. Again after that, the new sigma level was calculated after some implementation.

Table 5: Causes and Recommendation of Defects

		Causes	**Recommendation**
Floor	Finishing and Roughness	1) Unskilled labour. 2) Tile's concrete substrate did not cure long enough. 3) Improper level of RCC slab surface 4)Instrumental Errors 5) Colour Variation	1) Tainting should be provided
			2) Tile's concrete substrate should be cured long enough as per specification.
			3) Proper curing method should be required.(method: free flow)
			4) Calibrating different instruments (level tube, polishing machine) should be used during work at various period.
			5) Water Repellents used for preventing abrasion effect.
			6) In tiles at every re-manufacturing time of same tiles there is minor color or shade different are generated so proper ordering quantity of tiles for work with some extra because in future it may not available in same shade.
			7) Good workmanship/ monitoring/ supervising should be required
	Crack and Damage	1) Tile cracked under heavy loads. 2)Tiles are not handled with care by the labour 3) Improper storage for tiles. 4) Uneven sand bed layer 5) Improper cement sand mortar ratio 6) Poor Selection of Floor tiles or other as per usage.	1) Replace the tiles and use of correct adhesives should be done.
			2) Replace the damage tiles.
			3) Epoxy tanex should used
			4) Labours should be instructed strictly to handle tile with care.
			5) During transit of tile proper care should be taken.
			6) Worker should be more careful while placing tiles.
			7) Proper storage should be done
			8) Before laying any tile should to be check layer of sand mortar by lines and instruments
			9) Proper Batching and Mixing of mortar before laying is required
			10) As per usage of area tiles should be select like in heavier usage Full Charge tile & double charge

			tile should be used or else some very heavier vehicular running area epoxy flooring is best for it.
	Jointing	1) Tile was installed improperly. 2) Company Sizing Variation 3) Sizing 4) Cutting	1) Tile should be installed properly.
			2) Tiles of improper dimension should be replaced.
			3) Joint filler + epoxy should be used. Joint filler(Weber colour dewdrop)
			4) While taking /buying the tiles from the manufactured, it should be checked whether the dimension of tiles are proper or not.
			5) Before fixing of any tile it has to be check by laying tiles at floor level it useful in Check Bending, Check Sizing, Check Colour Variation
			6)Large Size tiles are generally found some bend at different corner so in good practice is mandatory to provide some space between to tile by spacers(groove)
			7)After laying of Tile if some corners are not matching then providing some heavy weight at jointing doing that after one day removal of weight tile bandage is not seen.
			8) Cutting of tiles is required to be straight during cutting by machine for reducing gap between two tiles.
Wall	Finishing	1) Poor workmanship. 2) Mortar proportion is not good. 3) Scaffolding	1) Good workmanship/ monitoring/ supervising should be required.
			2) Mortar proportion (1:6) should be good as per specification.
			3) Gypsum plasterboard, wall paper, POP punning should be used.
			4) Finishing of different base material is differ like fly wall ash block surface and conventional bricks. Fly ash block has good finishing surface as compared to bricks.
			5) Exposed concrete wall required good scaffolding so for that selection of scaffolding is properly done.
	Alignment	1) Improper plaster. 2) Marking at the base is not done properly. 3) Error of levelling instruments.	1) Proper plastering should be done.
			2) Proper marking on the floor should be done before laying the first layer of masonry.
			3) Bricks should be laid properly.
			4) POP punning should be used.
			5) Check the levelling instrument before work.
	Crack and Damage	1) Pre-wetting of bricks 2) Bricks are not handled with care by the labour. 3) Less curing. 4) Weather effect. 5) Movement of the roof structure.	1) Fly ash brick should be used.
			2) Fill the cracks by injecting the epoxy (MYK,keracol). Crack grout(perma grout-60SPL),glass fiber
			3) Labours should be instructed strictly to handle brick with care.
			4) Fill the damage part with mortar and seal properly.
			5) Proper curing should be required.
			6) The dimension of the bricks and blocks should be checked before using them.
			7) Construct the foundation of buildings on firm ground while doing construction.
			8) Fly ash brick should be used.

	Jointing	1)poor material(thermocol sheet)	1) Expansion sheet should to be used prior to thermocol sheet at structural joint.
			2) Fill of mortar or grout in joint
Ceiling	Finishing and Roughness	1) Improper formwork. 2) Improper slab casting. 3) Instrumental Errors 4) Environment: Casting during Raining Season 5) Improper level of RCC slab surface 6) Improper ingredient mixing for particular work.	1) Proper formwork should be done.
			2) Proper slab casting should be done.
			3) Good workmanship/ monitoring /supervising should be required.
			4) POP should be required.
			5) Maintain Scaffolding level before and after casting & During Casting check concreting final levels.
			6) Removal of formwork with Gently for maintaining concrete sharp edges.
	Crack and Damage	1) Initial heavy load. 2) Improper slab casting.	1) Initial heavy loading on slab should be avoided.
			2) Worker should be more careful while during slab casting.
			3) Proper needle vibrator should be used during casting.
			4) Cover up fresh slab by plastic sheet used for preventing cracks.
			5) Self cure compound should be required.(Antisol-A)
			6)Earlier Removal of Scaffolding
Door and Window	Joint and Gap	1) Poor workmanship. 2) Improper Installation. 3) Faulty Hinges 4) Expansion of Door Sizes	1) Filing of silicon in joint.
			2) Good workmanship/ Monitoring /supervising should be required.
			3) Installation should be done proper.
			4) Hinges operate smoothly during usage is required
			5) Selection of hinges as per door thickness and weight of door.
			6)Size of Hinge varies with thickness of doors and weight of door
			7) Selection of door from various vendors preciously for reduce future maintenance.
			8) Different R&D (research and development) should carried out at site level inspection.
	Damages	1) Poor material. 2) Poor workmanship. 3) Storing Place	1) Use of good quality of material.
			2) While taking /buying the material from the manufactured, it should be checked.
			3) Good workmanship/ monitoring /supervising should be required.
			4) Doors Should store at shade area which free from direct rain and sun.
			5) Fill the damage part with mortar and seal properly.
	Functionality	1) Unlevelled floor surface. 2) Poor installation.	1) Proper marking should be done.
			2) Installation should be done proper.
			3) Labours should be instructed strictly to handle with care.
			4) Ordering doors as per actual size on site preciously.

	Accessories Defects	1) Variation of dimension in frame. 2) Poor material.	1) The dimension of the frame should be checked before using them.
			2) Frame should be manufactured as per the standards.
			3) Use of good quality of material.
			4) While taking /buying the material from the manufactured, it should be checked.

5.1.4.1 New Evaluating Six Sigma Level:

Table 6: No. of Defects per Flats

No. of Flat	No. of Defect	No. of Flat	No. of Defect	No. of Flat	No. of Defect
1	5	**21**	10	**41**	15
2	7	**22**	15	**42**	9
3	11	**23**	7	**43**	11
4	12	**24**	12	**44**	13
5	15	**25**	10	**45**	11
6	11	**26**	6	**46**	8
7	13	**27**	13	**47**	6
8	16	**28**	8	**48**	12
9	4	**29**	11	**49**	5
10	10	**30**	5	**50**	19
11	20	**31**	19	**51**	4
12	13	**32**	7	**52**	8
13	11	**33**	14	**Total defects=564 Avg.=564/52 =10.85 ≅ 11**	
14	9	**34**	6		
15	17	**35**	12		
16	11	**36**	12		
17	19	**37**	10		
18	9	**38**	14		
19	6	**39**	12		
20	8	**40**	13		

$$\text{Yield}=\frac{\text{Total no.of perfects}}{\text{Total no. of checks}}\times 100\%$$

$$=\frac{(264-11)}{264}\times 100$$

Yield=95.83%

$$\text{DPMO}=\frac{\text{No.of 'X' in the data collection sheet}}{\text{No. of opportunities of defects} \times \text{No of unit}}\times 1000000$$

$$=\frac{11}{264}\times 1000000$$

$$=41{,}666.67$$

DPMO≅ 41,667

Based on the sigma conversion table 4, the equivalent sigma for 41,667 DPMO was calculated approximately 3.415. It was found out by interpolating the values from table. 4.Thus, the current sigma level of the green city gold is 3.415 which showed a good improvement. Thus, the positive results were obtained by implementing the six sigma.

VII. CONCLUSION

The strategy for applying the Six-Sigma tool in construction project was studied by undertaking a case study on Millennium Textile Market, which suggests that DMADV methodology works more suitably. For the successful application of Six-Sigma it is required to have a very supportive management, allegiance to quality, attaining satisfaction of the customer and knowledgeable staff which was fortunately the case with the undertaken case study that helped us out with effective practice of Six-Sigma tool in construction project.

The processes and procedures are likely to be more complex at Millennium Textile Market as it is a large scale project. The concept of Six-Sigma is new when talked about the quality in the construction industry but the results obtained from the case study revealed that if standard procedure of detecting the defects is adopted in the terms of quality, the sigma level can be calculated which gives a prediction about the level of quality and the room for improvement.

VIII. ACKNOWLEDGEMENT

I would like to take this opportunity to express my profound debt of gratitude towards Mr. Vyom B. Pathak, Mr. Hiren A. Rathod and Mr. Rushabh Shah for their valuable guidance, helpful comments and cooperation with kind and encouraging attitude at all the stages of the work.

REFERENCES

[1] Adure, Gautam S. and Shusma S. Kulkarni, "Process improvement in construction industry through six sigma approach", Global J. of Engg. & Appl. Sciences, 2012: 2(1), 49-55.
[2] Frank T. Anbari, Young Hoon Kwak, "Success Factors In Managing Six Sigma Projects", Project Management Institute Research Conference, London, July 11-14, 2004.
[3] Ganesh U. Borse, Prof. P. M. Attarde, "Application of Six Sigma Technique for Commercial Construction Project- A Review", International Research Journal of Engineering and Technology, Vol. 03, Issue: 06, June-2016.
[4] Low Sui Pheng and Mok Sze Hui, "Implementing and Applying Six Sigma in Construction", Journal of Construction Engineering and Management © ASCE, Vol. 130, No. 4, August 1, 2004.
[5] Ruchika S. Patel, Dr. Neeraj D. Sharma, Hiren A. Rathod, "Application of Six-Sigma Tool for Construction Project – A Review", International Journal for Scientific Research and Development, Vol.-4, Issue 12, 2017, ISSN : 2321-0613, pp. 906-908.
[6] Sarathkumar K, Loganathan R, "Evaluation of Six Sigma Concepts in Construction Industry", International Journal of Scientific & Engineering Research, Vol. 7, Issue 4, April-2016.
[7] Seung Heon Han, Ho Dong Ryu, Myung Jin Chae, Han Him Kim, Do Yon Kim, Sun Hee Kim, "Six-Sigma Based Approach for Productivity Improvement in Construction Project", International Association for Automation and Robotics in Construction, Taiwan.
[8] Sneha P. Sawant and Smita V. Pataskar, "Applying Six Sigma Principles in Construction Industry for Quality Improvement", Intl. Conf. on Advances in Engineering and Technology, 2014.
[9] Virender Narula, Sandeep Grover, "Six Sigma: Literature Review and Implications for Future Research", International Journal of Industrial Engineering & Production Research, Volume 26, No. 1, January 2015, pp. 13-26.
[10] "Defects In Brick Masonry, Brick Damage Types, Brickwork Defects", http://constructioncost.co/reasons-for-defects-in-brick-masonry.htm
[11] "What cause defects in brick masonry and its remedies?", http://civilblog.org/2015/09/21/what-cause-defects-in-brick-masonry-and-its-remedies/
[12] "Defects and malfunctions in wall and floor tilings", http://www3.ipc.org.es/guia_colocacion/defectos_disfunciones.html
[13] "Six Sigma Project Management", http://civilengineerlink.com/6-sigma/
[14] "What is DMADV?", http://www.sixsigmadaily.com/what-is-dmadv/
[15] "Six Sigma Guide", http://www.tutorialspoint.com/six_sigma/six_sigma_quick_guide.htm