IOSR Journal of Engineering (IOSRJEN)
e-ISSN: 2250-3021, **p**-ISSN: 2278-8719
Vol. 3, Issue 11 (November. 2013), ||V2|| PP 19-26

Analysis of Delay due to Material Supply by Tower Crane at different Height of High Rise Buildings in Mumbai

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Abstract: - Buildings are becoming higher and higher nowadays in maximizing land use and investment return. But along with this it is also very necessary to calculate the appropriate and accurate date of completion or duration by considering the delays which cannot be able to overcome anyhow. In construction of High Rise building it has been found that some of delays like delays in Material supply by Tower crane at higher levels are impossible to redeem. Hence, it becomes very important to take in to account and Reschedule the program to compute accurate date of completion of High Rise Project.
This report serves the purpose of high rise buildings, the importance of planning, scheduling, analysis of delays occurring due to decreasing capacity of material supply by Tower Crane at different levels of High Rise Buildings due to very High Wind Pressure at higher level and finally providing a Delays Factor analyzed for rescheduling purpose to get accurate date of completion of project. This includes study of delays, which would likely occur in the construction of high rise buildings of more than 43 storeys due to delay in material supply by Tower Crane at site due to High Wind Pressure at higher level.

Keywords: - *Delay, High Rise Building, High Wind Pressure, Material supply, Tower Crane*

I. INTRODUCTION

1.1. General

High-rise buildings are the essential form of building structure constructed extensively in urban areas, in particular, in the heart of the commercial zones of metropolitan cities or in densely populated areas. Scarcity of land supply encourages the construction of high-rise buildings. At this time it is known by all, that Mumbai is occupying approximately 20.5 million populations over 603.4 km^2 Area and hence, highly populated and densified metropolitan city in India an 4^{th} in World. To occupy such large numbers of population it becomes necessary to move towards sky i.e. vertically. Hence now days it is observed that, the Residential buildings of 40 to 45 storeys became very common in Mumbai. So the developers are moving towards the skyscrapers of around 70 to 120 storeys to accommodate lot of population and to earn very nice Fig. of returns on their investments in short period of time.

As the necessity of high rises are going to increase, it should increases the necessity of planning, scheduling, delay analysis, monitoring, controlling and updating or rescheduling of high rise residential buildings. So, the time and cost becomes very essence for the completion of the project. Any delays to the project completion decreases the earned value of money, decreases the total profit, demolish the image of the owner and increases the loss in terms of money, time and lives. Hence the accurate planning, scheduling and rescheduling are very important to complete the project successfully and to avoid these kinds of losses, the perfect delay analysis should be done and plan should be rescheduled to find nearer date of completion and on the basis of this the future value of the investment is calculated to neglect the losses and earned the maximum profit.

In actual practice it is observed that many kinds of delays will occurs during the construction of high rise. Some of them are controlled and mitigated, but some are only controlled to some extent and will not be able to mitigate. In rescheduling process the additional duration should be provided for those delays which cannot be mitigated, only controlled to some extent, such as “delays occurring due to decreasing capacity of material supply by ‘Tower Crane’ at different levels of High Rise Buildings due to high wind pressure at higher level”.

1.2. Purpose of Work

The undertaken project have a very bright future in terms of troubleshooter in the planning of the high rise building construction in countries like India and it supports the scheduling procedures to upcoming trend of huge skyscrapers.

1.1.1. It is a pre-requisite element to ensure the project in completing on time, planning and meeting the budget, quality, safety and environmental requirements.
1.1.2. Suitable for the planning of tower crane in execution of high rise buildings in countries like India.
1.1.3. It helps in the budgeting of the high rise building project.

II. LITERATURE REVIEW

1.3. Common Delays in Construction

Delays on construction projects are a universal phenomenon. It is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects. Chan and Kumaraswamy (1996) [1] conducted a research on potential delay factors in Hong Kong construction projects as seen by clients, contractor and consultants.

A comprehensive classification of causes of construction delays has also been recommended by Abd. Majid and McCaffer (1998) [2]. They classified the factor of causes of non-excusable delays into twelve groups: material-related delays; labor-related delays; equipment-related delays; financial-related delays; improper planning; lack of control; subcontractor-related delays; poor coordination; inadequate supervision; improper construction methods; technical personnel shortages; and poor communication.

Kaming, Olomolaiye, Holt, and Harris (1997) [3] studied influencing factors causing delay on high-rise projects in Indonesia. The most important factors are design changes, poor labor productivity, inadequate planning, and resource shortages. Tumi, Omran, and Pakir (2009) [4] conduct a survey aimed for identifying some of the most important causes of delays in construction projects in Libya. Six main causes are improper planning, lack of effective communication, design errors, shortage of supply i.e. steel, concrete, etc., slow decision making and financial issues.

In general, time-delays and cost overruns are among the most common phenomena in the construction industry from simple to complex projects. Morris and Hugh (1980) [5] examined the records of more than 4000 construction projects and found that projects were rarely finished on time, or within the allocated budget. Rad (1979) [6], Arditi et al. (1985) [7], Tah et al. (1993) [8] and Assaf et al. (1995) [9], also observed that time and cost overruns were commonplace in the construction industry worldwide. A comprehensive grouping of the main causes of construction delays, however, was recommended by Hensey (1993) [10]. These included: materials, labour, equipment and financial factors.

The causes of construction delays in a developing economy have also been studied by Ogunlana et al. (1996) [11]. The study involved a survey of delays experienced in the construction of high-rise building projects in Bangkok, Thailand. It was found that resource supply problems were by far the most acute problems of the Thai construction industry.

Besides that, Assaf and Al-Hejji (2006) [12] from Saudi Arabia studied the causes of delay in large construction projects and discovered that the average time overrun was between 10 % and 30 %.

1.4. Delays Due to Material Shortage at Site

According to Majid and McCaffer (1998) [13], material shortages are due to poor materials planning, inefficient communication, unreliable suppliers and late delivery. Mochal (2003) [14] stated that poor planning is mistake number one in project management. This is further supported by Aibinu and Odeyinka (2006) [15] who conducted a study of causes of delay in Nigerian construction projects in which they found that late delivery of materials is the main cause of delay.

In Turkey, Arditi et al. (1985) [7] ranked material shortages as the number one factor for delays in construction projects. They also found that cement, which is one of the most important materials to be used in the construction industry, cannot be kept for long periods of time. Thus, this may lead to shortages of cement. From all the studies mentioned above, it shows material shortage is a very significant factor that will contribute to delay in construction projects.

1.5. Effects of Delays on High Rise Project

Many previous studies have been carried out regarding the effects of delay. Studies from Aibinu and Jagboro (2002)[16], Sambasivan and Yau (2007) [17]; and Sun and Meng (2009) [18] found many effects of delay in construction projects. The studies and analysis on this subject have shown that Delays in High Rise Building Project can demolish the Foundations of the project budget and also breaks backbone of project.

1.6. Rescheduling of High Rise Project

According to Vieira et al. (2003) [19], rescheduling is the change of original schedule of time in order to respond to disruption and problems which have occurred. In the construction industry, schedules may be updated in order to monitor the time and work in construction projects (Liu and Shih, 2009)[20].The schedule is prepared assuming that the activities are carried out at constant duration. However, the duration of activities varies due to factors such as supply of materials, skill of workers, weather and efficiency of plant and equipment.

On the other hand, material hoisting plays an important role in high-rise building construction. "As the building 'grows', the transportation time increases and thus extends the duration for the crane and material Hoist related activities". Researchers have studied and developed the optimization models for cranes aiming at reducing the transportation costs (Rodriguez-Ramos and Francis (1983) [21]; Choi and Harris (1991) [22] and

Zhang, Harris and Olomolaiye (1996) [23]). Leung and Tam (1999) [24] [25] developed prediction models for improving the prediction of hoisting times. Normally, a tower crane can only be installed for a building block owing to both economic reasons and space availability. Therefore, the crane can only serve one activity at one time and it is important to optimize the usage of a tower crane which is one of the critical resources in high-rise construction (Leung and Tam (2001) [26]).

So, as we know that Rescheduling is the final stage of planning. This includes the analysis of delays that should occur in the project and which cannot be overcome like delays due delays in material supply site by tower crane and required some provision in the schedule. Rescheduling of any project should be done after fully finalization of Plans, Scopes, Drawings, Materials to be used, Material suppliers, Venders and Technology and also after finalization of optimizing location of tower crane (Jean B. Laramee (1983) [27]). Once the final rescheduling is done, there is no provision for any delays. It is not further rescheduled. Hence this process needs a point concentration, lots of studies, lots of experiences, lots of analysis, lots of discussions and many more.

III. ANALYSIS OF DELAY DUE TO MATERIAL SUPPLY BY TOWER CRANE

In the following subsequent subheads initially a metrological Data of Mumbai is explained and mainly focused on wind data which plays an important role in delaying the high rise project. This wind data have been used for identifying the rating reduction of Tower crane with respect to rating reduction chart provided by Sterling crane operation manual. Further, the % Delay due to the material supply by Tower Crane due to increase in height up to 120 floor i.e. 504 m have been found out which will be used for Rescheduling to get very accurate date of completion of high rise project.

1.7. Metrological Data

In this study, it has been observed that wind speed plays an important role to delay the High Rise project. In construction of high rise say up to 80 to 120 floors, as the building's height increases, wind speed also increases tremendously and interrupts the crane operation and labour to do any work. This increasing wind speed can create the delays by reducing the efficiency of the tower crane and Labours.

1.7.1. Wind Speed

From the collected date of wind speed it is observed that over the course of the year typical wind speeds vary from 0 m/s to 6 m/s, and some time exceeding 9 m/s. The Fig. 1, very well shows that, the highest average wind speed of 4 m/s occurs around July 19, at which time the average daily maximum wind speed is 6 m/s. The Lowest average wind speed of 2 m/s occurs around December 17, at which time the average daily maximum wind speed is 4 m/s.

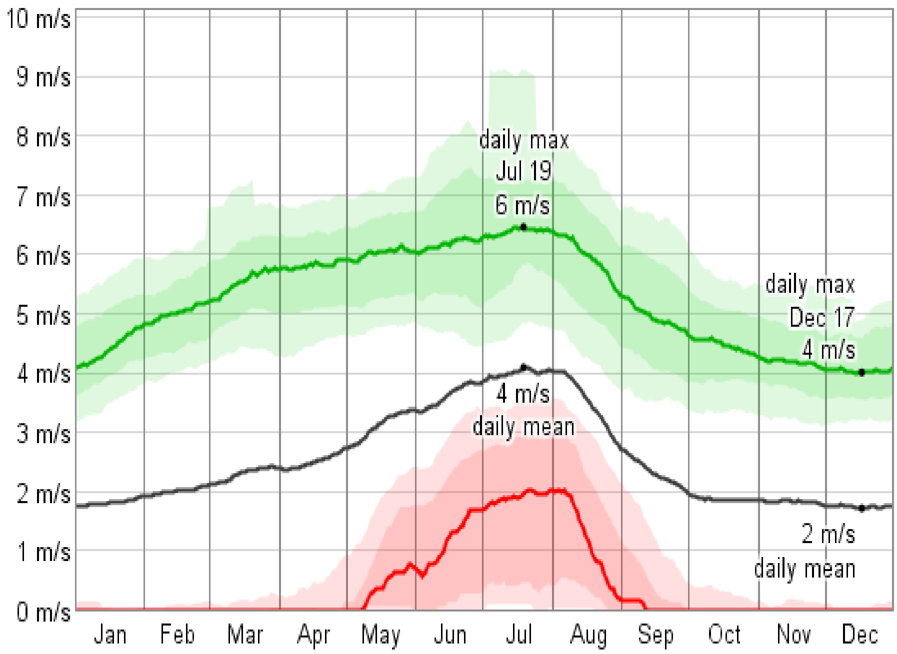


Figure 1: Daily wind speed in Mumbai (Source: - IMD, Mumbai)

Table 1: Height multiplying factors (Source: - IMD, Mumbai)

Height (m)	Height Multiplying Factors
500	2.460
480	2.450
460	2.437
440	2.419
420	2.394
400	2.369
380	2.344
355	2.318
335	2.285
310	2.247
290	2.213
270	2.188
250	2.162
230	2.114
210	2.064
190	2.013
160	1.962
140	1.908
120	1.818
100	1.731
80	1.596
60	1.443
40	1.218
20	1.000
0	0.833

Fig. 1 provides the basic wind speed taken at 10 to 15 m of height. For further calculation of wind speed at different Height up to 500 meter IMD have given the Height multiplying factors represented in Table 1. The multiplication of this factor with the basic wind speed gives us the wind speed at respected Height, which helps to find out the corresponding rating reduction of Tower crane with respect to height or floor levels and hence gives the % Delays per floor due to Delay in material supply by Tower crane.

1.8. Rating Reductions of Tower Crane

To relate the delays in high rise Project by wind speed and tower crane, a rating reduction data of tower crane is taken from one of the tower crane Manual by Sterling Crane and as Presented in Table 2. This table shows that operation rating of the Tower crane varies with the wind speed and boom length of the Tower Crane. This table also shows that at wind speed of above 20 m/s the crane is out of operation or in no service state. So, it cannot be operated above 20 m/s of wind speed and rating reduction will occurs according to the Table 2.

In Table 2 of Rating Reduction of Tower crane for various wind speed and wind gusts, it is clearly mentioned that Length of Boom also plays on important role in rating reduction. Here 1st row representing the boom length in ft., 2nd row representing boom length in meters, 1st column represents the wind speed in m/s and rest failed represents the % rating reduction of Tower crane with respect to wind speed column.

In India, the most commonly available and used crane are of boom length 35 m to 50 m, hence rating reduction taken for studies of delays analysis belongs to this column. So, it is observed from the table that, the crane with Boom length 36.6 m to 45.7 m does not affected very much when wind blows at a speed of 7 m/s, but rating reduction of 5 % occurs at 9 m/s, 10 % occurs at 11 m/s, 20 % occurs at 13 m/s, 30 % occurs at 16 m/s and 50 % occurs at 18 m/s, whereas it gives red signal at more than 18 m/s for this boom length i.e. operation of crane is strictly prohibited. According to this observation, the further analysis of delays due to Material supply by Tower Crane have done and model have presented to calculate the same for new project of high rise building.

Table 2: Rating Reductions of Tower Crane for Various Wind Speeds and Wind Gusts (Source: - Sterling Crane Manual)

Boom Length in ft	30 – 60	70 – 90	90 – 120	120 – 150	170 – 200	210 – 250	250 – 290
(m)	(9.1 – 18.3)	(21.3 – 27.4)	(27.4 – 36.6)	(36.6 – 45.7)	(51.8 – 61.0)	(64.0 – 76.2)	(76.2 – 88.4)
Maximum Wind Speed (m/s)	Percent Rating Reduction						
7	0	0	0	0	0	0	0
9	0	0	0	5	5	5	10
11	0	0	5	10	10	10	20
13	0	0	10	20	20	30	40
16	0	5	20	30	30	50	60
18	5	10	30	50			
20	10	15	40				
Above 20 m/s	OPERATION NOT PERMITTED						

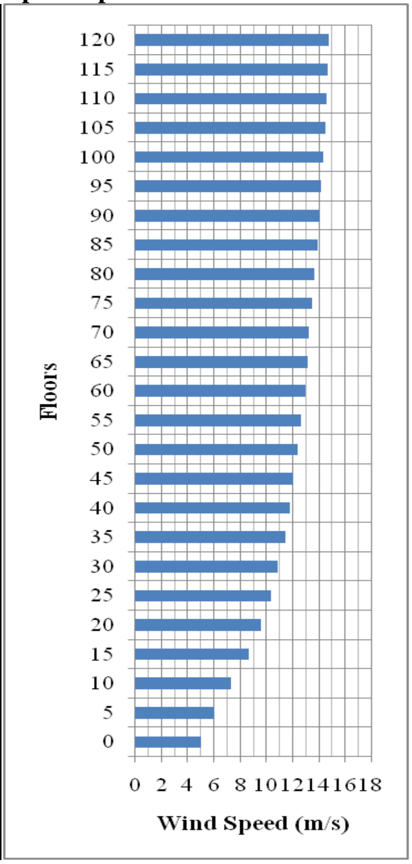
1.9. Wind Speed at Different Height of High Rise

The calculations of wind speed have done by the multiplication of daily maximum wind speed and height multiplication factor provided by IMD and tabulated in self-explanatory Table 3. The average daily maximum wind speed of 6 m/s is observed for Mumbai region. Hence this speed has been considered for maximum effect and wind speed at higher level have found out.

On the basis of this results presented in column no. 5 of Table 3, a statistic graph have prepared, which shows that from 0 floor level (0.00 m) to 25th floor level (105 m) wind speed increases with higher intensity and becomes double. But, it's increasing intensity decreases and becomes gradual after 25th floor level (105 m) and finally produces a result of 14.76 m/s i.e. triple of at level 0.00 m up to the level of 120 floors (504 m).

Table 3: Wind Speed at Corresponding Height with Graphical presentation

Floor (No.)	Height (m)	Height Multiplying Factors (A)	Daly wind speed (m/s) (B)	Wind speed at corresponding Height (m/s) (C = A x B)
120	504	2.460	6.0	14.760
115	483	2.450	6.0	14.699
110	462	2.437	6.0	14.623
105	441	2.419	6.0	14.515
100	420	2.394	6.0	14.364
95	399	2.369	6.0	14.213
90	378	2.344	6.0	14.062
85	357	2.318	6.0	13.910
80	336	2.285	6.0	13.709
75	315	2.247	6.0	13.482
70	294	2.213	6.0	13.277
65	273	2.188	6.0	13.126
60	252	2.162	6.0	12.974
55	231	2.114	6.0	12.686
50	210	2.064	6.0	12.384
45	189	2.013	6.0	12.078
40	168	1.962	6.0	11.772
35	147	1.908	6.0	11.448
30	126	1.818	6.0	10.908
25	105	1.731	6.0	10.386
20	84	1.596	6.0	9.576
15	63	1.443	6.0	8.658
10	42	1.218	6.0	7.308
5	21	1.000	6.0	6.000
0	0	0.833	6.0	5.000



1.10. Delays by Tower Crane due to High Wind Pressure at Higher Level

On compiling the rating reduction of Tower Crane from Table 2 and wind speed at different levels for Mumbai region from Table 3, the % Delays in Material supply by Tower Crane have been found out for different height levels of buildings with the help of data iteration method and represented in Table 4. The Boom length of Tower Crane considered is 27.4 m to 45.7 m which is most commonly available and under use in India. This % Delays are not possible to mitigate or redeem anyhow and required to provide provision in the duration while scheduling of high rise building to get most nearer or accurate date of completion of high rise project.

IV. CONCLUSION

The conclusion of the study is represented as below,

a) The average daily maximum wind speed in Mumbai Region at datum line is 6 m/s.
b) The maximum operating wind speed for Tower Crane mostly available in India is found to be 18m/s.
c) The rating reduction of Tower Crane, a regular increasing reduction has been observed with increasing height of the tallest structure. Hence, there are increasing patterns of delays have been found due to delay in material supply by Tower Crane at different levels of High Rise Building construction and represented in Table 4.
d) This delay is effective irreducible delays due delays in material supply by Tower Crane at Different Height and needs provision in the project schedule.

So, by adding these delays to basic duration, the Rescheduling of project should be done to achieve very accurate date of completion of high rise building projects.

Table 4: % Delays in Material supply by Tower Crane at different Height due to corresponding wind speed

Floor (No.)	Height (m)	Wind speed at corresponding Height (m/s)	% Delays in Material supply by Tower Crane at different Height due to corresponding wind speed (For Boom length of Tower Crane mostly available and under use in India)	
			Boom Length (27.4 – 36.6) m	(36.6 – 45.7) m
120	504	14.760	15.867	25.867
115	483	14.700	15.667	25.667
110	462	14.622	15.407	25.407
105	441	14.514	15.047	25.047
100	420	14.364	14.547	24.547
95	399	14.214	14.047	24.047
90	378	14.064	13.547	23.547
85	357	13.908	13.027	23.027
80	336	13.710	12.367	22.367
75	315	13.482	11.607	21.607
70	294	13.278	10.927	20.927
65	273	13.128	10.427	20.427
60	252	12.972	9.930	19.860
55	231	12.684	9.210	18.420
50	210	12.384	8.460	16.920
45	189	12.078	7.695	15.390
40	168	11.772	6.930	13.860
35	147	11.448	6.120	12.240
30	126	10.908	4.770	9.770
25	105	10.386	3.465	8.465
20	84	9.576	1.440	6.440
15	63	8.658	0.000	4.145
10	42	7.308	0.000	0.770
5	21	6.000	0.000	0.000
0	0	5.000	0.000	0.000

1.11. Recommendations

As far as, this research work is concern lot of exercise have done to represent a suitable model for calculation of accurate date of completion of project. But, with this exercise it is observed that there must be some quanta of fixed delays occurs which have been explained earlier and these needs a suitable provision in schedule. While providing provision in schedule by rescheduling work it has observed that the total duration of the project increases. Hence to maintain proficiency of the schedule some recommendations are provided as below,

a) The wind effect can be minimized and delays can also be reduced up to 25 % to 40 % by using two Tower Crane of shorter and suitable boom length instead of one tower crane of longer boom, but it increases cost up to some extent.
b) The location of tower crane can play an important role to reduce the effects of wind and hence reduces fixed delays in material supply by Tower Crane up to 20 %.

So, by adopting these methods and recommendations while rescheduling work, a proper and very precise planning can be achieved and a very accurate date of completion of project can be found out.

V. ACKNOWLEDGEMENT

This project report is a dedicated effort and many technical, managerial and subject experts have contributed to make this report complete, covering virtually all technical and managerial aspect of **"Analysis of Delay due to Material Supply by Tower Crane at different Height of High Rise Buildings"**.

I wish to experts my profound sense of gratitude to the following people without their invaluable support this project would have remained just dream, which has come true by successful completion.

I sincerely thank Dr. Prashant P. Nagrale, Associate Professor and Coordinator for his encouragement, suggestions and full support, goodwill and patience in this project of **"Analysis of Delay due to Material Supply by Tower Crane at different Height of High Rise Buildings"**.

I would like to express my special appreciation to Prof. Dr. P. H. Sawant, Principal, Sardar Patel College of Engineering, Mumbai for his suggestions, patient and support.

With immense pleasure I am submitting Paper of my project "**Analysis of Delay due to Material Supply by Tower Crane at different Height of High Rise Buildings in Mumbai**" and hope this work would be useful to others.

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