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Construction Materials Management: A case study of Residential Building Construction Project

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Abstract -

This paper is written to fill a void created by the absence of proper material management on construction sites. This project titled 'Construction Material Management: A case study of Residential Building Construction Project' is an attempt made on studying and assessing the material management principles and practices in a residential project. The objective of the present study is to understand about the problems occurring in the organization because of improper application of material management. In construction project operation, often there is a project cost variance in terms of the material, equipment's, manpower, subcontractor, overhead cost, and general condition. Material is the main component in construction projects. Therefore, if the material management is not properly managed it will create a project cost variance. Project cost can be controlled by taking corrective actions towards the cost variance. Therefore a methodology is made to classify the materials by ABC analysis and these materials are identified and are taken up to measure the variations involved by S-Curve analysis and suitable measures are suggested using cause and effect diagram. EOQ analysis helped to suggest the root causes for many types of problems that were detected at the project site.

Key Words*:* Material Management, ABC (Always Better Control) Classification, Material Requirement Plan (MRP), S-Curve analysis, Cost variance, Cause and Effect diagram.

1.INTRODUCTION *(Size 11, Times New roman)*

Material management is a management process where coordination, supervision and execution of the task are related with a flow of material in and out of an organization. Material management deals with principles and practices which effectively optimizes the cost of material used in the project. Material management is the line of responsibility which begins with the selection of suppliers and ends when the material is delivered to its point.

Material management is associated to planning, acquiring, storing and providing the proper materials of right quality, right quantity at right places in right time so as to co-ordinate and schedule the construction activity. Materials management is the single manpower organization concept embracing and planning, developing and monitoring of all those activities and the line responsibility which begins with the selection and personnel primarily concerned with the flow of material into and within the organization.

Study of material management suggest that real saving in cost can happen in improved labor productivity, reduced surplus, and improved cash flow. Suggesting the necessity for high level attention towards materials has not been easy, however, despite the evidence that materials cover more than half of the project cost and the deficiency of material is the major cause of project delays.

2. CASE STUDY

General

For the purpose of studying the material management practices in construction industry, a row housing residential building is taken up for the case study. The details are given below.

Location of case study

This site is located at samata nagar, DP road, Kopargaon, 423 603. Survey number of plot is 196/12/15.

Type of structure: RCC structures.

Type of structure of case study is RCC structure. RCC contains embedded steel bars, or fibers reinforcing the material. Such materials magnify the load carrying capacity, and because of this, RCC construction is used in case study.

Project structure

Row house 1,2 – 83.80 Sq.m (2bhk)

Row house 3,4 - 83.80 Sq.m (2bhk)

Table-2.1: Project details.

Particulars	**Information**
Project start date	7 sep 2021
Estimated structure completion date	10 feb 2022
Estimated project completion date	30 april 2021
Estimated project duration	8 months
Total built up area	177.93 sqm (1914 sq.ft)
Estimate approximate value of materials	4605746
Cost per square feet	1350
Main usage of building	residential building
Civil contractor	Shafik Mansuri
Architect	Er. Emran Y Shaikh

Structural consultant	Nirmiti associate
Number of floors	Ground floor + 2 floors

3. DATA ANALYSIS:

From the study of the material management practices in the project, which is presented in the previous chapter, following conclusions can be drawn.

- Material management does not have a well-defined place in the management system created for successful completion of the project.
- Material classific ation of the consumable material items are based only on the material cost or the usage. ABC classification of materials is not based on the cost or usage, but on the Annual Usage Value for each material item throughout the project plan period.
- ABC analysis is independent of the importance of the material item. The limits of ABC analysis are not uniform but depend upon the size of inventory as well as the number of items controlled.
- Practices of material management are having same importance as that of contract management or financial management as it can directly help in boosting the profit of the project.
- Material management practices demonstrates that integration of well-defined material management system in a project not only optimizes project cost, but also strengthens project management system multifold.

With these backgrounds, following material management practices, which could be directly integrated into the existing project system have been suggested. The input cost to maintain these practices are almost nominal. If these practices are used, an integrated material management system will steadily evolve in construction industry.

3.1 Materials planning:

An effective material planning requires three basic and vital information as input to have a validated output.

- Construction schedule
- Quantities of materials required for various activities
- Inventory record

Since the organization was using materials from the vendor and not from any of the previous projects, the inventory records of previous projects were not required. Even though the entire project duration was for 8 months, only 3 months plan could be made.

Bill of material explosion could be the technique, which can be used to do MRP for the project. Depending upon the schedule of work, the various activities in each month can be studied. Each of these activities will be consuming different types of materials. For each activity a bill of materials could be prepared which will indicate different types of materials required in the activity. In similar manner material requirements for various activities can be made. In a particular month, the activities that will be taken up can then be summarized along with their material requirements.

Methodology Adopted:

In preparing the explosion chart for Class A materials, the following methods have been adopted.

1. The quantity of materials required for unit work has been arrived at by using standard rate analysis.
2. The quantity and duration of the various works executed have been taken from the project estimates and project schedules which are updated on a monthly basis.
3. The material explosion chart has been formulated by combining the above two steps.
4. For further study Class A materials has been considered and the Material explosion chart has been formulated based on the updated schedule

Table 3.1.1: Material Requirement Plan

description	Steel (ton)	Cement	Sand (brass)	CA	Brick
Upto PL	2.5	248	6	9.40	3700
PL to GF	3.318	282	7	9.20	6000
GF to FF	3.115	282	9	8.20	15000
FF to SF	2.54	500	12	8.20	25700
Total	11.48 ton	1312	34 brass	35 brass	50400 nos

Table 3.1.2: Requirement of steel upto plinth

Sr no	Description	Steel quantity in mt
1	Footing tmt	0.420
2	Plinth jali tmt	0.250
3	Column tmt	0.73
4	Beam tmt	1.10

Table 3.1.3: Requirement of steel from plinth to ground floor

Sr no	Description	Steel quantity in mt
1	Column	0.88
2	Beam	1.23
3	Slab	1.208

Table 3.1.4: material required upto plinth

Item no	**Description**	**Quantity**	**Unit**	**Cement Bags**	**Sand brass**	**Aggregate**
1	Rubble soling	26.3	Cum			9.29 rubble
2	Murrum	24.1	Cum			9 brass
3	PCC M15	11.61	Cum	70	1.62	3.48 brass
4	Rcc M20 footing	7.2	Cum	60	1	2.14 brass
5	M20 column	6.022	Cum	49	0.93	1.72 brass
6	M20 beams	7.1	Cum	57	1.10	2.02 brass

Table no 3.1.5: material required from plinth to ground floor

Material no	**Description of material**	**Quantity in cum**	**Cement Bags**	**Sand Brass**	**Aggregate Brass**
1	M20 column	5.30	44	0.73	1.57
2	M20 beams and lintels	7.68	63	1.20	2.25
3	M20 slabs	11.85	100	1.76	3.78
4	M20 chajja	1.05	8	0.16	0.299
5	Waist slab	4.61	37	0.72	1.318
	Total quantity		252	4.57	9.20

Table no 3.1.6: material required from first floor to second floor

Material no	**Description of material**	**Quantity in cum**	**Cement bags**	**Sand brass**	**Aggregate brass**
1	M20 column	6	50	0.84	1.80
2	M20 beams and lintels	7.70	64	1.06	2.30
3	M20 slab	11.85	100	1.75	3.78
4	M20 chajja	1.05	8	0.16	0.30

3.2 ABC analysiss:

The grouping of all materials used in production into materials which require the highest attention, materials which require medium attention and materials which require the least attention such that the control mechanism be focused on selective class of materials is called selective inventory control.

Literally, thousands of items are kept in inventory. Periodic reviews of inventories of items have to be taken under for effective inventory control. An equally critical analysis of all items is very expensive and time consuming. Material classification with reference to a particular function under examination is the solution. Among the methods that are available for the purpose of classification, ABC analysis is most commonly used.

This method is very well suited for the construction industry and are also being used very widely. The organization was not following any of the control techniques for the particular project.

Methodology Adopted for ABC analysis for Original Schedule:

1. List all the client free issue consumable materials items used in the project along with unit price and quantity consumed annually.
2. Compute the Annual Usage Value (AUV) of each material item.
3. Arrange the items in the ranking order of AUV and compute the cumulative percentage units consumed and cumulative percentage of AUV for each item.

For the classification process the materials used for this project have been classified using ABC analysis which is being shown.

- Material items used till 24 May 2022 has been used which is based on the original schedule.
- The quantity of items used in the project are obtained from project estimate.

- The current market prices are adopted.

Table no 3.2.1: A, B, C Classification of material

A, B , C Classification Of Material						
Sr. No.	**Material Code**	**Material Description**	**Unit**	**High cost – high usage A**	**High cost – medium usage B**	**Medium cost – low usage C**
1	RM010001	M10 concrete grade	cum	√	-	-
2	RM01002	M15 concrete grade	cum	√	-	-
3	RM01004	M20 concrete grade	cum	√	-	-
4	ST010001	Rebar steel – TMT 8 mm FE 415	MT	√	-	-
5	ST010002	Rebar steel – TMT 10mm FE 415	MT	√	-	-
6	ST010003	Rebar steel – TMT 12mm FE 415	MT	√	-	-
7	ST010003	Rebar steel – TMT 16mm FE 415	MT	√	-	-
8	TL010001	Tiles ceramic	sq. m	√	-	-
9	TL020001	Tiles glazed	sq. m	√	-	-
10	TL030001	Tiles vitrified	sq. m	√	-	-
11		Green marble	sq. m	√	-	-
12	TL150001	Carpet	sq. m	√	-	-
13	TM030002	Panddled door skin	sq. m	√	-	-
14	TM040004	Door frames	EA	√	-	-
15	GH010008	Curtain rod	EA	-	√	-
16	GH010010	Door chain	EA	-	√	-
17	GH010011	Door closer	EA	-	√	-
18	GH010016	Handle 10”	EA	-	-	√
19	GH010021	Handle 8”	EA	-	-	√
20	GH010032	Lock-cylindrical lock with key	EA	-	√	-
21	GH010033	Lock-cylindrical lock without key	EA	-	√	-
22	TL130002	Tiles false ceiling vinly flooring	EA	√	-	-
23	TM020001	Flush door bsc	sq. m	-	√	
24	GH010009	Door bush	EA	-		√
25	PL010001	Basing zindal	EA	-	√	-
26	PL010002	Diverter	EA	-	√	-
27	PL010003	Wall mixer	EA	-	√	-
28	PL010004	Shower	EA	-	√	-
29	PL010005	Plumbing cock	EA	-	√	-

30	EL010001	Light fitting = copper wiring 0.75mm	mm	√	-	-
31	EL010002	Copper wire 1 mm	mm	√	-	-
32	EL010003	Copper wire 1.5 mm	mm	√	-	-
33	EL010004	Copper wire 2.5 mm	mm	√	-	-
34	EL010005	Copper wire 4 mm	mm	√	-	-
35	EL010006	Copper wire 6 mm	mm	√	-	-
36	EL010007	Switches	mm	-	-	√
37	EL010008	Consilt wiring pipe	Ft	√	-	-
38	PL010006	Plumbing pvc pipe 2”	Ft	√	-	-
39	PL010007	Plumbing pvc pipe 2.5”	Ft	√	-	-
40	PL010008	Pvc pipe 1”	Ft	√	-	-
41	PL010009	Pvc pipe 1.5”	Ft	√	-	-
42	EL010009	Insulation tape	EA	-	-	√
43	EL010010	Consilt metal box	EA	-		√
44	EL010011	Mcb box	EA	-	√	-
45	EL010012	Insulator switch	EA	-	√	-
46	EL010013	Decorate light	EA	-	√	-
47	EL010013	Fall ceiling light	EA	-	√	-
48	EL010014	Foot lamb	EA	-	√	-
49	RL010001	Rubble	Brass	√	-	-
50	SD010001	Sand	Brass	√	-	-
51	CA010001	Coarse aggregate	Brass	√	-	-
52	MM010001	Murrum	Brass	√	-	-
53	BW010001	Binding wire	Kg	-	-	√
54	SW010001	Screw	Kg	-	-	√
55	OL010001	Oil for centering work	Litre	-	-	√

3.3 S-curve analysis:

Material management is not just a concern during the monitoring stage in which the construction is taking place. For variation observed between the planned and actual material consumption S- curve analysis is formulated. The deviation of the quantities is produced by the cumulative expenditure of certain parameter (material cost) against time and it is the representation of project path. This analysis is carried for comparison of planned and actual cost for Class A material items.

Methodology Adopted:

1. The class A material items used in the project plan period is considered from the material classification of item (ABC analysis).
2. The cost variance is computed for this material is given by

Cost Variance = (BCWP − ACWP)

Where, BCWP – Budgeted Cost of Work Performed and

ACWP – Actual Cost of Work Performed.

Cost Performance Index is calculated using the formula

Cost Performance Index = (BCWP/ACWP)

3. These variations of Class A material items used in the project plan period is considered along with planned and actual consumption of material items as a function of cost.
4. Compute the cumulative planned and cumulative actual cost of Class A material items for same period.
5. The variation between the planned and actual cost is computed using the formula –

Percentage under run =

$$\left(\frac{\text{Planned Cost} - \text{Actual Cost}}{\text{Planned Cost}}\right) * 100$$

Illustrations:

The Cost variance and the Cost Performance index for the Class A materials is as shown in the table below.

Table no 3.3.1: S-curve analysis for cement

Period	Planned Cost (BCWP	Actual Cost (ACWP)	Cost Variance (BCWP-ACWP)	Cost Performance Index (BCWP/ACWP)
Sep-21	90000	82500	7500	1.09
Oct-21	90000	82500	7500	1.09
Nov-21	36000	33500	2500	1.07
Dec 21	54000	51700	2300	1.04
Jan 22	90000	85000	5000	1.05
Feb-22	72000	70000	2000	1.02
Mar 22	108000	106500	1500	1.01

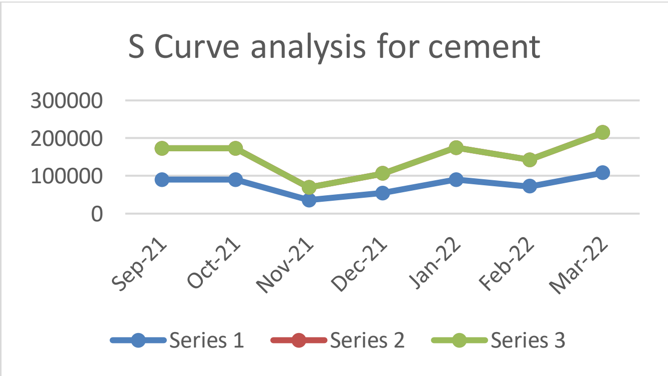


Table no 3.3.2: s curve analysis for rebar steel

Rebar Steel					
Sr. No	**Period**	**Planned cost**	**Actual cost**	**Cost variance**	**Cost performance index**
1	Sep-21	90000	81000	9000	1.11
2	Oct-21	60000	53500	6500	1.12
3	Oct-21	120000	106000	14000	1.13
4	Nov 21	72000	64800	7200	1.11
5	Nov 21	60000	55000	5000	1.09
6	Dec 21	60000	55500	4500	1.18
7	Dec 22	60000	56000	4000	1.07
8	Jan 22	60000	57000	3000	1.05
9	Jan 22	30000	29000	1000	1.03
10	Jan 22	60000	59000	1000	1.01

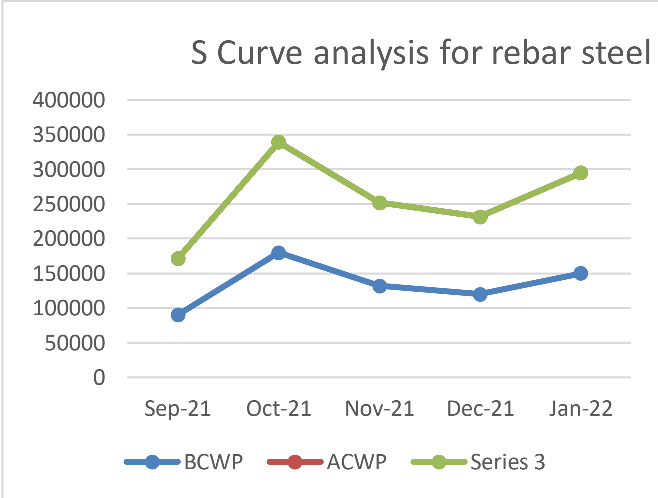


Table no 3.3.3: S-curve analysis for sand

Sand					
Sr. No	**Period**	**Planned cost**	**Actual cost**	**Cost variance**	**Cost performance index**
1	Sep 21	45000	35000	10000	1.28
2	Oct-21	45000	35000	10000	1.28
3	Nov 21	45000	36000	9000	1.25
4	Nov 21	27000	22800	4200	1.18
5	Dec 21	45000	40000	5000	1.125
6	Jan 22	72000	67200	4800	1.11
7	Feb 22	45000	42000	3000	1.07

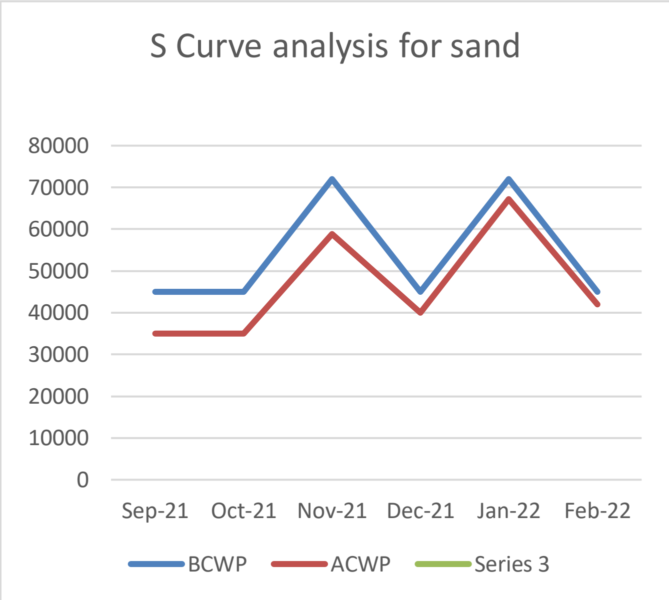


Table no 3.3.4: S curve analysis for bricks

Bricks					
Sr.no	**Period**	**Planned cost**	**Actual cost**	**Cost variance**	**Cost performance index**
1	Sep 21	37500	30000	7500	1.25
2	Oct 21	37500	30000	7500	1.25
3	Nov 21	60000	52000	8000	1.15
4	Nov 21	52500	47600	4900	1.10
5	Dec 21	75000	70000	5000	1.07
6	Dec 21	45000	42000	3000	1.07
7	Jan 21	70500	67680	3600	1.04

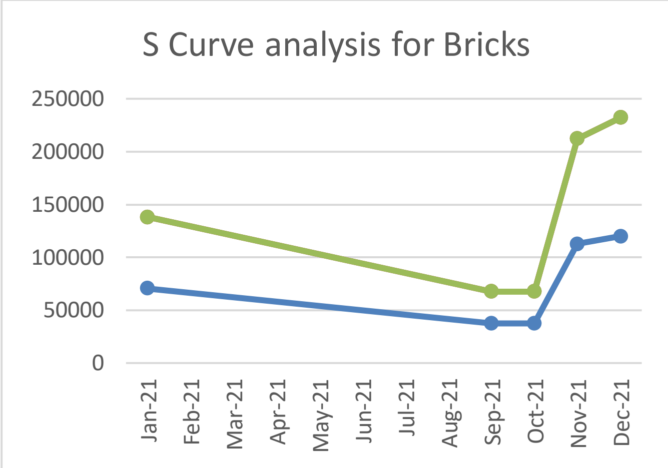
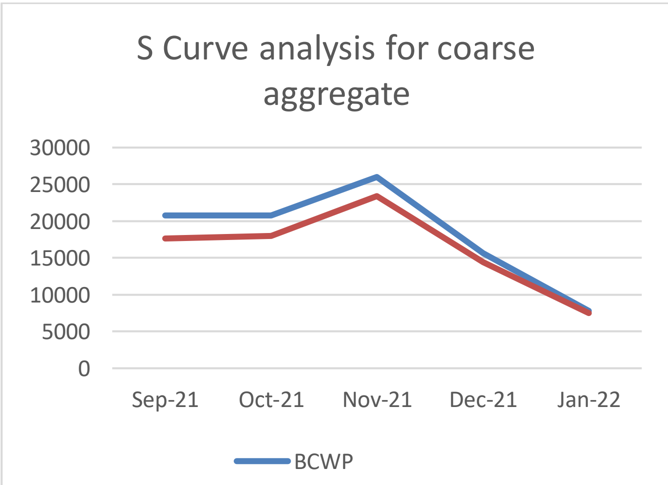


Table no 3.3.5 : S curve analysis for coarse aggregate

Coarse aggregate					
Sr.no	**Period**	**Planned cost**	**Actual cost**	**Cost variance**	**Cost performance index**
1	Sep 21	10400	8800	1600	1.18
2	Sep 21	10400	8800	1600	1.18
3	Oct 21	10400	8800	1600	1.18
4	Oct 21	10400	9200	1200	1.13
5	Nov 21	15600	13800	1800	1.13
6	Nov 21	10400	9600	800	1.08
7	Dec 21	15600	14400	1200	1.08
8	Jan 22	7800	7500	300	1.04



3.4 EOQ Analysis

1. The economic order quantity (EOQ) refers to the ideal order quantity a company should purchase in order to minimize its inventory costs.
2. A company's inventory costs may include holding costs, shortage costs, and order costs
3. The economic order quantity (EOQ) model seeks to ensure that the right amount of inventory is ordered per batch so a company does not have to make orders too frequently and there is not an excess of inventory sitting on hand.

EOQ is necessarily used in inventory management, which is the oversight of the ordering, storing, and use of a company's inventory.

The formula for Economic Order Quantity (EOQ)

$$EOQ = \frac{\sqrt{2 \times A \times S}}{\sqrt{Cu.i}}$$

Where:

A = annual requirement

S = processing charge

i = carrying cost

Cu = cost per unit

- For cement
  A =1312 BAGS
  Cu = 340 rs
  S = 1600
  I = 30 per = 0.3

From formula, EOQ=202.88

NO of orders = 7

Duration of order = 30 days

Cost of one order = (EOQ X Cu) + Co = 70579

So the cost of cement including material and order cost by EOQ analysis is 494053 rs

- For steel
  A = 11.48 ton
  S =1000 rs
  Cu = 58000
  I = 30 per = 0.3

From formula , EOQ = 1.14 Ton

Duration of order = 20 days

Cost of one order= 67120 rs

Total cost of steel including material and order cost by EOQ analysis is 671200 rs.

- For coarse aggregate
  A = 35 Brass
  S = 200rs
  Cu = 2400 Rs
  I =30 Per = 0.3
  EOQ = 4.40 Ton
  No of order = 8
  Duration of order =15 days
  Cost one order = 10784 rs
  Total cost of aggregate including material and order cost by EOQ analysis is 86272 rs

- For bricks
  A = 50400 NOS
  S = 1200 RS
  Cu = 7 rs
  I = 30 per = 0.3

  EOQ = 7589.46 =7590 NOS
  Number of order = 7
  Cost per order = 54327 RS
  Total cost of bricks by EOQ analysis is380283 RS.

Table no 3.4.1: EOQ analysis

EOQ analysis				
Description of material	**Annual requirement**	**EOQ**	**No . Of ordering**	**Total cost of inventory using EOQ analysis**
Cement	1312 bags	202.8	7	494053 rs
Steel	11.48 ton	1.14	6	671200 rs
Bricks	50400 nos	7590	7	380283 rs
Aggregate	35 brass	4.40	8	86272 rs

4.RESULTS

1. The table of Material Requirement Plan can have the following advantages:
   - Reduction in inventory costs
   - Reduction in idle time of items
   - Advance notices to the Project Managers to see the planned schedule before release orders of the material items.

2. From the ABC analysis following conclusions can be made,
   - Class A materials – 30 items (70% of AUV)
   - Class B materials – 16 items (25% of AUV)
   - Class C materials – 09 items (5% of AUV)

Class A materials constitute of Concrete, bricks, Steel and sand. The organization which does not follow this kind of classification is expected to suffer from the problems

- Maximum inventory investment.
- Maximized direct costs associated with inventory.
- Lack of concentration on high value items which is major drawback found in the organization practice.

3. From the Table, the Cost Variance values for the Class A materials is positive. It indicates the project has a cost under run i.e. the cost incurred is less than the planned or budgeted cost. Further, the Cost Performance Index value are as follows
   - Cement = 1.04
   - Rebar steel = 1.117
   - Sand = 1.18
   - Bricks = 1.13
   - Coarse aggregate = 1.125

   where the index values are greater than 1 indicating a favourable performance of the material items in the project. And has a better cost efficient condition in the project. The percentage under run is calculated from cumulative value of planned and actual cost.

   The percentages obtained in the under run indicates that the project is in the under budget condition. This is a small comparison of variations observed in Class A material items. These variation has a greater impact in the project and the study is very significant in the project.

   All these study shows that these percentage variations has a major impact on the project

4. The study on EOQ analysis is performed on Cement, Steel, Bricks, Sand and Aggregate. While performing EOQ analysis ordering cost and Inventory cost is assumed for all materials with practical execution procedure of construction. Inventory carrying cost incurred for inventory maintenance, Cost of Storage is include Insurance taxes, Deterioration & obsolescence this calculate in %. Inventory Carrying Cost = Economic Order Quantity is calculated.

   Also the total cost of inventory after adoption of EOQ analysis is less than without adopting EOQ.

   EOQ analysis gives better result for all the materials i.e Cement, steel, aggregate expect bricks.

   When we apply EOQ on steel for both the Projects then we conclude that the annual amount of bricks with EOQ analysis is greater than the annual amount of steel with without EOQ analysis. So in that case our EOQ analysis is fail in this case.

5. CONCLUSIONS

Adopting Alpha-numeric coding system effectively for material storing and handling can improve a lot for proper control, tracking and monitoring of the material items in the systems. (Material planning and coding)

From the above study made, we can conclude that materials for the project, which is a very important resource if properly managed and handled can vary the cost of the project to a large extent, especially Class A material items. If strictly followed the measures to handle the materials properly and efficiently for a construction project, it can reduce the total material cost of the project. (ABC analysis)

The materials classification is based on the information provided by the top management based on the materials that will be consumed in the project plan period. This is not will account for the entire project plan period. Greater the variations in cost of materials more will be overall cost of materials. It has a direct bearing on the project cost. The variation in cost among Class A materials is of prime importance and affects the overall cost of the project. (ABC analysis)

The Cost Performance Index values for Class A materials are greater than 1. indicating a favorable performance of the material items in the project. And has a better cost efficient condition in the project. The cost of materials have been optimized effectively indicating the under budget condition of the materials. (s curve analysis)

The Cost Variance values for the Class A materials is a tool to measure the profit and it has a positive value. It indicates the project has a cost under run i.e. the cost incurred is less than the planned or budgeted cost. (s curve)

The actual classification methodology. But the materials are classified based on two both the factors - Cost and Usage. The actual classification is based on Annual Usage Value for material items. (EOQ analysis)

The study clearly shows the importance to manage all materials from the design stage to the construction stage. The systematic literature review identifies that materials management processes require a transformation to improve the overall process in handling of materials for more efficiency and effectiveness on the construction site. This is because poor handling of construction materials affects the overall performance of construction projects in terms of time, budget (cost), quality and productivity. Most importantly awareness and accountability of materials should be created within the organization.

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