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Construction Solutions used for Improvement in Labor Productivity on Site

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ABSTRACT

Construction labour productivity improvement is important role in now day's for all construction projects. The labour productivity effects on contractors, sub-contractors, clients and labours. There are number of factors affecting labour productivity on construction sites so in this project suggested number of solutions to increase labour productivity. The questionnaires survey was conducted for top ranked important factors which are affecting labour productivity and expert's solutions were collected from questionnaires for useful to improvement in labour productivity. First of all, on site labour productivity is calculated; at the same time factors affecting labour productivity are identified. We found some practical solutions and these were implemented on site to improve labour productivity. After implementation of solutions, it was observed that, labour productivity is increased. Then we carried out comparative study of before and after labour productivity.

Keywords: Labor Productivity, Productivity Factors, Relative Important Index (RII), Practical Solutions.

I. INTRODUCTION

Construction is the world's largest and most challenging industry. Construction labour productivity is of critical importance to the construction industry, as it directly affects the competitiveness and profitability of construction companies. There are many challenges facing the construction industry in India, but one of the most important is low productivity. Human resource today has a strategic role in the increase in productivity in any organization and this makes human resource superior role in the industrial competition. Construction costs are constantly on the rise, duration for completion of the project is substantially increasing and most projects are significantly overrunning their budgets in India. Higher productivity levels allow constructors to improve competitiveness, simultaneously increase profitability and pay higher wages to workers while completing activities in time. Economists defined the labour productivity as the ratio of total product output to total labour input or simply the ratio of output to input.[1] Construction is a labour-intensive industry and labour related costs in most countries often account for 30–60% of the total costs of a construction project.[2]

The current traditional practice of estimating and scheduling relies on several sources to predict the productivity rates, which would include an estimator's personal judgment, published productivity data, and historical project data. The construction industry has progress last few decades through advances in heavy equipment, tools and materials. Nevertheless, labour productivity still needs improvements. Non-value-added activities spend 50–75% of the productive time on construction site. [3] Therefore maintaining and improving labour productivity is a key to making a construction project successful. The researchers have studied on which factors affecting labour productivity but not given any perfect practical solutions to improvement in labour productivity. [4,5,6] The researchers have studied and analyzed construction tool time, labour productivity on construction sites and have investigated the real composition of the total time spent by construction labourers on different activities. The general observation was that the real direct tool time was only 40–60% of the total time of activities. [7] In this study we analyzed factors affecting labour productivity and practical solutions were implemented on construction sites.

II. METHODOLOGY

The questionnaires survey was conducted for top ranked factors affecting labour productivity and solutions were collected from questionnaire for use by contractors, engineers and sub-contractors on sites and improve in labour productivity. We calculated labor productivity in terms of time and cost on selected construction site for formwork, reinforcement work and concrete work activities. Factors were identified affecting labour productivity. Then practical solutions are found out to increase labour productivity. These solutions were implemented on site for improvement in labour productivity. After implementation of solutions, again productivity is calculated to find out increase in the productivity. The detail of work was given below:

Data collection

The construction sites were selected to calculate daily labour productivity. Fifty factors were collected from literature survey to prepare questionnaires survey. These questionnaires were distributed to contractors, engineers and sub-contractors and responses were collected to improve labour productivity.

Questionnaires survey

Questionnaires survey was preferred as the best effective and suitable data-collection technique for the study. Questionnaires were collected by hand to hand in Sangli district (Maharashtra, India). First, pilot survey was conducted by 8 experts and then questionnaires were collected by 50 engineers, contractors and construction companies. By using Relative Important Index (RII) method [10] top 25 factors were selected (Table 1) from the data collected by Questionnaires survey and these factors were divided under five groups. In questionnaires, respondents suggested number of solutions for improvement in labour productivity. (Table 3)

- Ranges:**-** 1 – Does not affect it, 2 – Somewhat affect it, 3 – Directly affect it.
- Relative Important index (RII) = [Sum weights] / [Total No. of Respondents* Highest Range (3)]
- Sum Weights ranges [1 – Does not affect it, 2 – Somewhat affect it, 3 – Directly affect it]
  * Number of respondents for each Factor

Table 1 Relative Importance Indices and Ranks of all Productivity Factors

Sr. No.	Factors Affecting Labor Productivity in Building Construction	Ranges			Sum Weights	Relative Importance Index (RII)	Rank
		1 – Does not affect it	2 – Somewhat affects it	3 – Directly affects it			
A	**Management Factors**						
	1) Payment delay	3	17	30	127	0.85	**2**
	2) The level of management control	5	24	21	116	0.77	**3**
	3) Work planning and scheduling	2	17	31	129	0.86	**1**
	4) The professionalism of the design team	7	28	15	108	0.72	**5**
	5) The incompetence of site supervisor	4	28	18	114	0.76	**4**
B	**Site and Resource Management Factors**						
	1) Availability of materials	2	8	40	138	0.92	**1**
	2) Availability of workforce	1	19	30	129	0.86	**2**
	3) Availability of tools and machinery	2	25	23	121	0.81	**3**
	4) Payment terms	7	31	12	105	0.70	**5**
	5) Sequence of work	5	29	16	111	0.74	**4**
C	**Project Characteristics factors**						
	1) Design requirement	7	25	18	111	0.74	**2**
	2) Specification and drawings	5	18	27	122	0.81	**1**
	3) Site access	4	32	14	110	0.73	**3**
	4) Inclement weather	6	29	15	109	0.73	**4**
	5) Subcontract	10	36	4	94	0.63	**5**
D	**Workforce characteristics factors**						
	1) Morality (alcohol influence)	2	5	43	141	0.94	**1**
	2) Safety	1	22	27	126	0.84	**2**
	3) Quality experience and training	2	31	17	115	0.77	**3**

	4) Frequent changes in labors	2	38	10	108	0.72	**5**
	5) Disturbance	2	35	13	111	0.74	**4**
E	**External characteristics factors**						
	1) Rain	1	15	34	133	0.89	**1**
	2) Economic conditions	2	17	31	129	0.86	**2**
	3) Overtime	18	27	5	87	0.58	**4**
	4) Order variations	4	40	6	102	0.68	**3**
	5) Development and research	28	16	6	78	0.52	**5**

The Data analysis software SPSS in reliability statistics checked Cronbach's Alpha value. The following table result was taken from questionnaires survey data output results in the SPSS Software. The SPSS software gives you your Cronbach's alpha coefficient. You are looking for a score of over 0.7 for high internal consistency. In this case, **Alpha value = 0.83**, which shows the questionnaire is reliable.

Table 2 Reliability Statistics for questionnaires survey data

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.83848066	0.839063138	20

Table 3 Questionnaires Survey – Factors Affecting Labor Productivity and Solutions

Sr. No.	Factors and Solutions	Sr. No.	Factors and Solutions
1	Payment delay 1) Weekly payment 2) Proper planning and provision 3) Payments as per schedule 4) Cash flow pre-arrangement 5) Target oriented payment condition	2	The level of management control 1) Maintain proper communication 2) Experienced project manager 3) Arrange a weekly meeting 4) The responsible person should be arranged 5) Experienced management team
3	Work planning and scheduling 1) Planning and scheduling should be done properly 2) Keep daily attention on bar chart of the project 3) Re-scheduling 4) MSP, Primavera software used 5) Proper re-planning or updated	4	The professionalism of the design team 1) Expert design team required 2) Better communication between site engineer and design team 3) Monthly meetings 4) Prepare design before execution 5) Experienced designer appointed in team
5	The incompetence of site supervisor 1) The advice was taken from senior 2) Experienced supervisor appointed 3) Training for the site supervisor 4) Replace 5) Site supervisor must have a thorough knowledge of the site	6	Availability of material 1) Making proper scheduling of work material 2) Stock in advance 3) Material available before work starts 4) The daily register of material should be maintained 5) Use material receipt book
7	Payment terms 1) Maintaining proper payment schedule 2) As per measurement 3) Should be clear 4) Should be written format in contract 5) Before work order all terms and condition	8	Inclement weather 1) Have to consider prior base 2) Take advice from a senior engineer 3) Can be overcome 4) Not so affected

9	Availability of workforce 1) Maintained as per required 2) Manpower as per schedule 3) Sufficient of labour force should be arranged 4) Resource planning necessary	10	Availability of tools and machinery 1) Should be present on site before work starts 2) Modern tools and machinery available on site 3) As per quantity of work requirement 4) Extra standby machinery and tools 5) Procure those are essential
11	Sequence of work 1) As per proper planning 2) Sequence of work should be the plan before work starts 3) With bar chart 4) According to schedule 5) Penalty to sub-contractor	12	Design requirement 1) Priority has to be given designer and communicate 2) Design in advance 3) Before site start all design required 4) Available before of work 5) Design should be correct and proper
13	Overtime 1) Give them some expense to labour 2) Allow but in less extent 3) Shouldn't do or avoided, if not necessary 4) Should be carried out to speed up the work	14	Development and research 1) Must be maintained as per required 2) Use some new techniques 3) Must necessary 4) Promote development and research department organization for the company
15	Specification and drawings 1) All Specification and drawings should be made available before the work start 2) Specification and drawings should be correct and proper 3) Drawing should be easy to read 4) Well communication to architect	16	Rain 1) Concrete and fabrication work care is taken 2) Rainy season planning 3) Provide raincoat, gumboots and plastic paper on site 4) Concreting should do before rain season 5) See forecast and after making the plan
17	Site access 1) Site layout is necessary 2) Site access should be done before starting of work 3) Proper house-keeping required 4) Site access details should be displayed on site	18	Subcontract 1) Selection of subcontractor as per rules and regulations 2) Subcontractor should be appointed to speed up the work 3) Proper agreement
19	Morality (alcohol influence) 1) Should not allow on-site 2) Taken strictly fine and action 3) Organize campaign for healthy labour production 4) Lectures of doctors should be arranged to give information on side effects of alcohol consumption	20	Safety 1) Labour indication is necessary 2) Should provide safety equipment's 3) Safety training required for labour 4) Organize campaign for safety 5) OSHA guideline used for safety (Occupational Safety and Health Administration)
21	Quality of experience and training 1) Before the start of work experience supervisor required 2) Quality experience and training to company staff 3) Training arranged new labours and experienced labour for new work	22	Frequent changes in labours 1) Resource planning 2) Re-scheduling the work 3) Do not change the labour force 4) To give work perfect contractor 5) Another arrangement of labour should be their
23	Disturbance (Social issue, water, light) 1) Solved by mutual understanding 2) Controlled by site engineer 3) Keep communication with all agency involved with the project 4) If pre-planned then not affected 5) Rescheduling the work	24	Economic conditions 1) Maintain proper cash flow 2) Ensure proper funding for smooth progress of work 3) Arrangement of finance and provide time to time money as per requirement to site 4) Economic condition use properly
25	Order variations 1) The order should not be repeated and subsequent and As per plan calculate quantity before the order 3) Stock maintain and Variation should be minimized 4) Proper communication between supplier and engineer 5) Daily update of available material and material required and As per estimation		

Case Study (Site - Shri Ladage Apartment, Sangli)

The labour productivity was calculated and factors regarding labour produtivity were analyzed on selected site. Site details are as follows,

Site1- Shri Ladage Apartment, Sangli.

This site were located in Sangli city, Maharashtra, India at different locations. Sites are having Labour Contract.
We calculated actual daily labour productivity for one floor only and we analyzed which factors are affecting labour productivity. Afterwords we developed solutions for factors affecting labour productivity and then these solutions were implemented on site. Then we calculated labour productivity for next floor. We found that, labour productivity was increased than previous floor. This labour productivity was calculated in terms of cost and time.

Table 4 Site Details

Project Name	Shri Ladage Apartment, Sangli
Main Works	Basement +G+4 Floor Apartment (10 Flats, 2BHK)
Duration (months)	11 Months
Total Project cost (Rs.)	2,00,00,000/-
Contractor Name	Project Management Consultancy, Sangli
Contract type	Labor Contract
Site Working Time	9 Am to 7 pm
Labor Native	Maharashtra
Selected Activity	Formwork, Reinforcement work, Concrete work
Total Activity Rate (Rs.)	115/- sq.feet (1237/- sq.m)
Formwork Rate (Rs.)	30/- sq.feet (323/- sq.m)
Reinforcement work Rate (Rs.)	25/- sq.feet (269/- sq.m)
Concrete work (Rs.)	60/- sq.feet (645/- sq.m)
Skilled Labor Rate (Rs.) per day	550/-
Un-Skilled Labor Rate (Rs.) per day	400/-

Calculate labour productivity before and after implementation of solutions on site
First of all we prepared a Labour Productivity Chart for formwork, reinforcement work and concrete work activities. Every day we noted down the quantity of work completed on site. Then produtivity for each day is calculated. Also we found factors affecting produtivity of labours. We calculated daily labour productivity for Skilled and unskilled labours. Labour productivity is calculated only for one-floor; before and after implementation of solutions on site. This skilled, unskilled and daily productivity less than 1 in terms of time is less productivity and higher than 1 is high productivity.[6] The labour productivity in terms of cost is depends on labour rate and work order rate, so project to project labour productivity change.

For calculation of labor productivity, following formulae are used. The labour productivity charts making in excel sheet and set formulae's to sheet.(Table No. 5) Sites reading was putting into chart after give automatic results of labour productivity. The sum of labor productivity for all activities were calculated from start to end for one floor and these total labor productivity for activities are written in following tables. (Table 5)

Productivity Formula:-Productivity is generally the ratio of the output to input. [8, 9]

1. Productivity = Output ÷ Input
2. Labor Productivity (In terms of Cost) = Output quantity cost ÷ Labor time cost
3. Labor Productivity (In terms of Time) = Output work ÷ Work hour

Table 5 Format of Labour Productivity Chart

Date	10/23/2017 to 12/18/2017	Unit	Total Quantity	Work done				Achieved	Productvity Per Day in (Time)	BOQ Rate	Total Amount in Rs.	Productvity Per Day in (Cost)	Factors affecting Labor Productivity
	Activity			No	L	B/W	D	Qty.					
24-Oct-17	C1 to C6 columns starter and lift shuttering work	sqm	152.10					10.318	0.34	279	2,878.72	2.13	Labour force, Material availability, Non tool time
28-Oct-17	C11 to C22 columns suttering,scaffolding,lining,material shifting	sqm	125.00					19.5469	0.28	279	5,453.59	1.76	Non tool time, Work Planning and Scheduling
31-Oct-17	Deshuttering of columns and lift and material shifting	sqm	105.45					46.6539	1.17	139	6,484.89	3.71	-
1-Nov-17	staircase and 1 feet upper columns shuttering and scaffolding	sqm	58.80					18.55	0.88	279	5,175.45	5.48	Non tool time
										TOTAL	116,906.68		
Date	Activity	Unit	Labour (WORK TIME:Day Shift:9.00 A.M to 7 P.M)				Total time (in Hours)	Siklled Labour Rate (550)	C-Productivity in Cost	Unsiklled Labour Rate (400)	H-Productivity in Cost	Total Labour Amount(Rs.)	Difference Amount
			Carpenter in Time (hrs)	C-Productivity in Time	Helper in Time(hrs)	H-Productivity in Time		Total cost Carpenter in Rs.		Total cost Helper in Rs.			
24-Oct-17	C1 to C6 columns starter and lift shutering work	sqm	9	1.1	18	0.6	30	495	5.82	720	4.00	1,350.00	1,528.72
28-Oct-17	C11 to C22 columns suttering, scaffolding, lining,material shifting	sqm	18	1.1	45	0.4	70	990	5.51	1800	3.03	3,100.00	2,353.59
31-Oct-17	Deshuttering of columns and lift and material shifting	sqm	9	5.2	27	1.7	40	495	13.10	1080	6.00	1,750.00	4,734.89
1-Nov-17	staircase and 1 feet upper columns shuttering and scaffolding	sqm	6	3.1	12	1.5	21	330	15.68	480	10.78	945.00	4,230.45
											TOTAL	20,365.00	80,301.68

Table 6 Labour Productivity before Implementation of Solutions on-site - Time (1st Floor)

Site Name:- Shri Ladage Apartment, Sangli (1st Floor)			
Labour Productivity			
	In Terms of Time		
Activity	**Carpenters/ Fitters/ Masons (Sq.m/hrs)**	**Helpers (Sq.m/hrs)**	**Total Daily work Productivity (Sq.m/hrs)**
Formwork	(911/368) = 2.48	(911/714) = 1.28	(911/1210) = 0.75
Reinforcement work	(456/285) = 1.6	(456/423) = 1.08	(456/768) = 0.59
Concreting work	(463.92/117) = 3.97	(463.92/492) = 0.94	(463.92/673) = 0.69
	Total All Activity Productivity		**(1830.92/2651) = 0.69**

Table 7 Labour Productivity before Implementation of Solutions on-site - Cost (1st Floor)

Site Name:- Shri Ladage Apartment, Sangli (1st Floor)			
Labour Productivity			
	In Terms of Cost		
Activity	**Carpenters/ Fitters/ Masons (Sq.m/hrs)**	**Helpers (Sq.m/hrs)**	**Total Daily work Productivity (Sq.m/hrs)**
Formwork	(1,45,423.60/20,240) = 7.18	(1,45,423.60/28,560) = 5.09	(1,45,423.60/53,320) = 2.73
Reinforcement work	(1,31,431/17,416.66) = 7.55	(1,31,431/18,800) = 6.99	(1,31,431/34,435) = 3.82
Concreting work	(2,50,028.85/6,435) = 38.85	(2,50,028.85/19,680) = 12.7	(2,50,028.85/28,855) = 8.67
	Total All Activity Productivity		**(5,26,883.45/1,16,610) = 4.52**

Table 8 Labour Productivity after Implementation of Solutions on-site - Time (3rd Floor)

Site Name:- Shri Ladage Apartment, Sangli (3rd Floor)			
Labour Productivity			
	In Terms of Time		
Activity	Carpenters/ Fitters/ Masons (Sq.m/hrs)	Helpers (Sq.m/hrs)	Total Daily work Productivity (Sq.m/hrs)
Formwork	(974.98/216) = 4.51	(974.98/440) = 2.22	(974.98/766) = 1.27
Reinforcement work	(456/182) = 2.5	(456/303) = 1.5	(456/546) = 0.83
Concreting work	(478.68/48) = 9.97	(478.68/198) = 2.42	(478.68/292) = 1.64
	Total All Activity Productivity		**(1,909.66/1,604) =1.19**

Table 9 Labour Productivity after Implementation of Solutions on-site – Cost (3rd Floor)

Site Name:- Shri Ladage Apartment, Sangli (3rd Floor)			
Labour Productivity			
	In Terms of Cost		
Activity	Carpenters/ Fitters/ Masons (Sq.m/hrs)	Helpers (Sq.m/hrs)	Total Daily work Productivity (Sq.m/hrs)
Formwork	(1,79,224.97/1,880) = 15.09	(1,79,224.97/17,600) = 10.18	(1,79,224.97/17,600) = 5.43
Reinforcement work	(85,874/11,122) = 7.72	(85,874/13,467) = 6.38	(85,874/25,560) = 3.36
Concreting work	(2,78,686.08/2,640) = 105.56	(2,78,686.08/7,920) =35.19	(2,78,686.08/15,325) =18.19
	Total All Activity Productivity		**(5,43,785.05/58,485) = 9.29**

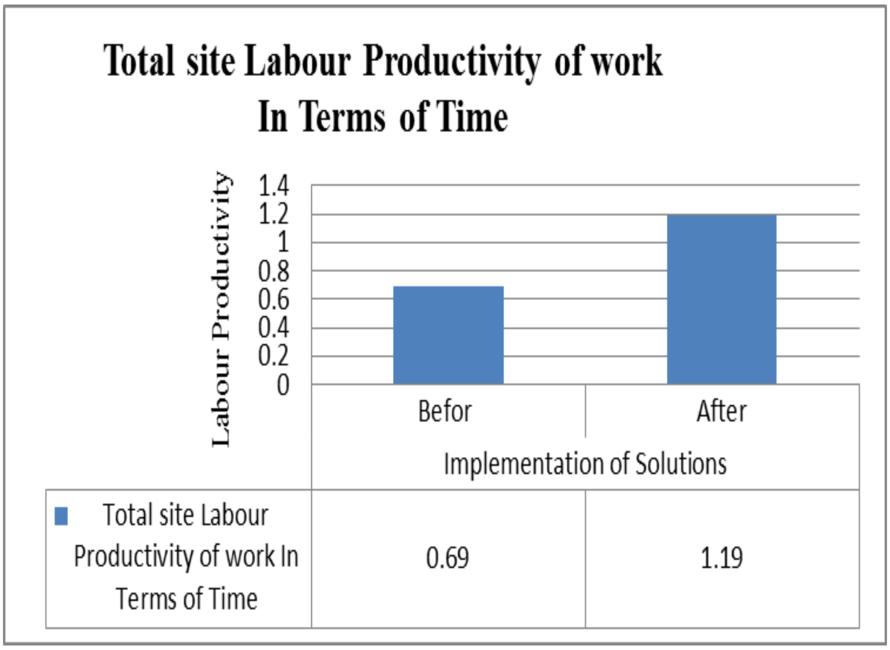

Fig.1:- Total Site Labour Productivity before and after Implementation of Solutions in terms of Time

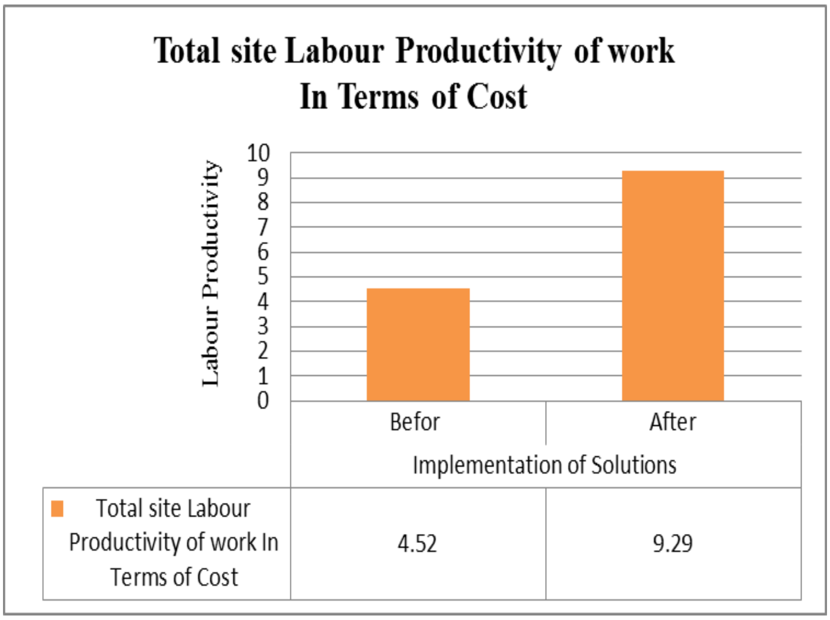

Fig.2:- Total Site Labour Productivity before and after Implementation of Solutions in terms of Cost

The "labour work-time difference amount" is the cost for work completed by labours and cost of time required to complete work. The total labour-time difference amount is calculated separately for formwork, reinforcement work and concrete work activities before and after implementation of solutions on the site. (Table 10)

Table 10 Total Labour Work–Time Difference Amount

Total labour Work-time Difference Amount Before Implementation of Solutions				
	Formwork (Rs.)	**Reinforcement work (Rs.)**	**Concrete work (Rs.)**	**Total work Amount (Rs.)**
Site (1st Floor)	80,301.68	96,995.74	2,21,173.85	**3,98,471.27**
Total labour Work-time Difference Amount After Implementation of Solutions				
site (3rd Floor)	1,35,638.61	60,314.28	2,63,361.08	**4,59,313.97**

On-Site factors affecting labour productivity and implementation of solutions

Factors affecting labour productivity are found out from the calculations. The day which is having less productivity shows there are some problems. Then problems are analyzed and solutions for these factors were implemented on site, which shows the increase in labour productivity. It means solutions applied are correct and are useful to contractors, engineers and sub-contractors. The first factor non-tool time was an important factor to affecting labour productivity. Non-tool time and tool time was calculated before and after implementations of solutions on site. After implementations of solutions the increases the tool time, these are indicated in the graph 1, 2.

Table 11 On-site Factors Affecting Labour Productivity and Solutions

Sr. No.	**Factors affecting labour productivity**	**Implementations of Solutions on site**
1	Non-tool time	Supervisor to control labours and Motivate to labours towards the completion of the project
2	Site access	Proper site access clear as per site layout
3	Safety	Safety tools and equipment, Insurance Provided to labours
4	Lack of Material Transportation	Formwork – Use Extra Unskilled Labors Concrete work – Use Lift Machine or RMC Pump

5	Housekeeping and cleaning	Weekly
6	Availability of Material	Maintained Stock of Material on site
7	Availability of workforce	As per Requirement Activity of work
8	Work planning and scheduling	1. Primavera P6 Software used for Planning and Scheduling, monitoring of work 2. As per Resource Planning and scheduling of work
9	Sequence of work	
10	Frequent changes in labours	
11	Communication problems between Site Management and Labor	Every day communicate between site engineer and labour contractor
12	Communication break between labour and supervisor	Every day communicate with supervisor and labours, labour contractor

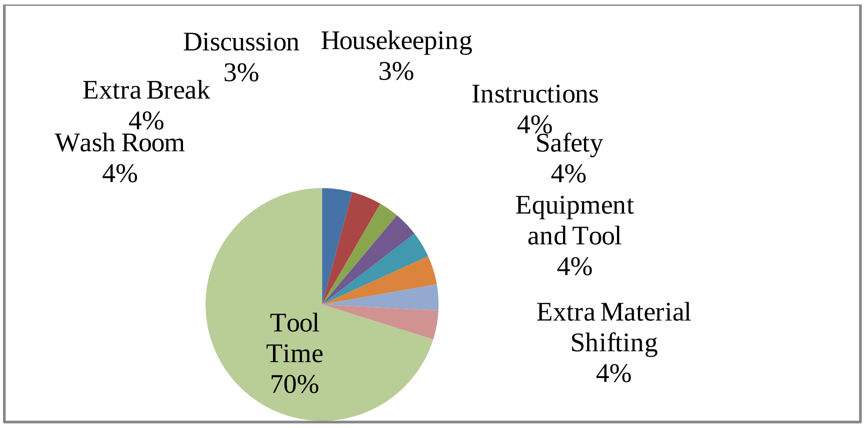

Fig.1 Tool Time and Non-Tool Time before Implementation of Solutions on Site

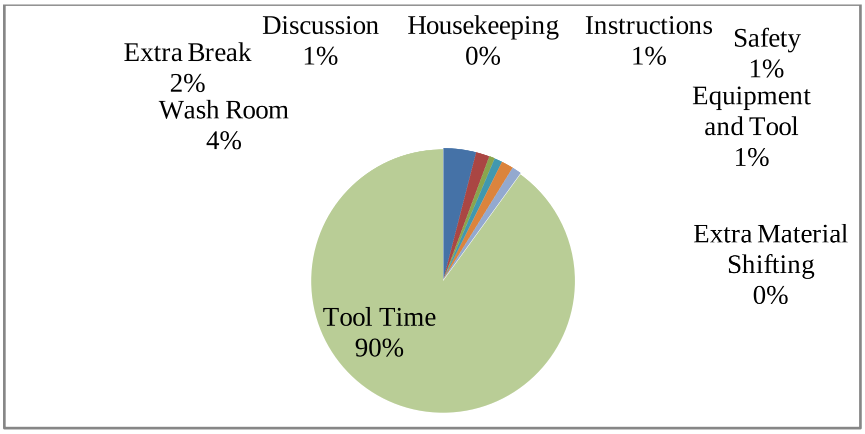

Fig.2 Tool Time and Non-Tool Time after Implementation of Solutions on Site

CONCLUSION

1. The 25 top factors affecting labour productivity and solutions were collected through questionnaires survey from Sangli area. These factors and solutions will be used in future to increase the labour productivity for engineers, contractors, sub-contractors and construction companies in many types of construction work. (Table 1, 3)
2. Labour Productivity for site is calculated for formwork, reinforcement work and concrete work in terms of time; before and after implementations of solutions and it is found that labour productivity for site is increased by 0.57sq.m/hr. (Table 6,8)
3. Before and after implementations of solutions the labour productivity for formwork, reinforcement work and concrete work increases in terms of cost ratio for site by 3.92. (Table 7, 9)

4. Total work cost and time cost amount difference was increased for the site - Rs.60,843. (Table 10)
5. The factors which are affecting on labour productivity were identified for the activities formwork, reinforcement work and concrete and practical solutions for these factors were found out. The practical solutions were implemented on site to increase labour productivity. The increase in labour productivity shows that solutions implements on the site are correct and useful for engineers, contractors, sub-contractors and construction companies in many types of construction work. (Table 11)

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