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Optimization of Concrete Batch Mix Plant Using Inventory Management

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Abstract*— The construction industry has been improvising through the advances in technology and methodology. Concrete, which is the integral part in construction industry, is being used more than any other man-made material and it consumes more raw material than any other product. Concrete is of considerable volume in any structure and consumes bulk quantities in the construction of infrastructure projects. Though, India being one of the world's top concrete consumers as well as producer, the construction industry in the country lacks in accurate planning, managing and scheduling of raw materials being used in manufacturing of concrete. The present scenario in the construction industry is very difficult for construction companies to remain competent and competitive. The credit squeeze situation, the space constraint problems, the supply chain delay, the improper market visibility, artificial scarce and artificial demands are haunting every company in the industry. The requirement of efficient management in the construction industry came to light in the early nineties. Hence forth the demand for the managers in the engineering background has increased in the industry. An earnest attempt is made through this project to fulfill the cost optimization technique and the space optimization technique by doing statistical analysis. The data used in this project is taken from the concrete production department for a large infrastructure project which has employed the concrete batch mix plant for the production of concrete.

In this project work, the comprehensive effort is made to analyse the inventory level management and re-ordering points for each material required in the production of concrete. The effort of this project for the construction industry would certainly be much effective and useful in the future.

Keywords— Optimization, GGBS, Cement, Coarse Aggregate, Inventory methods

I. INTRODUCTION

A. *Introduction:*

This Construction is a fundamental aspect for the development of the country, which demands proper management to sustain in this competitive world. Competition may not always refer to making profit to the company, but may also have the objective of saving mother earth, sustainable usage of energy and raw materials, optimizing time and space, minimizing capital and total cost without hampering the conformance to the desired quality and specifications.

The every rising production cost due to the progressive increase in labour and material costs have brought the Construction industries into perplexity today. For the companies to remain competitive, economics has to be effected. To incorporate the economics in the project, proper management of the very project is necessary. For any project to be successful the time, scope and cost should be carefully managed. An Engineer by himself has to be a good manager for him to be extremely successful in the industry.

A manager has four major resources at his command for making the project successful – Men, Material, Machine and Money. These four resources form the input for any project, while the possible outputs are the goods and services. The important task for the manager is to optimize the input resources to produce required quality products and services. For doing these, the manager uses various management tools/processes – organizing, planning, staffing, leading, controlling, motivating, coordinating etc. Out of these, the major phase of management which defines and elaborates the project work is the planning stage. This stage decides the upcoming activities, procedures for these activities, time table or the schedule for these activities, requirement of materials, technology, machine and man power for executing these activities as per the schedule and specifications.

Regarding the input resources, the manager has hardly any control on the expenditure on men. The remuneration of men will have to continue to rise to meet his requirements in this inflationary condition. The operational cost of machine keeps on rising with the aging of machine itself. The scrapping of the old machines and replacing it with the newer technology based machines may for extent be helpful. Money is always scarce and is just not be available in these days of credit squeeze. The only resource in which considerable economics are still possible and which has remained practically uncharted in India is Management of Materials.

The material management has come to light only in the late fifties, while the importance for the same has been showed in the very recent past only. The materials form the greater share in the project cost, which gives us a hint to think that managing the materials would be a major benefit in reducing the cost and time of the project. The greater efficiency of material management is highly important in today's situation of rising prices, shortages, lower productivity etc.

The major flow of materials in the construction industry is towards the production of concrete which stands as the integral portion in the construction industry. India being the developing country stands second, next to China in the consumption of concrete. The sustainability and eco-friendly criterion are slowly incorporated in the production of concrete in India, while the optimization of the raw materials which comes with high uncertainties will be a greater help for the industry.

The production of concrete includes several resources like aggregates (fine & Coarse), cement, admixtures and water. Out of these resources, in India, major uncertainty lies with the procurement of aggregates. These aggregates are being the major consumable in the production of concrete comes with greater cost and unstable cost as well. Although, managing the other raw materials being minor consumable will also help in optimizing the production cost and time of the concrete. In major projects like infrastructure construction, construction of multi-storied buildings, dams, bridges, airport, ports etc., installing a project based concrete batch-mix plant at the site in order to save time of procurement of concrete (when outsourced) and production of concrete (when machine mixed) and to optimize the cost of production has become a practice. Managing the inventory at the batch-mix plant could further optimize the cost, time and space in the production of concrete.

B. ***Material management***

The fast developing Indian economy demands great responsibility to manage the materials of construction. This can be further supported with recognition of more than ` 15,000 crores per annum is spent on raw materials alone in India|1|. It is always learnt that in any construction project, the raw materials make the lion's share in the production cost of the construction product. Also, the major constraint lies with the procurement and the space requirement to store the raw materials, while the cost of the raw materials is never stable. So this explains the need for material management in the construction industry.

The scope of material management is not restricted to one dimensional. It involves scheduling of materials, material purchase management, store management, inventory management, surplus and scrap management, material handling management, transportation management and space management of the materials stored. So this task is not restricted to a single person, but should be a team effort by the resource management department to make efficient and effective usage of the materials.

The material management helps in,

1. assuring the raw materials well within time for the required activity to be carried forward without delaying
2. optimizing the capital amount on the inventory
3. store management by providing storing conditions and environment to avoid quality and quantity degradation
4. vendor selection in terms of quality and cost
5. optimizing the space required for storage on materials
6. supply chain management of the materials to avoid delay

The above advantages can be availed by the dedicated team of material management. These advantages further helps in decreasing the production cost, assuring the right quality and avoid time delay in completion of the project, hence making the company more competitive and competent for the further works.

Although, the material management in construction industry is not exempted from disadvantage like not able to achieve Just-In-Time method, Six-sigma achievements and so on.

C. ***Concrete batch-mix plant***

Concrete batch-mix plants are the devices used to initially batch (volume or weigh) the required ingredients (normally aggregates, cement, admixtures and water) separately and then mixed thoroughly for the required consistency in the central concrete mixer. Later the concrete can be transported through the concrete transport truck to the job site.

The batch-mix plant is of two types, namely Ready Mix Plant (RMP) and the Central Mix Plant (CMP). The difference between the two is in the time of mixing the water to the concrete. In the Ready Mix Plant, the dry concrete mix is fed into the concrete transport truck and the water is then added in the truck while transporting, whereas in Central Mix Plant, all the ingredients including water is added in the central concrete mixer and then transported in the concrete transport truck.

The RMP is preferred for the job sites which are far away from the plant to avoid early setting of the concrete to be transported, whereas the CMP is more preferred when the plant is located near to the job site and the lead time being well within the setting time of concrete. Usually, a small CMP are preferred to be installed at the job site in big projects which helps in timely supply of the required grade of concrete.

The concrete batch-mix plants are usually computer assisted in order to maintain the precision in batching of ingredients to the required quantity and mixing the thoroughly for the required consistency. However, the technology has not come to the extent of availing men-free batching plants to the industry.

The raw materials are transported to the plant by human-driven trucks and stored at the batching plant. Cement and puzzolanic materials are stored in silos and the aggregates are either stored in open space (if available) or in the store bins. However, the aggregates have to be fed into storage bins to be made available for batching. These stored aggregates are further sieved and transported from storage bins to the mixer through the conveyor belts (while it is sprinkled with water to avoid dust).

The central mixer receives the ingredients in the required proportions to produce the required grade of concrete through the conveyor belts and cement and water through conveyor pipes. The number of rotations for uniform homogeneous mix for the desired quantity is also pre-fixed by the computer. The operator's job is only to feed the computer with the grade of concrete to be prepared and the quantity required. These are the operations that are performed in the concrete batch-mix plant

II. OPTIMIZATION OF THE CONCRETE BATCH-MIX PLANT

A. ***Introduction:***

The project work is an attempt to contribute to the major construction projects which involves the usage of the concrete batch-mix plant. The selected concrete batch-mix plant has produced 87,000 cum of concrete for the project over the period of two years. The project goes in the direction to optimize the inventory stock upto just satisfying the day-to-day requirement of the plant. By doing this, it gives a twin benefit such as, save on the capital cost on the inventory as well as the space required for the stocking of the inventory. On proper analysis, the optimization or in other words degradation of the specifications of the plant can also be suggested if the lower version meets all the requirements of the project work.

The conclusions and the suggestions helps the industry in the future endeavors to compete with low estimation without hampering any kind of quality issues or conformance to the specification. By this project we can also learn that not only by substituting the materials, but also by substituting the technology and the processes can also make the project economical and competent in this competitive world.

B.***Procedure of the study***

The present study to optimize the concrete batch-mix plant has been divided into four stages. The following are the four stages which give the entire knowledge of the phases of the project and the road which led to the complete analysis of the project work.

C. ***Data Collection***

In this stage, the data required for the study has been decided. Then the company selection was done based on the nature and scope of the company and the project which best suits for our project study. In the construction industry, the data collection is the most difficult job because the industry has forgotten the learning from the past projects and hence most of the companies do not record every details of the project. The data required were the day-to-day receipt of each raw material, day-to-day production of the concrete, day-to-day usage of each raw material, daily closing stock of each material, details of the concrete production unit, details of the source, production capacity and the supply capacity of the sources and the batching plant and so on for a period of two years which collectively helped us to analyze and conclude. For success of the analysis stands on the data collection from the right source and the genuinity of the data collected. The analysis becomes universally accepted only if the sampling of data is very similar to the present projects in the industry, because if there is similarity inly the analysis holds good for the other projects also.

D. ***Data Interpretation***

The raw data collected has been interpreted and brought into a format that is suitable for the the analysis. The two years day-to-day recording of the data has been brought into a simpler format where all the useful data has been retained while others have been discarded. Also, when the data has to be discarded it has to be checked for its influence on the retained data. If the data has no influence on the retained data, then those data can be discarded, else the data has to be accounted for their influences. The whole analysis stands on the way the data collected has been interpreted. The useful data has been brought into the following format which has become the base for all the further analysis and interpretation. A typical format is given below which remains same for the entire data of two years.

E. ***Life Cycle Cost Analysis***

The life cycle cost analysis of the concrete batch-mix plant gave a turning point to the project study. The life cycle cost analysis showed that the cost per unit volume that was incurred by the company was way too less when compared to the cost that would have been incurred if it was out sourced from any other ready mix concrete plant. This is mainly because that the company has its own rented quarry which had cut down its cost drastically. The following table shows the life cycle cost analysis of the concrete batch-mix plant.

TABLE I : LIFE CYCLE COST ANALYSIS OF THE CONCRETE BATCH-MIX PLANT

Life Cycle Cost of the Concrete Batch-Mix Plant					
Sl No.	**Particulars**	**No of Units**	**Unit**	**Unit Rate in `**	**Amount in `**
1	Erection of the CBM Plant	1	no	200000	200000
2	Rent of the CBM Plant	24	months	280000	6720000
3	Cost of Cement	19766.14	MT	5344.58	105641716.5
4	Cost of Aggregates	171536.19	MT	320	54891580.16
5	Cost of GGBFS/Fly Ash	10367.2	MT	1700	17624240
6	Cost of Admixtures	232250	MT	36.62	8504995
7	Cost of Water	8499.4402	MT	10	84994.402
8	Production Cost	87451.93	cum	1200	104942316
9	Storage Cost of Aggregates	10517105.64	MT	6	63102633.83
10	Storage of Cement	166480.60	MT	4	665922.4
11	Storage of GGBFS/Fly Ash	122715.04	MT	4	490860.168
12	Storage Cost of Admixtures	232250	MT	16	3716000
13	Cost of Management of CBM Plant	24	months	658000	15792000
14	Periodic Servicing	24	months	15000	360000
15	Dismanteling & Shifting	1	no	200000	200000
16	Depretiation of the CBM Plant	2	years	1000000	2000000
	Total (`)				**384937258**
	Cost of Concrete when outsourced	87451.93	cum	5200	**454750036**

F. ***Optimization of Excess Inventory***

From the observation of the data, the inventory stock in the plant is not in relationship with the requirement in the plant. Because of this the capital investment on the purchase of the inventory is very high and also the space utilized by the raw materials is too high. Hence, the aim of the project study was to optimize the inventory stock at the plant. This could actually reduce the capital investment that is required for the purchase of the materials and also the interest on the capital investment, which in turn reduces the cost incurred by the company and could be a better competitor in the market.

There are many ideas in which the inventory stock can be optimized and many of the research programs that have been conducted earlier tell us to plan the inventory purchase as per the requirements in the sudden future. But, that method has become very conventional.

In this project work, attempt has been made to analyze in two ways, where one of it has zero risk and the other is the expanded conventional method. These two methods are entirely explained below.

Method 1: In this method the main motive was to plan the inventory such that there is minimum or negligible risk in the availability of raw materials for the production of concrete. Here, the safety stock that has to be maintained for each material for each month has to be taken as that of the highest demand of that material in that very month. So, by maintaining the stock as that of the highest demand of the month there will be no day which exceeds the requirement of the material in that month. So, in this method the only motive is to refill the raw materials with upto the safety stock level as soon as it is being used each day i.e., if the raw materials consumed today is say 100MT, then the stock has to be filled by 100MT by the very next day. This is how the scheduling has to be done for each material. The following tabular columns and Figures give us a better idea of how this method works.

III. ANALYSIS RESULTS AND DISCUSSIONS

In the present study, based on the analysis made by method 1 and method 2 the following observations have been made. This will help the companies to stay competitive in the market.

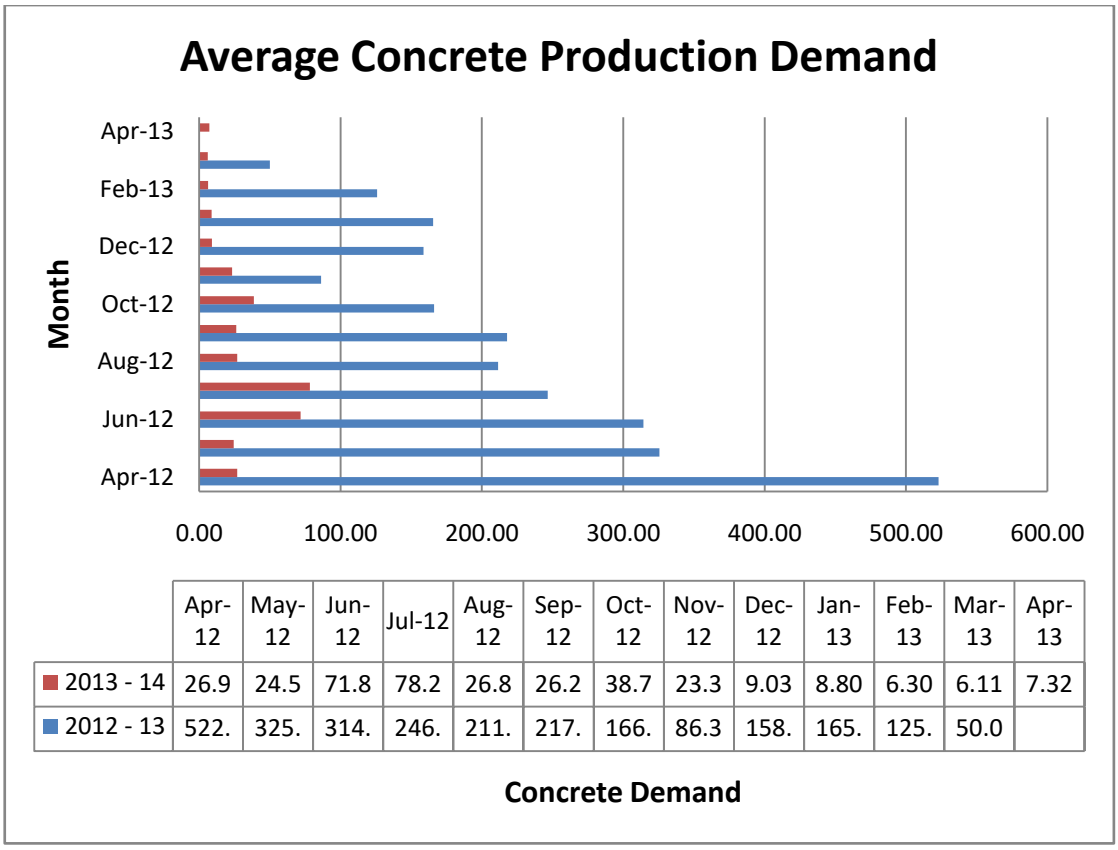
- It has been observed that the maximum demand for the production of concrete in the entire project period is about 731cum while the maximum production capacity of the concrete production plant is about 72cum/hr which comes to 1440cum/day (considering 20 hours of working). Hence the smaller capacity concrete batch-mix plant could have been more economical and the daily idle time could be reduced.

- The production of concrete from 16-04-2013 to 22-05-2013 has been observed to be nil, which accounts for 37 days of idle period for the concrete batch-mix plant.

- The inference from this observation is that the cost of rent of the concrete batch-mix plant, the capital investment on the inventory, the interest on the capital inventory, the depreciation of the plant has been incurred by the company without being produced any concrete in that period. Proper planning of the schedule for concrete production ensuring the concrete production on all the days could reduce the idle period of the plant and optimize the inventory.

- Figure no: 1 shows that the demand for concrete production over the two years. The blue bar represents the concrete production demand in the first year, while the red bar represents the concrete production demand in the second year.

- In Figure no: 1, it has been observed that the production demand for concrete is less than 10% in the second year when compared to the concrete production demand in the first year. The demand could be either leveled over the project period or it could be compressed to the shorter period or the construction sequence can be scheduled in such a way that there is uniform production of concrete throughout the project duration. Any of the three suggestions can bring down the cost incurred by the company.



	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13
2013 - 14	26.9	24.5	71.8	78.2	26.8	26.2	38.7	23.3	9.03	8.80	6.30	6.11	7.32
2012 - 13	522.	325.	314.	246.	211.	217.	166.	86.3	158.	165.	125.	50.0	

Figure No:.1 Average Concrete Production Demand

It can be noted from Figure no 1 that the production capacity of the concrete batch-mix plant is high when compared to the daily demand for the production of concrete..

From this observation, the surplus capacity of the concrete batch-mix plant can be marketed leading to additional revenue for the company. The excess inventory can be made use of in the production of concrete in the idle period of the concrete batch-mix plant and supplied based on the market demands. The Figure no: 2 gives a better idea of the concrete daily demand over the project duration.

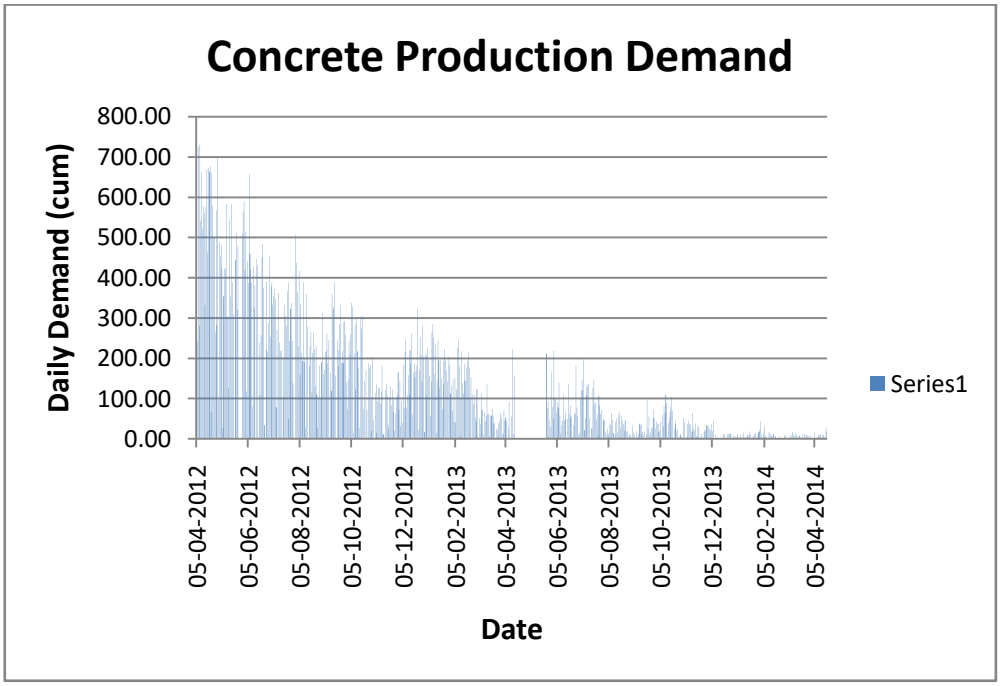


Figure No: 2 Concrete Daily Demand

IV. CONCLUSIONS AND DISCUSSIONS

A Conclusion :

The experimental research program deals with the optimization of the concrete batch-mix plant that is being employed for major projects in terms of cost and space. This particular study has been conducted for a major infrastructure construction project that was constructed during the period of 2013 – 14. It is hoped that the project work would be helpful for the construction industry.

Based on the present study, following conclusions can be drawn.

- Maintaining optimal inventory stock level leads to reduction in capital investment by 83.9%.
- Maintaining optimal inventory stock level also reduces the space required for storing the raw materials by 15%.
- Maintaining optimal inventory stock level also reduces material handling cost and material carrying cost by 63.29%.
- Noting the above points, it can be concluded that optimization of concrete batch-mix plant can cut down cost of the project work.
- Reducing cost of production makes the company to be competitive in the global market.

b Future scope of study

The optimization of the concrete batch-mix plant is not limited to the present study. There are a lot of other statistical analysis that can be applied not only to the concrete batch-mix plant but also to every construction activity.

The following are some of the future scope of studies future generations can attempt to study.

- The inventory management can be applied to every material required for construction activity.
- Present study considered only one type of concrete. Further analysis considering different types of concrete can be carried out.
- The time delay can be analyzed with the study on the supply chain for each raw material.
- Logistical problems can be addressed for the uncertainties attached with the procurement process of the raw materials.
- The repetitive materials and the non-repetitive materials can be analyzed separately in order to increase efficiency in management.
- The application of ERP and SAP can be tested for the inventory management of raw materials like aggregates etc.
- The Just-In-Time method which has been successful in other streams of engineering can be adopted for analysis.

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