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IMPACT OF CONSTRUCTION EQUIPMENT DOWNTIME ON CONSTRUCTION PROJECTS

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Abstract— Equipment plays a very important role in construction industry as it allows for speedy completion of project. As sites are becoming more and more equipment intensive, it is necessary to have an equipment management policy which keeps the equipment in acceptable condition. Breakdown of equipment can cause huge cost to the contractors and delay the schedule. Literature review on breakdown of equipment and its impact has brought out lot of issues in construction industry. Concreting process at residential tower site was observed to understand the working of equipment. Batching plant and Concrete pump were identified as two of the critical equipment at site. Concrete pump had a very high breakdown rate in comparison to other concreting equipment. Failure mode and effect analysis (FMEA) on equipment breakdown showed that failure of electrical nature posed higher risk than any other failure in batching plant. Similarly, in concrete pump choking of concrete in steel pipes were given a high risk priority. Analysis of working hours of equipment showed that transit mixer and pumping equipment worked in a specific proportion to the batching plant working hours in a given site. Consequential cost for breakdown of batching plant was found to be twenty four times the cost re- ported at site. Maintenance policy of equipment was analysed to understand issues in data collection and accounting methods at site.

Keywords— Construction equipment; Batching plant; Failure mode and effect analysis; Maintenance policy.

I. INTRODUCTION

Most of the projects are done at an accelerated pace and mechanical equipment help the project managers to keep up with the pace. But breakdown of equipment disrupts the en- tire schedule of activities and increases the scheduled time and cost. Downtime caused by non-availability of equipment and equipment breakdown is amongst the most common factors that have a non-trivial impact on the equipment productivity, project and organizational performance (Edwards et al., 1998)[8].

Equipment costs are normally divided into two categories: ownership cost and operating cost. Ownership cost covers purchase price, finance, and resale value and Operating cost covers costs such as fuel, consumables, repair, and maintenance. A third category which is consequential costs is defined to cover the intangible costs arising from the fact that equipment often performs less well than expected and thereby impacts many aspects of the production process. Despite its significance, few construction companies pay attention to the impact of DT and take managerial action to reduce it.

The activities involved in construction projects where the magnitude of the work is on a large scale, speedy work and timely completion of work with quality control are very vi- tal. The need for mechanization arises due to the following reasons:

- Magnitude & complexity of the project
- Projects involving large quantities of material handling
- complexity of projects using high grade materials
- High quality standards
- Importance of keeping the time schedules
- Optimum use of material, manpower and finance
- Shortage of skilled and efficient manpower.

NEED FOR STUDY

Indian construction industry is increasingly getting mechanized. This is evident from the fact that the Sales for top six listed construction equipment companies in India rose at a CAGR of 14.1 per cent over the last five years (FY08-12) as shown in Figure 1.1. In FY12, sales grew 12.4 per cent to reach USD 2,160 million. Total sales of the construc- tion equipment industry stood at 54,162 units in FY11 as shown in the Figure

Figure 1– Sales for top six listed construction equipment companies *Figure 2 – Total number of construction*
equipment units sold(Indian Brand Equity Foundation, March 2013) *(Indian Brand Equity*
Foundation, March 2013)

RESEARCH OBJECTIVES

The main objective of the study is to assess the impact of downtime of construction equipment on construction project Sub-objectives are as follows:

- To identify the factors causing Downtime of different construction equipment
- To identify major failures in concreting equipment
- To quantify the Downtime cost and its impact on project performance
- To understand the issues in breakdown and maintenance records of equipment

RESEARCH METHODOLOGY

The research methodology adopted to achieve the objectives consists of four stages. Existing literature was studied to understand the issues in construction industry with respect to breakdown. Meanwhile, construction sites were also visited to understand the maintenance policy of the equipment being followed. Interviews were conducted with plant and machinery in-charge at site and headquarters, foremen, quality control engineers, site engineers etc. After the major failures were identified, Failure mode and effect analysis was carried out. Plant managers were asked to give ratings based on the risk posed by the failure mode. To understand the cost implication of breakdown of equipment, cost data and working hours of equipment at site, were referred. Analysis of working hours was done to find the dependency of transit mixer and pumping equipment on batching plant. Maintenance policy of equipment is also studied.

II. LITERATURE REVIEW

OVERVIEW

Any plant and machinery at site, are planned, controlled and maintained with the objective to meet customer requirement with a predetermined quality level and maximize the utilization of available production capacity. As time progress, the machines frequently encounter un-planned failures/ breakdowns reducing the productivity of the system as a whole. As and when breakdown occurs, the plant and machinery must be periodically re- stored to its desired level as soon as possible. This can only be achieved by having a maintenance strategy.

UNDERSTANDING IMPORTANCE OF HAVING AROBUST EQUIPMENT MANAGEMENT MODEL

In today's world, construction companies execute the construction projects at immense schedule constraint. The construction companies need to utilize their available resources efficiently to meet the project requirements and deadlines without sacrificing quality and safety. A huge workforce is required to complete these projects in time. A frequent change imposed by the client and the engineer, adds up to the existing problems and causes lot of work disruption and cost overrun. Use of construction equipment eases these problems to a great extent and helps the clients complete the project in the stipulated period.

In construction industries, despite predictive maintenance being practiced, plant break- downs are inevitable due to the working environment, age of the machines, over utiliza- tion of various systems. Construction plant stumbling due to breakdowns, directly influ- ence the project completion time and the credibility of the contractor in the long run. Therefore, a need for a swift action during breakdowns is felt in the construction plant maintenance system (Mohideen, 2011)[17].

EFFECTS OF BREAKDOWN

In general, firms operate with the combination of old/new equipment, rented/owned fleets, in dust prone polluted conditions with extreme weather conditions. Even though there are many maintenance strategies followed, as the general wear and tear of these plant and equipment are likely to be very high, the breakdowns are inevitable. Oloke and Edwards (2001)[20] mention that "the plant breakdown and associated maintenance costs continue to affect the optimization of plant utilization throughout the construction sector". Hisham (2003)[14] mentioned that "proper maintenance of plant and equipment can significantly reduce the overall operating cost while boosting the productivity of the plant". During breakdown, the capital money invested in the construction plant and equipment, fail to work for the business, placing strain on site productivity, and ultimate- ly the organization's liquidity is lost. Canter (1993)[3], indicated that plant breakdown relates to the state in which a plant item is temporarily, or permanently, unusable.

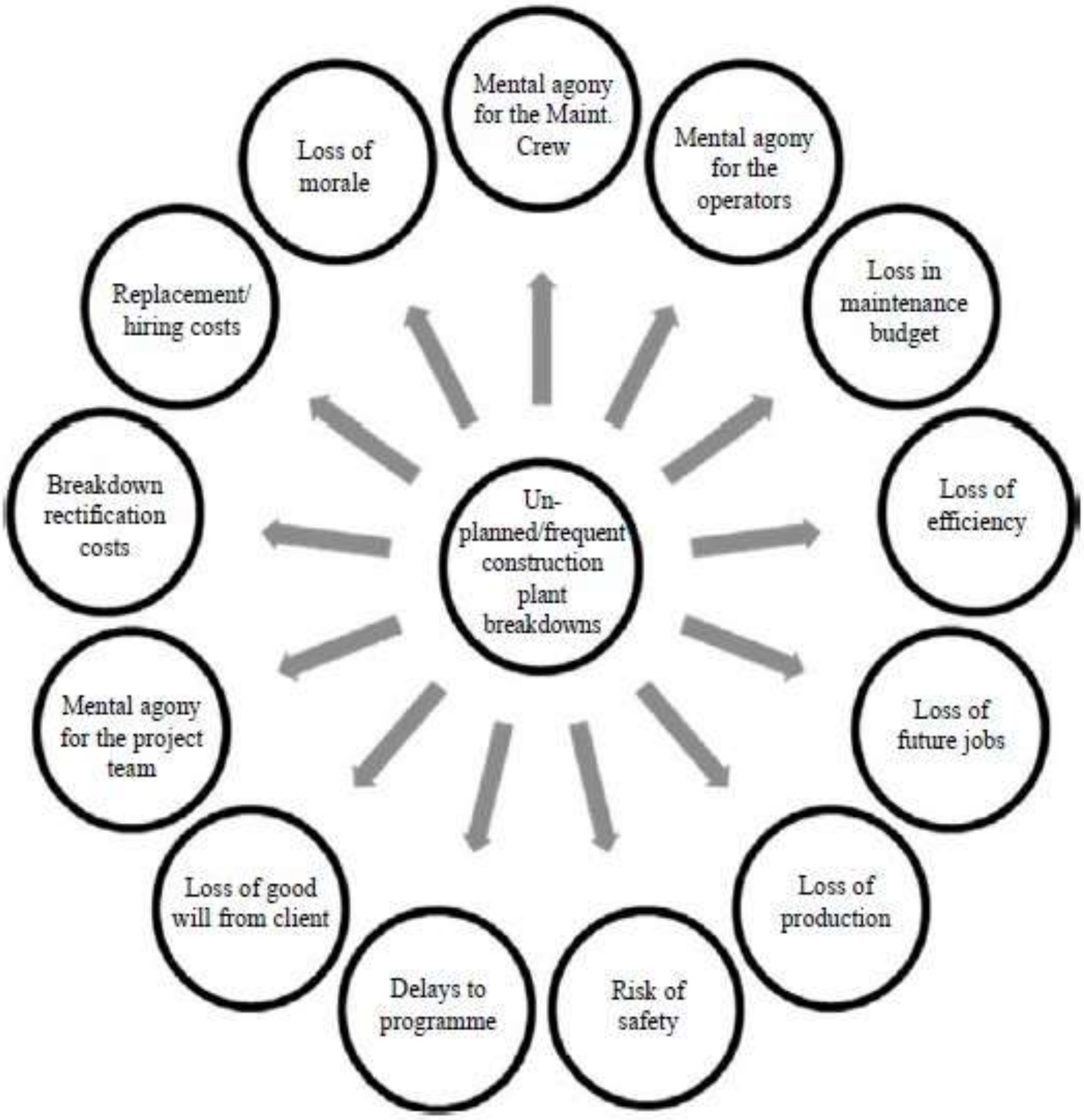


Figure 3 – Dissociation effect of construction equipment breakdown (Mohideen et. al., 2011)

THE CHANGING REALM OF MAINTENANCE

In earlier days when mechanization was low, most equipment in the factory was basic and repairing/restoration process was done at a very short time. Thus, the term downtime was not so important and maintenance was not given high priority. Subsequently, equip- ment started becoming more and more complex. This led to increase in mechanization and industry was beginning to depend on these complex machines. Repairing and restora- tion had become more difficult and special skill and more time is needed to repair the machinery. Downtime became a problem and was critical to equipment management. Concept of preventive maintenance came into existence. The growth of mechanization and automation has becoming more complex and some small breakdowns in equipment could affect the operation of the whole plant. Following Table 2.1 shows the effect of maintenance on equipment.

Effective Maintenance	Non - effective maintenance
Restore system productivity	Increased maintenance cost
Avoid any unnecessary shutdown	Reduced efficiency of heat transfer
Prolong the system life	Can effect product quality
Improve the overall plant productivity	Reduced plant productivity
Essential to maintain product quality	Downgrade system effectiveness
Increases plant profit	Decrease plant profit

Table 1– Effect of Maintenance

GAPS IN LITERATURE

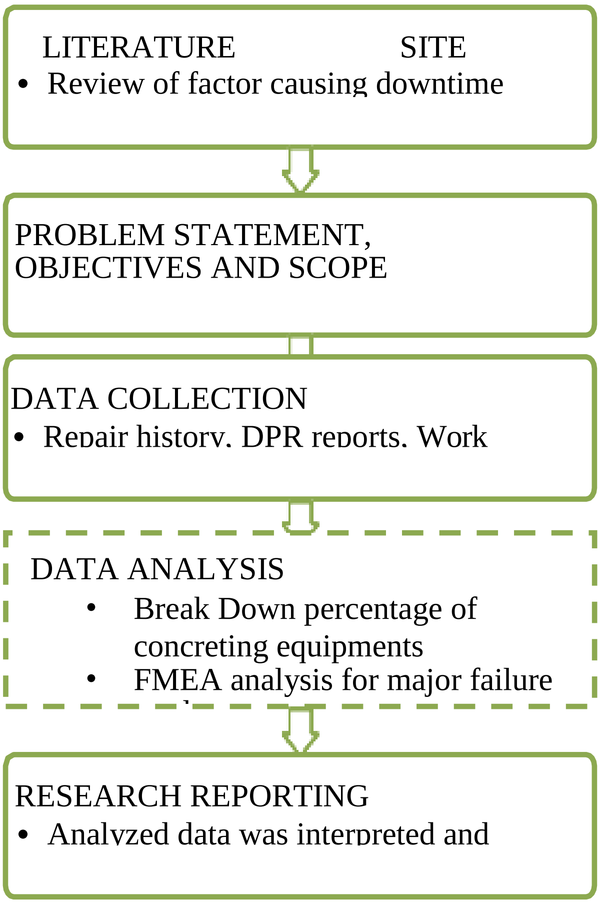
Literature survey was done to understand the process of concreting at time. Following issues were identified to be left out from the literature

- Breakdown issues in construction equipment involved in concreting have seldom been discussed in literature. Batching plant, concrete pump are critical equipment which under breakdown will have a negative impact on the site.
- No literature review is available on critical type of failures occurring in concreting equipment and its influence on cost and time in Indian construction site. It was also found important to study average downtime percentage of different equip-ment.
- Downtime costs were analyzed in some of the literature but it discounted the idle- ness of other equipment that was dependent on the failed equipment
- Maintenance policy of equipment in Indian construction site needs to be studied In the next chapter, we discuss the research methodology that was used to study and meet the objectives of the project.

III. RESEARCH METHODOLOGY

This chapter discusses the methodology adopted for conducting the study. Figure 3.1 gives a schematic representation of the research methodology. In the initial stages, avail- able literature on construction equipment was studied to find issues related to breakdown and its impact on the construction project. Some of the gaps in literature were identified and objectives were formed based on the observation made in literature review.

Figure 3.1 Steps involved in research methodology



SITE VISIT

Residential tower construction site was visited to study the concreting process. The criti- cality's of breakdown of equipment in the site were studied. Production data and the working hours for batching plant, wheel loader, concrete pump, boom placer and transit mixer were taken to understand its role in concreting. Work breakdown report of the site was collected and P&M personnel were interviewed regarding the consequences of breakdown at site.

DATA COLLECTION

Repair history of a large construction company's entire equipment fleet was collected to analyze the major failures in concreting equipment. Major equipment failures of each of the equipment were categorized for further study. The Monthly production of concrete and working hours, Internal hiring charges, labor cost, Repair charges, Fuel cost and Spares cost were obtained.

FAILURE MODE AND EFFECT ANALYSIS

A questionnaire was prepared categorizing the major types of failures of each equipment. Ratings were given by experienced P&M personnel and conclusions were drawn from it.

INFERENCES

Inferences were drawn after performing detailed analysis of all the data collected. Factors causing downtime and consequences of it were established in construction of residential apartments. Analysis was done on the repair history obtained.

IV. DOWNTIME OF EQUIPMENT

Downtime (DT) caused by non-availability of equip- ment and equipment breakdown is among the most common unanticipated factors that have a non-trivial impact on the equipment productivity and project and organizational performance (Edwards et al., 1998; Elazouni and Basha, 1996)[10].

One method of assigning downtime cost to a particular year of equipment life was to use the product of the estimated percentage of downtime multiplied by the planned hours of operation for the year multiplied by the hourly cost of a replacement or rental machine (Nunnally 1977)[19]. But this approach did not recognize the impact of breakdown on other resources associated with the equipment.

FACTORS CAUSING DOWNTIME

Site-related factors

Following are the Site related factors which influence downtime of equipment

- Poor working conditions - Concreting equipment like transit mixer need to haul concrete over long distances. Due to Bad road conditions and grade of road, it will exert immense stress on the engine and the equipment may deteriorate rapidly causing breakdown more often.
- Uncertainty during equipment operation – Equipment may be operated in differ- ent environmental conditions which might causes greater risk of equipment breakdown (Arditi et al., 1997; Edwards et al., 1998)[1,8].
- The location of the site, limits the type and size of equipment that can be trans- ported to the site (Day and Benjamin, 1991)[5]. Also, the remoteness of a con- struction site may affect the repair time of equipment by affecting communication and the prompt procurement of parts.

DOWNTIME AND ITS CONSEQUENCES

Following literature discuss about the downtime and its consequences

- Downtime causes idleness of equipment and crews, work disruption, activity de- lays and loss of productivity. Each of the consequences interacts with site management actions, company's procedure and policies, project-level factors, and crew-level factors etc.
- Construction projects are primarily "solution driven" and mostly focus on minimizing costs and limiting immediate consequences (Mitropoulos and Tatum, 1999)[16]. Thus, it is possible that site management may underestimate the actual impact of DT that may evolve from their action in due course. Site management, therefore, should understand the underlying phenomenon of DT and its possible impact on project performance in a systematic way.'

DOWNTIME PERCENTAGE FOR CONSTRUCTION EQUIPMENT

The downtime consists of administrative time, maintenance time, and supply delays. Ad- ministrative time includes hours necessary to report a machine failure and give work di- rections for maintenance. The maintenance time is the number of hours required to carry out preventive and corrective maintenance (Komatsu, 1986)[14]. The supply delays rep- resent the hours during which maintenance work is not possible, because of the lack of immediate availability of parts and materials necessary to perform maintenance.

Repair History was collected from a construction company having a fleet of construction equipment. The analysis involved was taken from 12 batching plant, 26 concrete pump. 16 transit mixer and 29 wheel loader. The repair history was available for the year 2012 and 2013.

Downtime percentage is percentage of breakdown hours against the working hours for the equipment. Downtime percentage for the concreting equipment like batching plant, transit mixer, wheel loader and concrete pump were calculated as shown in Table

Table 4.1 – Breakdown percentage of concreting equipment

Sr. No.	Equipment	No. of Equipment	Total engine hours clocked	Breakdown hours	Breakdown percentage (in Percent- age)
1	Batching Plant	12	33910	3456	10
2	Concrete Pump	26	31498	14016	44
3	Transit Mixers	16	227069	17472	8
4	Wheel Loader	29	62564	14112	23

As seen from table above, it is seen that concrete pump had a very high breakdown percentage of 44%. Wheel loaders had a breakdown percentage of 23 % followed by batching plant and transit mixers with 10% and 8% respectively.

V. MAJOR FAILURES IN CONCRETING EQUIPMENT

BATCHING PLANT

A Concrete batching plant is a device that combines various ingredients like (Cement, fine aggregate, coarse aggregate, admixtures etc.) to form concrete. The major parts of a Batching plant are mixers (tilt-up or horizontal), cement batchers, aggregate batchers, conveyor belt, scrapers, aggregate bins, cement silos, heaters, chillers, cement silos, batch plant controls, and dust collectors. The center of the concrete batching plant is the mixer. There are three types of mixer: Tilt, pan, and twin shaft mixer. Figure 5.1 shows different components of a batching plant.

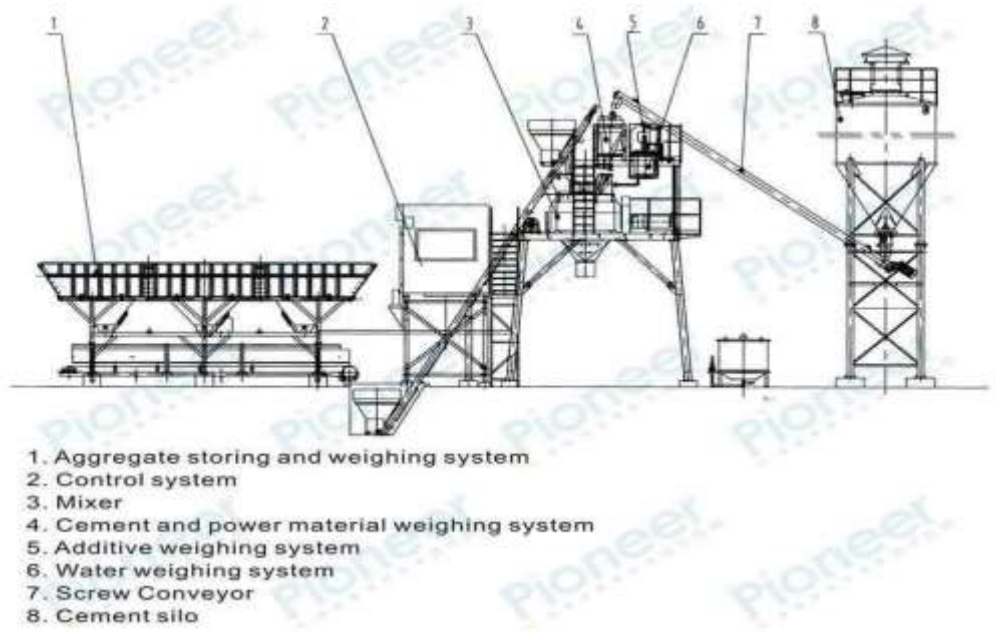


Figure 5.1 – Different components of batching plant

Concrete Batching plant is the heart of a construction site involving concreting activity. It starts a chain of activity involving transit mixers transporting concrete to site; concrete pump used to pump concrete at level or raised heights; spreading operation and shutter- ing. Breakdown of batching plant causes not only loss of IHC for the batching plant but causes idleness of other associated equipment as well.

Pan Mixer failure - Mixer arm and Blade wear out

As the batching plant is subjected to continuous concrete production, thick crust of con- crete keeps forming over the mixer. Hence it is important to replace the wearing packing once it worn out. Otherwise mixing arm will get damaged and cause downtime.

Figure 5.2.1 - Pan Mixer of a CP 30 batching plant

Figure 5.2.2 - Pan Mixer – M1 inline silo plant

CONCRETE PUMP

Concrete Pump is employed at mass concreting sites to transport the concrete through pipelines to higher elevation and long distance. It is used to transport concrete of high slump. Concrete pump is either truck-mounted concrete pump or placed in a trailer. Steel or flexible concrete placing hoses are attached to outlet of the machine. Those hoses are linked together and lead to wherever the concrete needs to be placed. The dual cylinder models have the ability to deliver concrete up to 120 m^3/h with a pipeline diameter of 150 mm. Line pumps pump concrete at lower volumes than boom pumps. Figure 5.5 shows the parts of a concrete pump.

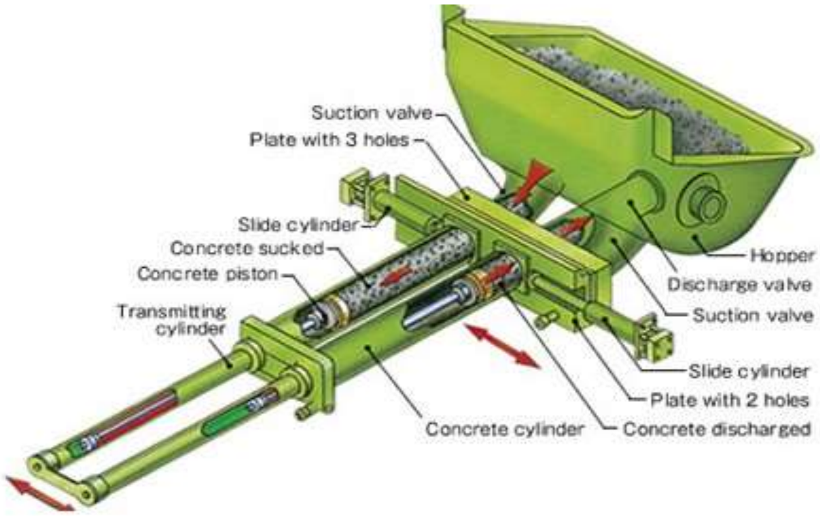


Figure 5.4 – Hydraulic pump and its component of a concrete pump

Some of the major failures observed in concrete pump are

Hydraulic Cylinder and Hydraulic Pump failure

This is caused when the lubricating oil applied on the surface of the cylinder loses it vis- cosity at high temperature and fluid leaks out. Proper choice of lubricating oil must be done and regular check must be performed. Due to the friction between the concrete and cylinder walls, lubrication fails rapidly and can cause rapid wear of cylinder walls. Hy- draulic fluid leakages can also occur due to less maintenance or bursting of old pipe but it can be detected easily.

Fuel Pump and Injection failure

It is caused due to the fuel leakage in the fuel injection pump as a result adequate pres- sure is not developed to open the injector. It can be avoided by regular inspection of lu- bricating oil in fuel injection pump. Fuel contamination/ Rusting in harsh environment can also damage the fuel injection the system by clogging or wear and tear. Due to bad road conditions, the engine is subjected to more loads, causing the engine to heat up and injector gets clogged. .

Choking of concrete inside concrete pump

When the pump is idle and concrete is not agitated, due to negligence, concrete may set inside the concrete pump and may cause problems in concrete pump.

Engine Overload

As the equipment gets old, it is important that engine oil is replaced at regular intervals else it causes rapid wear and tear of engine parts. When the engine is subjected to thermal loading due to continuous working, thermal heating and absence of lubrication may cause piston scuffing which would jam the piston.

TRANSIT MIXERS AND WHEEL LOADERS

Transit mixers are used to haul concrete to long distances from the batching plant to site of pouring. Concrete can directly be poured into the hopper of concrete pump and pumped to the required place. Normally, in Indian construction sites 6 metric cube capacity plant is used for transportation.

Wheel loaders are used in batching plant to stack the aggregate material from the storage yard to the hopper from where it is fed to the conveyor of batching plant or is stacked near the batching plant so as to be within the reach of the scraper. Failures in transit mixer and wheel loader were of the same nature excluding the hydraulic repairs and drum repairs. Major failures observed for both the equipment were

Mechanical failure

One of the major mechanical failures was transmission failure. It was observed that clutch failure/wear and thermal failure of clutch was caused due to inappropriate coolant used or coolant leakage.

Clutch repair is caused by sudden engagement or disengagement of clutch at high loads or sudden change of loads which can cause the clutch to break or slip. Slipping of clutch causes thermal loading and wear of clutch causes clutch failure.

Engine failure

Fuel pump and injection failure is caused due to the fuel leakage in the fuel injection pump, since adequate pressure is not developed to open the injector. It can be avoided by regular inspection of lubrication oil in fuel injection pump.

The equipment gets old, the engine gets imbalanced and vibration increases. The parts wear out and it leads to breakdown. Engine failures are caused due to overloading/high torque application which does not allow engine to pick up the load. This could be caused by misfiring of engine (one cycle combustion does not occur), inappropriate fuel quantity and fuel air ratio with respect to the load.

Drum Repair in Transit Mixer

Concrete gets hardened over a period of time and forms a thick crust over the drum. Also the drum motor and other mechanical equipment needs to be maintained.

Tire failure

Due to bad road conditions, tires of transit mixer may get punctured, worn out or its wheel may get misaligned.

Hydraulic failure

Hydraulic cylinder piston may not be able to exert force it was designed for, if oil leakage occurs.

In the next chapter we analyze the failure modes of equipment using Failure mode and effect analysis (FMEA).

VI. ANALYSIS OF WORKING HOURS OF CONCRETING EQUIPMENT

In a mass concreting site, major equipment like concrete batching plant, transit mixer, boom placer, wheel loader and concrete pump are available. They are interdependent on each other as shown. Figure 7.1 shows the flow of transit mixer during concreting.

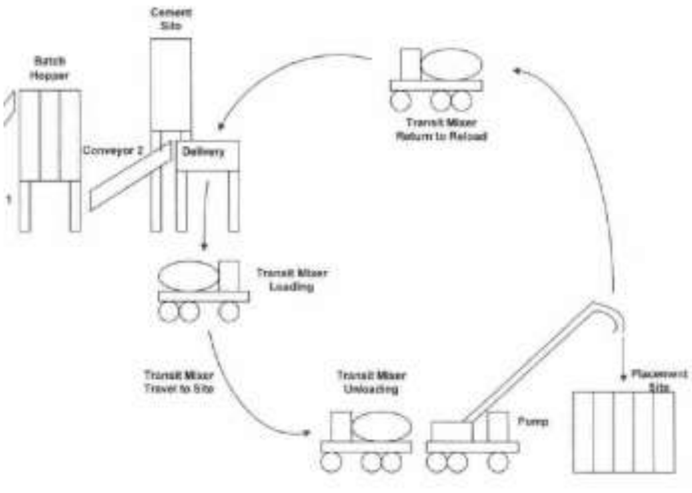


Figure 7.1 – Concreting process and transit mixer cycles

Concreting starting from production of concrete in batching plant to placement of con- crete at site can be seen as a process. Since the process is not well planned at site, it is very difficult to calculate the working hours of equipment at site beforehand. From the daily progress report, the working hours and the quantity of concrete placed was analysed.

The utilization ratio for wheel loader in configuration I was found to be .87 whereas it was found to be 0.69 in case of configuration II. This can be attributed to the fact that when the requirement was more than 5000 m^3/month, Wheel loader would have worked more efficiently without stoppages. When the requirement was not high, it works intermittently, increasing the working hours of equipment.

Transit mixers were found to have a utilization ratio of 6.27 for configuration I and 6.15 for configuration II. It was observed that with 4 transit mixers at site, the utilization ratio of each transit mixer ranged from 1.54 to 1.6 in configuration I. In configuration II, 5 transit mixers had a utilization ratio in the range of 1.2 to 1.27.

Hence in a concreting process for a given site for which analysis was performed, it is found that working hours for a transit mixer has a specific range of utilization ratio when compared to the working hours of a batching plant. Similarly, in concreting equipment the overall utilization ratio is found to be ranging from 2.5 to 2.7.

In this chapter, it is realized that transit mixers and pumping equipment like boom placer and concrete pump work in a specific range of proportion to the batching plant working hours in a given site for a given configuration. In the next chapter, this technique of utilization ratio is used to estimate the consequential cost of batching plant breakdown.

VII. TIME COST ANALYSIS OF EQUIPMENT

CONSEQUENTIAL COST CAUSED DUE TO BREAKDOWN OF EQUIPMENT

When concreting equipment working in close association with other equipment, breaks down at site, it affects the site drastically. The costs of breakdown can be divided into two broad categories.

- Tangible cost of the labor, materials, and other resources needed to repair the ma- chine
- Intangible, or consequential, costs that arise from the failure like idleness of other equipment, crew idleness, and other factors that impact the organization as a whole Tangible costs can be estimated using normal cost-accounting methods. Consequential costs present an entirely different problem in that they cannot be assessed with any de- gree of certainty except under very rigid, well-defined circumstances.

To understand the impact of breakdown of batching plant, in a construction site and the cost of breakdown caused by the idleness of other equipment, following technique of uti- lization ratio was utilized. For calculating the costs due to idleness of equipment and crew, following assumptions were made

- Effective rent of the equipment was calculated as the Internal hiring charges di- vided over the average working hours of the equipment and not the entire month.

Internal hiring charges for construction equipment were obtained from the Cost Plan statement of the company. Average working hours for 3 months of equipment (having the same configuration) was calculated. To calculate the loss of Internal Hiring Charges (IHC) cost for equipment during breakdown, internal hiring charges per working hour was calculated. As shown in Table 8.1, this value was then multiplied with the utilization ratio for each of the equipment and added up.

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Table 8.1 - IHC loss of concreting equipment due to B/D of batching plant

Asset Description	IHC per month (in Rupees)	Average Working hours	UR	IHC/ Working hours	IHC Loss for an hour (in Rupees)
BATCHING PLANT	211500	188	1.00	1127	1127
WHEEL LOADER	69000	163	0.87	422	368
TRANSIT MIXER	110000	294	1.57	374	586
TRANSIT MIXER	110000	285	1.52	386	586
TRANSIT MIXER	110000	288	1.53	382	586
TRANSIT MIXER	110000	298	1.59	370	586
BOOM PLACER	270000	278	1.48	971	1439
CONCRETE PUMP	97100	235	1.25	413	517
				Total	5795

CONSEQUENTIAL COST DUE TO IDLE LABOR

Similarly, to calculate the loss of labor, due to idleness of equipment during breakdown, labor cost per working hour is multiplied with utilization ratio of equipment for which operators and helpers are required. The total value obtained is the loss of labor in the event of breakdown of batching plant as shown in the Table 8.2. Batching plant had 2 op- erators for two shifts, 2 scraper operators and 2 helpers. For transit mixer, concrete pump and wheel loader, 2 operators were available. Spreading operation at site involved 5 members of pipe gang and 10 masons. Each operator was paid Rupees 15,000 per month and helpers were paid Rupees 10,000 per month. Pipe gang crew had a salary of Rupees 9,000 per month. Table 8.2 – Consequential cost due to idle labor due to breakdown of batching plant

Asset Description	**Labor cost (in Rupees)**	**Average Working hours**	**Labour Cost/Work -ing hours (in Rupees)**	**Utilization ratio**	**Consequent ial cost (in Rupees)**
BATCHING PLANT	80000	188	426	1.00	426
WHEEL LOADER	30000	163	184	0.87	160
TRANSIT MIXER	30000	294	102	1.57	160
TRANSIT MIXER	30000	285	105	1.52	160
TRANSIT MIXER	30000	288	104	1.53	160
TRANSIT MIXER	30000	298	101	1.59	160
BOOM PLACER	30000	278	108	1.48	160
CONCRETE PUMP	30000	235	128	1.25	160
SPREADING OPERATION	99000	235	421	1.25	528
				Total	2073

The total cost obtained by both IHC loss and labor loss is Rupees 7,868 per hour for Batching plant breakdown. The IHC loss and labor cost for Batching plant, being the highest i.e. Rupees 1,553 per hour.

In the current accounting method, the IHC is distributed across the entire period of 26 days and hence the IHC loss for Batching Plant breakdown is reported very low. Consid- ering 26 working days in a month and 12 hours per day the IHC loss is as calculated.

IHC loss = Rupees 679/ hour

As seen from the analysis for the site, it is evident that breakdown of batching plant, has a very high impact on site. The consequential cost of breakdown is around Rupees 8000 per hour which is very high, when compared to cost captured at site based only on the internal hiring charges of the particular equipment which broke down.

Table 8.3 –Consequential costs and actual cost reported at site for batching plant break- down

Sr. No.	**IHC loss (in Rupee)/ Hour**	**Labor loss (in Rupee)/ Hour**	**Total loss (in Rupee)/Hour**	**Actual loss reported/ hour**
Site 1	5795	2073	7868	679

Table 8.4 – Cost comparison between consequential cost and actual cost reported at site for batching plant breakdown

Site	**Consequential cost (in Rupee)/Hour**	**Actual loss reported (in Rupee) / hour**	**Total loss/ Actual loss**
Site 1	7868	679	12

As seen from Table 8.4, the actual cost reported highly underestimates the impact of breakdown of critical construction equipment at site. The consequential costs found at site considering only the IHC of the equipment and the crew idleness is around 12 times the cost reported by the P&M department.

In this chapter, consequential cost of batching plant breakdown considering internal hir- ing charges and crew idleness was calculated. In the next chapter, maintenance policy of equipment and issues related to data management is discussed.

VIII. MAINTANANCE POLICY OF EQUIPMENT

CURRENT TRENDS IN DATA MANAGEMENT OF CONSTRUCTION EQUIPMENT

Proper record keeping and accounting of equipment is the key to effective equipment management. With equipment working continuously, it is necessary to understand its productivity, maintenance history, repair history and various other factors which can help maintenance manager keep the equipment or the plant in acceptable condition.

A leading construction company's maintenance policy of equipment was analyzed to un- derstand the maintenance management of construction equipment. It was found that five major records were maintained for each of the equipment, recording specific details about the equipment. They are as follows

- Cost Plan statement
- Work breakdown report
- Daily Plant report
- Maintenance schedule
- Fuel consumption report

Cost plant statement consist of following section under which equipment details are recorded

- Asset code
- Asset description
- Depreciation value

Daily Plant report keeps track of the quantity of the production, hour meter and kilometer run by the equipment. It calculates the productivity of the equipment for each day for both hired and rented equipment. It is a useful report to understand the performance equipment. It has following sections

- Asset code
- Asset description
- Hour meter/Kilometer start and closing reading
- Production quantity
- Productivity (calculated)

ISSUES FOUND IN DATA COLLECTION AND ACCOUNTING METHODS FOLLOWED AT SITE

For effective maintenance, it is necessary that information collected is capable of defining the nature of the problem and not merely its size. Some of the issues in database management of equipment observed are

- It recognizes an equipment to be under breakdown, only if the breakdown continues for more than 24 hours. For a period lesser than 24 hours, equipment is not considered to be under breakdown. In contrast, it has clearly been explained in the previous chapter, that stoppage of Batching plant even for an hour, which could be considered as critical equipment, will cause a very high impact on site.

One of the quality objectives of equipment management is Internal Hire Charges recovery. It indicates the amount recovered from the equipment from the site. As and when the equipment breaks down, the IHC of the particular equipment is not recovered. But as discussed before, the consequential costs of the breakdown in case of Batching plant is much higher.

- Another quality objective for equipment is Mean time between failures (MTTF). It indicates average time elapsed between two failures. As mentioned before, since the breakdown is considered only for more than 24 hours, it gives a wrong notion on the mean time to failure of equipment.
- Loss of production due to downtime of equipment is not accounted in the report. This data is subjective as it is difficult to estimate the production, if the equipment had been working. But under a given working condition and with enough experi- ence, managers can make a rough estimate of the loss.
- In many of the construction companies, the information system has been designed primarily for production control or accounting, and little attention is paid to re- quirement of maintenance management.
- Maintenance personnel being relatively inexperienced in the analyzing and under- standing the information as a management tool.

In this chapter, issues related to maintenance and data management of equipment was discussed. Following chapter discusses the summary and conclusion for the entire study carried out.

IX. CONCLUSIONS

The study focused on identifying breakdown issues in concreting equipment like Batching Plant, Concrete pump, Transit mixer and wheel loader. It also focused on understanding the concreting process and dependency of one equipment over other. Failure mode and effect analysis was performed to find the failure modes having major risk. Issues in maintenance policy of equipment were brought out.

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other. Failure mode and effect analysis was performed to find the failure modes having major risk. Issues in maintenance policy of equipment were brought out.

Factors causing Downtime of equipment

Based on literature study done, following factors were found to cause equipment down- time in different ways.

- Site-related factors and Crew-related factors
- Equipment-related factors
- Company procedure and policies
- Project- level factors
- Site management actions

Percentage breakdown

Using the repair history of a leading construction firm, it was found that concrete pump had a very high breakdown percentage of 44%. This was accompanied by wheel loader which had a breakdown percentage of 23%. Batching plant and transit mixer had a breakdown percentage of 10 and 8 percent respectively.

Failure modes of equipment

Failure modes which posed a high risk were identified in construction equipment but it varied based on the site conditions and working environment. Electrical repairs posed a high risk in batching plant as it required service engineers from the manufacturer for re- pairing. It was observed that concrete pump had problems related to choking of pipes at site which had a high occurrence rating. Quality control at site to achieve a pumpable

As mentioned earlier in scope, this study was limited only to residential tower site shaving an average concreting of more than $50m^3$ per day and it was conducted for concreting equipment (Batching plant, Concrete pump, Wheel loader and Transit mixer). Consequential cost calculation was done based on the assumption that all the equipment are de- pendent on batching plant and will lead to complete halt of concreting process. This is subjective as situation may change depending on the site management actions.

REFERENCES

[1] Arditi, D., Kale, S. and Tangkar, M. (1997), "Innovation in construction equipment and its flow into the construction industry", Journal of Construction Engineering and Management, ASCE, 123(4), pp. 371-8.
[2] Collier, C.A and Jacques, D.E, "Optimum equipment life by minimum life-cycle costs", Journal of construction Engineering and Management, ASCE, 110(2), pp 248- 265.
[3] Canter, M.R. (1993). Resource Management for Construction, The Macmillan Press, London.
[4] Cooper, K.G. (1994), "The $2,000 hour: How managers influence project perfor- mance through the rework cycle", IEEE Engineering Management Review, Vol. 22 No. 4, pp. 12-23.
[5] Edwards, D.J., Holt, G.D. and Harris, F.C. (1998), "Financial management of con- struction plant: conceptualizing cost prediction", Journal of Financial Management of Property and Construction, Vol. 3(2), pp. 59-73.