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Utilization Of Tower Cranes In Construction Of Multi-Storeyed Buildings

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Abstract

Mechanical handling and material handling go together as that of hand-in glove in the modern construction of the Dams, Roads, Bridges, Buildings, Over head Water Tanks, Towers, High-rise buildings, etc., having many stories, etc. The present paper deals with the material handling equipment involved in the construction of multistoried buildings / High-rise buildings where the manual handling is very difficult. The main equipment is TOWER CRANE. The utilization of Tower Crane in terms of manual is analyzed and compared the time and cost effectiveness with that of manual handling. The findings have revealed that the Mechanical Handling time saving is 75 times than the manual work and the reduction in cost of labour times. Suggestions are made to further improvement of the efficiency of the equipment.

Keywords: Material handling, Mechanical handling, Manual handling, Tower crane, Construction, Concrete.

Introduction

Tower Cranes usage is a common fixture at any construction site. They often rise hundreds of metres into the air and can reach-out just as far. The construction crew uses the Tower Crane to lift steel, concrete, large tools like acetylene torches and generators and a wide variety of other building materials.

Manual material handling is the largest single cause of losing working days due to injuries in construction. The use of correct handling technique is one of the ways to help reduce injuries. Untrained workers often to do the job in hard way and soon get tired with possible injuries. Many workers suffer from low back pain, much of which results from improper handling of materials.

Improper handling technique can cause strains in other areas than the back. Strains to hands, wrists, arms, neck, shoulders and legs are also common. They too can be prevented by using proper material handling methods. Continuous straining to any of such areas can lead to more serious problems. There have been few studies of injuries and deaths related to lifting of personnel and rests of these have been investigation of selected injuries.

The present paper investigates the impact of mechanized Material Handling in the construction methods and techniques in comparison of the Material Handling for speed of construction and savings on construction cost of high-rise buildings.

Literature Survey

Work study is the term for those techniques particularly Method study and Work Measurement which are used in the examination of human work in all its contexts and which leads systematically to the investigation of all the factors that affect the efficiency of the situation being reviewed, in order to seek improvement. Work Study deals with the best and most efficient way of using available resources, i.e. men, materials, money, machinery and methods. It tries to achieve best quality production in the minimum possible time. The time required to complete a task depends upon the manufacturing procedure and one phase of work study known as Method Study aims at finding the best possible procedure which involves, least time and does not cause fatigue to the workers. It is also a best way of doing a job. Method study is the investigation of the existing method of doing a job in order to develop and install an easy, rapid, efficient, effective and less fatigue procedure for doing the same job and at lower costs. The issues of improving production performance with shortening construction time, reducing costs, etc. are the topics for researchers since a long time due to the urban growth.

The productivity investigation and the analysis of planning, and scheduling techniques are studied in [1, 2]. The effect of managerial action on the objectives of reducing time, cost and improving quality are investigated in [3]. The Technological Improvements as defined by Rosenfeld, et al., [4], refers to using different materials, tools and / or equipment and to adopt new construction methods. Being one of the greatest technological improvements in construction, pre-fabrication and industrialization have long been recognized as the major way to achieve a quantum leap in productivity improvements in the Building Industry.

Pre-fabrication and Industrialization have been used successfully not only in limited regions such as Finland and Israel [5] but also wider regions such as rebuilding of Europe after the destruction of the Second world War or operation break through in the United States [6] in early 1960s. Pre-fabrication and other frames / assemblies have also been used widely in the public housing construction in the Hong Kong and Singapore since early 1980s.

The methods are considered having the potential to considerably reduce the labour requirement on the site, total construction costs and the project completion time are explained in [7]. Other innovative construction methods such as Modular Boxes, Pre-stressed Panels and Polystyrene blocks have been developed in Israel [5]. Accordingly, the multi storeyed building construction in Hyderabad is considered for the ground Floor [8] as a Case Study in the present Research Work.

Indian Context

A very high demand for public housing is prevailed in India. Recently, the Andhra Pradesh State Government has announced the housing construction target of 80,000 units per year, of which 50,000 units fall into the category of public housing under the scheme of Rajiv Gruha Kalpa (RGK) and Rajiv Swagruha Corporation (RSC). The Government demands the speedy construction with priority over the construction cost, since the cost of construction is increasing and hence the accountability of the Government.

Therefore, in the developed cities like, Delhi, Mumbai, Kolkatta, Bangalore, Chennai, etc., the Building Construction Industries cannot engage sufficient young labour to join and thus has a severe shortage of skilled workers. As such, difficulties are being faced to achieve the construction target. Therefore, the research is taken-up with the objective so as to investigate the relationship between construction methods, time duration, labour requirement and costs of labour. The Methodology involved in the construction of a multi-storeyed building is considered in the present research work is explained in the following.

Construction Methodology

As discussed in [8], the construction of ground floor was over. Further, construction of the floors becomes difficult due to the limited space for material handling around the building. The present methodology is explained in the flow chart, Figure – 1, considering different operations.

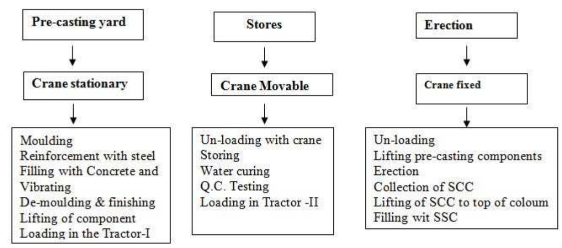

Figure – 1: Elements of the Works in the Construction of Multi storeyed Building

The investigation is carried-out in the construction site of a block of G+14 floors with 12 flats in each floor. The building construction starts from Ground floor, First floor, Second floor and so-on. In such building structural works, Tower Cranes pickup the Pre-casted RCC Columns form the yard by Hoists, Swirling Machines, Trolleys and then place into the each floor in position. Then the M.S. props are used for scaff-holding and wire ropes used to support the columns. The Self Compacted Concrete (SCC) of required grade is prepared in Concrete Batching Plant (CBP) with required materials in proportionate of good quality, conveyed by Transit Concrete Mixer (TCM) to the nearest place of erection of columns. The special type of Hopper / Bucket is used for collecting the SCC from TCM and it can be lifted by Tower Crane to the top of the hollow columns, holding upto filling the hollow portion. Such equipment operation is run by Electric Motors for loading and un-loading. The other supporting materials are taken from one floor to another floor by using trolley, wire ropes, holding device, climbing frame, counter weight, chassis, anchored device, operation cab, etc. Once the Material Handling is completed, then the assemblies are completed. Thus, the site is ready to start the next stage of the roof slab work.

1 Pre-Casting Yard

The steps involved in the preparation of Steel Frames and RCC Components are given in the following.

1.1 ***Moulding*** **:** The ready prepared Moulding Boxes for required size of Column / beam are placed on the solid surface with bottom plate fixed near the casting points

1.2 ***Reinforcement with Steel*****:** The reinforcement with MS rods is designed for RCC works. The rods are cut to the required size as per the design and then bend mechanically following the bar bending schedule. The MS rods of required diameter and number for laying the RCC columns / beams are collected from the yard and formed as frames.
1.3 ***Filling with Concrete & Vibrating*****:** The RCC of M30 grade is prepared in the Way Batch Plant at the separate yard where the raw materials collected automatically in the mixing chamber in required proportion and quality. The ready mixed RCC is collected into the TCM and conveyed to the required locations. Casting the RCC in moulds for column / beam and then vibrating is done for compaction.
1.4 ***De-moulding and Finishing:***
After completion of maximum setting time of one day, all the sides of the moulding boxes are removed and the surfaces, edges upto required sizes of columns / beams are touched upon with cement slurry.
1.5***Lifting of Components***: Pre-casted RCCcolumns/beams are lifted by using Tower Crane
4.1.6 ***Loading in the Tractor-I*****:** The RCC components are loaded in the Tractor so as to transport to the stores**.**

2 Stores

2.1 ***Unloading with Crane*****:** The RCC columns / beams are transported by the Tractor and un-loaded by using Tower Crane.
2.2 ***Storing*****:** The RCC columns / beams un-loaded from the Tractor are placed at the convenient point for the water curing.
2.3 ***Water Curing*****:** After completion of maximum setting time of one day, the newly laid RCC Columns / Beams require further strengthening. Hence, protection of hydration from atmosphere is necessary. Accordingly, water curing over the top of RCC is maintained for a period of 21 days.
2.4 ***Quality Control*****:** After completion of water curing period of 21 days, a piece of RCC is tested in the Lab. and testing the compressive strength to maintain Quality.
2.5 ***Loading in the Tractor –II*****:** After completion of required Quality Control tests on RCC columns / beams, the components are lifted and loaded by the Tower Crane into the Tractor-II to convey the to the nearest for erection.

3 Erection

3.1 ***Unloading RCC columns / beams***: The RCC columns / beams conveyed from the stores to the construction site by the Tractor-II are un-loaded by the Tower Crane and keep at the nearest place for erection.
3.2 ***Lifting pre-casted Components***: The Pre-casted RCC columns / beams, which already available near by the erection location are lifted by Tower Crane by means of Hook and belt system. Male Workers are engaged in lifting process and in the following works.
3.3 ***Erection RCC Columns & Beams*****:** The RCC columns over the top of the floor, which are holding by the Tower Crane, fixed at the required place and the dwell bars / steel rods from bottom column are protruded into the hollow portion of the column. Simultaneously, the RCC beams are also erected in the required place and position. The M. S. props and wire ropes are used for scaff-holding to make the columns and beams so as to put them in the required position.
3.4 ***Collection of SCC***: The SCC is prepared in the Concrete Batching Plant, collected and conveyed by Transmit Concrete Mixer (TCM) to the construction place. The SCC from TCM is collected in the Concrete Bucket.
3.5 ***Lifting of SCC to the top of Column***: The SCC which is collected in the Concrete Bucket is lifted by the Tower Crane upto top of the column and beam junction.
3.6 ***Filling with SCC***: The ready SCC from Concrete Bucket at the top of column and beam junction is filled with opening the bottom gate of Bucket.
3.7 ***Grouting*****:** The SCC is filled in the hollow portion of the columns and junctions as half portion, full portion as per the requirement. Finally, the total grouting work is completed for maintaining all the columns and beams as mono-lithick structure.

The standard time and labour charges are calculated as per Andhra Pradesh Departmental Standard Specifications (APDSS) [9], ie, 1.25 times higher for I floor, 1.50 times for II floor. Total cost of labour for Mechanical construction per RCC beam = Cost at pre-casting yard + Cost at II floor.

Case Study

A Study is carried-out in the site where-in a multy-storeyed is being constructed. The data is collected from the site. The Tower Crane – Potan M85 Crane (Refer Figure -2) is used in handling the materials. The specifications / working dimensions of the Tower Crane are shown in Table -1. For convenience sake, the figures, tables and graphs are given after the Theory part. The data is collected for a day of 8 hours duration and the components involved in the transportation from and to the places and return to the concerned places are shown in the tables. the labour charges both for Mechanical and Manual Handling are given. The sample calculation are shown. The details given in the Tables are self explanatory.

Name	Dimensions (Metres)	Lifting Capacity	
		Lifting at Radius (Metres)	Kg
Height of the Tower Crane	16	50	1200
Length of the boom (Forward)	50	45	1500
Length of the boom (Backward)	15	40	1800
Working length (Radius)	36	35	2200
Dead length (Front side)	14	25	3300
Dead length (Back side)	15	14	5000
Hoisting Motor Capacity (1 No.)	18.50 KW		
Trolley Motor Capacity (1 No)	3.00 KW		
Slewing Motor Capacity (1 No)	5.10 KW		

Table -1 : Working Dimensions of the Tower Crane – Potan M85 Crane

Sl. No	NOW	QCs	Wt	Destination		Li / Lo	D W	TN	Total DWg	D Id	TN	Total DId	If Manual		
				From	To								MR	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC5	1	1224	Pf-II	Tr	14	80	1	94	-	-	-	40	320	5840
2	RT	-	-	Tr	Pf-I	14	-	-	-	74	1	88			
3	RCCC4	11	11880	Pf-I	Tr	14	74	11	968	-	-	-			
4	RT	-	-	Tr	Pf-I	14	-	-	-	74	11	968			
5	RCCC2	5	2400	Pf-I	Tr	14	72	3	258	-	-	-			
6	RT	-	-	Tr	Pf-I	14	-	-	-	72	3	258			
7	CSFS4	7	756	Tl	Pf-I	12	32	1	44	-	-	-			
8	RT	-	-	Pf-I	Tl	12	-	-	-	32	1	44			
9	CSFS3	18	1260	Tl	Pf-II	12	22	3	102	-	-				
10	RT	-	-	Pf-II	Tl	12	-	-	-	22	3	102			
			17520						**1466**			**1460**	**40**	**320**	**5840**

Table -2: Tower Crane used in Pre-casting Yard for shifting of RCC columns, Dt: 21-06-2010; Duration: 8-00 hrs

Sl. No.	NOW	QCs	Wt	Destination		Li / Lo	D Wg	TN	Total DWg	DId	T N	Total DId	If Manual		
				From	To								MR	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC4	7	7560	Pf-II	Tr	14	86	7	700	-	-	-	62	496	9052
2	RT	-	-	Tr	Pf-II	14	-	-	-	86	7	700			
3	RCCC3	18	12528	Pf-II	Tr	14	86	9	900	-	-	-			
4	RT	-	-	Tr	Pf-II	14	-	-	-	86	9	900			
5	CSFS4	23	2484	Tl	Pf-II	12	32	4	176	-	-	-			
6	RT	-	-	Pf-II	Tl	12	-	-	-	32	4	176			
7	CSFS5	10	1250	Tl	Pf-II	12	22	2	68	-	-	-			
8	RT	-		Pf-II	Tl	12	-	-	-	22	2	68			
			23822						**1844**			**1844**	**62**	**496**	**9052**

Table -3: Tower Crane used in Pre-casting Yard for lifting of RCC columns, Dt: 22-06-2010; Duration: 8-00 hrs

Sl. No.	NOW	QCs	Wt	Destination		Li / Lo	D Wg	TN	Total DWg	DId	T N	Total DId	If Manual		
				From	To								MR	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC5	1	1224	Pf-II	Tr	14	86	1	100	-	-	-	105	840	15330
2	RT	-	-	Tr	Pf-I	14	-	-	-	76	1	90			

3	RCCC3	47	32712	Pf-I	Tr	14	76	24	2160	-	-	-			
4	RT	-	-	Tr	Pf-I	14	-	-	-	76	24	2160			
5	RCCC2	5	2400	Pf-I	Tr	14	72	3	258	-	-	-			
6	RT	-	-	Tr	Pf-I	14	-	-	-	72	3	258			
7	CSFS1	37	1332	Tl	Pf-I	12	34	8	368	-	-	-			
8	RT	-	-	Pf-I	Tl	12	-	-	-	34	8	368			
9	CSFS2	16	768	Tl	Pf-II	12	32	4	176	-	-	-			
10	RT	-	-	Pf-II	Tl	12	-	-	-	32	4	176			
			38436						**3062**			**3052**	**105**	**840**	**15330**

Table -4: Tower Crane used in Pre-casting Yard for shifting of RCC Columns, Dt: 23-06-2010; Duration: 8-00 hrs

Sl. No.	NOW	QCs	Wt	Destination		Li / Lo	D Wg	TN	Total DWg	DId	T N	Total DId	If Manual		
				From	To								MR	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC3	27	18792	Pf-I	Tr	14	74	14	1232	-	-	-	50	400	7300
2	RT	-	-	Tr	Pf-I	14	-	-	-	74	14	1232			
3	RCCC1	10	3600	Pf-II	Tr	14	84	5	490	-	-	-			
4	RT	-	-	Tr	Pf-II	14	-	-	-	84	5	490			
5	CSFS4	14	1512	Tl	Pf-I	12	30	3	126	-	-	-			
6	RT	-	-	Pf-I	Tl	12	-	-	-	30	3	126			
7	CSFS3	18	1260	Tl	Pf-II	12	26	4	152	-	-	-			
8	RT	-	-	Pf-II	Tl	12	-	-	-	26	4	152			
			25164						**2000**			**2000**	**50**	**400**	**7300**

Table -5: Tower Crane used in Pre-casting Yard for lifting of RCC columns, Dt: 24-06-2010; Duration: 8-00 hrss

Sl. No.	NOW	QCs	Wt	Destination		Li / Lo	D Wg	TN	Total DWg	D Id	TN	Total DId	If Manual		
				From	To								MR	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC6	2	2832	Pf-I	Tr	14	82	2	192	-	-	-	65	520	9490
2	RT	-	-	Tr	Pf-I	14	-	-	-	82	2	192			
3	RCCC4	7	7560	Pf-II	Tr	14	80	7	650	-	-	-			
4	RT	-	-	Tr	Pf-II	14	-	-	-	80	7	658			
5	RCCC3	18	12528	Pf-I	Tr	14	82	18	1728	-	-	-			
6	RT	-	-	Tr	Pf-I	14	-	-	-	82	18	1728			
7	CSFS6	4	560	Tl	Pf-II	12	32	3	132	-	-	-			
8	RT	-	-	Pf-II	Tl	12	-	-	-	32	3	132			
9	CSFS2	60	2880	Tl	Pf-I	12	34	12	552	-	-	-			
10	RT	--	--	Pf-I	Tl	12	-	-	-	34	12	552			
			26360						**3262**			**3262**	**65**	**520**	**9490**

Table -6: Tower Crane used in Pre-casting Yard for lifting of RCC Columns, Dt: 25-06-2010 Duration: 8-00 hrs

Sl. No.	NOW	QCs	Wt	Destination		Li / Lo	D Wg	TN	Total DWg	DId	TN	Total DId	If Manual		
				From	To								M R	Time	LCH
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	RCCC5	10	12240	Pf-I	Tr	14	78	10	920	-	-	-	125	1000	18250
2	RT	-	-	Tr	Pf-I	14	-	-	-	78	10	920			
3	RCCC4	23	24840	Pf-II	Tr	14	80	23	2162	-	-	-			
4	RT	-	-	Tr	Pf-II	14	-	-	-	80	23	2162			

5	RCCC3	13	9048	Pf-I	Tl	14	72	7	602	-	-	-			
6	RT	-	-	Tr	Pf-I	14	-	-	-	72	7	602			
7	CSFS5	6	750	Tl	Pf-I	12	40	2	104	-	-	-			
8	RT	-	-	Pf-I	Tl	12	-	-	-	40	2	104			
9	CSFS2	66	3168	Tl	Pf-II	12	32	13	572	-	-	-			
10	RT	-	-	Pf-II	Tl	12	-	-	-	32	13	572			
			50046						**4360**			**4360**	**125**	**1000**	**18250**

Table -7: Tower Crane used in Pre-casting Yard for lifting of RCC Columns, Dt: 26-06-2010; Duration: 8-00 hrs

Nomenclature / Notations Used:

RCC : Reinforced Cement Concrete; CSFS: Column Steel Frame Structure;
Components = Cs; Distance (m) = D; Q = Quantity; Labour Charges (Rs) = LCH;
Lifting= Li; Lowering =Lo; Platform = Pf; Required = R; Trailer = Tl; Truck = Tr;
Load =Wt (Kg); Working = Wg; Id = Idle; RT = Return Travel; TN= No. of Trips;
NOW = Nature of Work; Wt = Weight in Kg.

Date	Wt. of RCCC (Kg)	Wt of SF (Kg)	Total Wt. of Cs (Kg)	Mechanical Handling		Manual Handling		
				Time	Maintenance	Men	Time	LCH
21.06.2010	15504	2016	17520	8	1200	40	320	5840
22.06.2010	20088	3734	23822	8	1200	62	496	9052
23.06.2010	36336	2100	38436	8	2000	105	840	15330
24.06.2010	22392	2772	25164	8	1200	50	400	7300
25.06.2010	22920	3440	26360	8	1200	65	520	9490
26.06.2010	46128	3918	50046	8	2500	125	1000	18250
	163368	**17980**	**181348**	**48**	**9300**	**447**	**3576**	**65262**

Table -8 Shifting of components from pre-casting yard in 6 days.

Calculations of Charges

1. Labour charges of the M/c operator : Rs.200; 2. Labour charges of the skilled labour: Rs.200
3. Labour charges of the Man mazdoor : Rs.146;
4. Crane maintenance charges : Power charges + labour charges of M/c Operator + Labour charges of Skilled worker +Oil & Grease charges
5. Average lifting and carrying capacity of a man mazdoor : 35 Kgs
6. Time required for completing one cycle by manual handling : 30 Mins.

Sample Calculation:

7. Total Working Distance (Twg) = TN (Li + DWg + Lo) = RCCC3 = 14 (7 + 74 + 7) = 1232 M
8. Return Travel (RT) = TN (Li + DId + Lo) = 14 (7 + 74 + 7) = 1232 M

Block Type	Volume (lxbxh) M^3	Wt of each Block (Kg)	Frame Type	Wt of each Frame (Kg)
RCCC1	2.520x0.30x0.30	360	CSFS1	36
RCCC2	2.835x0.60x0.30	480	CSFS2	48
RCCC3	2.835x0.75x0.30	696	CSFS3	70
RCCC4	2.835x0.90x0.30	1080	CSFS4	108
RCCC5	2.835x1.00x0.30	1224	CSFS5	125
RCCC6	2.835x1.20x0.30	1416	CSFS6	140

Table - 9: Type of RCC Columns / Steel Frame used in Building Construction

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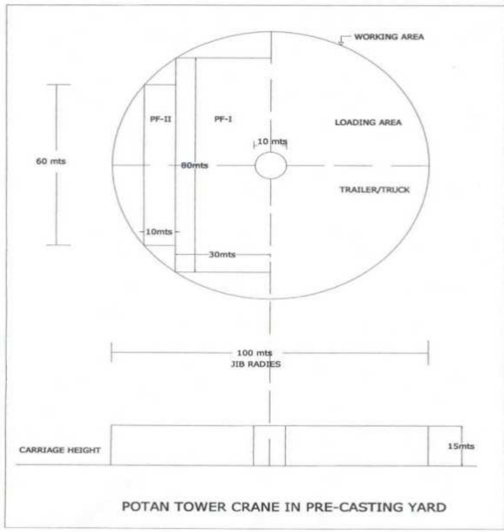

Figure - 2: Tower Crane Working Dimensions

Figure – 3: RCC Columns Loading in the Trailer

Figure – 4: RCC beams lifting

Figure – 5: Steel Frames Lifting

Figure – 6: RCC Columns lifting

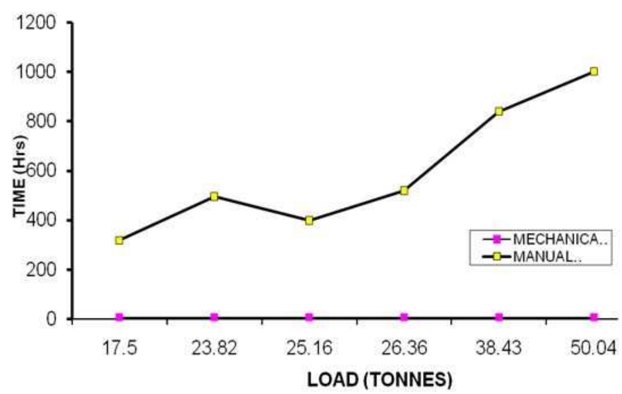

Figure -7: Total load carrying vs Time in Hours

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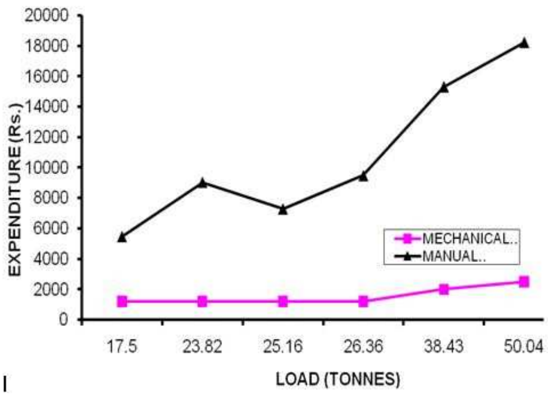

Figure - 8: Total load carrying vs Expenditure (Rupees)

Result And Discussion

The time and cost involvement with manual and Mechanical shifting of RCC Columns and Steel Frames from the Pre-casting Yard are shown in Table – 7. From the table it can be seen that the time is reduced from 3576 to 48 hrs, with a saving of 3,528 hrs to handle 181.348 tons. Similarly, the handling costs are reduced from Rs 65262/- to Rs 9300/- with a total savings of Rs. 55,962/-.

Conclusion

The time taken for shifting of RCC Columns and steel frames in both Mechanical handling and manual handling is studied and compared. It is observed that the taken in Mechanical Shifting is reduced by 75 times and the expenditure reduction by seven times. Therefore, the Mechanical Handling for shifting of RCC columns and Steel frames is much easier in risk factor, time and cost savings from the Manual Handling. Therefore, it is concluded that the Mechanical Handling is preferred to Manual Handling in the construction of Multi-storeyed and High Rise Buildings.

Further Work

Line balance techniques will be studied.

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