Application of Lean Production Principle in construction project: Case study of Piling phase in Ahmedabad Metro Rail Project

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Abstract: ***In India current scenario in construction industry shows old conventional construction methods and less use advance management system. Modern management method based construction system is more effectively beneficial and productive as compare to traditional construction system by focusing on detailed reasons for getting late in time, over in budget and poor thinking for safety, health & wealth awareness of resources in construction project in India. In this study, research is based on lean production principle by applying in piling activities of Ahmedabad Metro Rail Project, mention reasons and recommend solution after data collection and analysis. From this study, easily differentiate traditional construction method and advance management system in construction industry. Limitation of this study is think practically not ideally, can't innovate but recommendation for better management. Implication of lean construction is underestimated this hard work by higher authorities of construction project and have to stop this work after giving recommendation due limitation of being a student.***

Keywords: Lean Construction Case study, Lean concept in Construction

I. RESEARCH OBJECTIVE/AIM

To conduct research to access significance of lean production principle in construction project to minimize various types of waste(s) and then by increase efficiency of timely completion of project with effective utilization of resources with incorporating proper health and safety of workers.

1 The following objectives are need to be achieved to fulfil above mention aim for research.
2 Examine case study, to check the effects of lean principle on productivity of any construction project.

To identify VAT, NVAT and Waste in Ahmedabad Metro Rail project and set recommendation for effective execution of project.

II. INTRODUCTION OF CONSTRUCTION PROJECT

Ahmedabad metro rail project phase-1 is the project of MEGA (Metro Express Link between Gandhinagar and Ahmedabad) projects. This project having 2 routes for connecting north end to south end and east end to west end.

North end to south end named as south-north corridor which is from APMC market (south end) to Motera stadium (north end) and east end to west end named as east-west corridor which is from Vastral gam (east end) to Thaltej gam (west end).

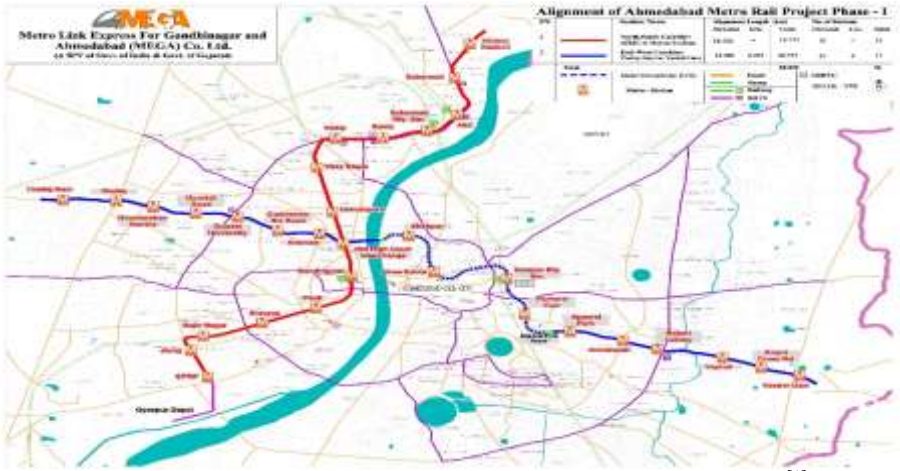

Figure 1:-Alignment of Ahmedabad Metro Rail Project Phase – 1 [1]

Having two route of the total project,

Route-1 East-West corridor from Thaltej Gam to Vastral Gam, having 20.737 km total length which include 14.402 km length of via-duct and 6.335 km length of underground and 17 numbers of station which include 13 elevated and 4 underground.

Route-2 North-South corridor from APMC to Motera Stadium, having 18.522 km length of via-duct and 15 numbers of elevated station.

Having a 4 phase in construction of bridge in Ahmedabad metro rail projects, which are given below:

1 Construction of pile
2 Construction of pile cap to pier cap
3 Segment casting
4 Erection of segment

Author has applied Lean production principle in 1st and 3rd phase of construction of pile segment casting at casting yard at north end of south-north corridor.

Construction of pile

There are main 3 secondary cycle are used to complete one pilling preliminary cycle for construction of pile which are name by removing of soil, ready mix concrete and polymer adding-removing.

In this pilling preliminary cycle having activities are

1 Pointing and levelling: - In this activity engineer and surveyor make a mark for boring of pile and checked by consultant then approved for boring is given to engineer.
2 Auguring: - Auguring is done for fixing mud pump, mud pump bin and casing
3 Boring: - Boring will be start after removing augur and fixing soil bucket for getting require depth as per requirement.
4 Depth checking: - Chainage method used for depth checking after boring completed and also cross checked with boring machine's depth meter.
5 Reinforcement cage installation: - Reinforcement cage has been made at casting yard and shifted to site in three pieces a per drawing description. Welder is taking time for welding joints of two reinforcement cage and hook at third cage.
6 Fixing trimie pipe: - Fixing trimie pipe up to full depth and attach hopper at top for easily place in concreting.
7 Concreting: - Transit mixer comes to site from concrete RMC plant at casting yard and starting concreting directing without any pump or boom placer.
8 Removal of trimie pipe, casing and pump: - Once pacing of concrete starts, removing of trimie pipe begin simultaneously, and then removal of pump, bin and casing after completion of concreting.

Limitations of Case Study

Applying lean production principle in any one product base.

Major parameter is time, so application of lean production principle should be focused on time

Limited only for particular site only

Construction method, plan, requirement and resource neither be change nor recommended for change.

Consideration in Construction Project

10 seconds of error should be possible/acceptable/negligible.

Pilling activity having production cycle less than 1-day, so readings is taken as it starts point at zero and span of taking readings in multiple 10 seconds format.

Taking a limited area activity or say single cycle has been taken, rest are considered as ideal or 100% productive

Consultant permission is either approved or rework, no extra comment or reason should be given.

Preliminary or production cycle ended as if maintenance or machine breakdown occurs while taking reading of production cycle.

III. RESEARCH METHODOLOGY

Method for data collection

Author have to take out full and constant readings, without breakage in any major/effective cycle through observation from construction project. If it's not possible to take readings through observation due to certain limits like being student/intern/trainee unable to stay on site at particular time, stay connected with authorized person at site and take out all activity readings.

Method for data analysis

Find Customer requirement: Study in detail what exactly customer/client needs, should be describe in all parameters like quality, time, quantity, condition, material, formats, methods and techniques.

Divide time in N-VAT & VAT & Waste: Convert all process/activity cycle time in to non-value added time, value added time and waste for every resources, machine power and man power.

Make value stream mapping, cardiogram and bar chart: Make a diagram of value stream mapping, cardiogram and bar chart for all process and add time and cost in this diagram.

Remove excess activities: Remove excess activities which doesn't affect client/customer's requirement.

Conclusion

Recommendation

IV. DATA COLLECTION

Piling Data 1

Table 1: - Pile Data-01

Act	Description	Start (S)	End (S)	Dur. (S)
A1	Point & level	0	4200	4200
	NVAT1	0	3330	3330
	Marking	3330	4200	870
A2	Auguring	4200	10020	5820
	WW1	4200	6060	1860
	Hook fixing of Mait	6060	6240	180
	NVAT2	6240	6720	480
	Positioning Mait	6720	7380	660
	Auguring	7380	8340	960
	Casing	8340	10020	1680
A3	Boring	10020	38280	28260
	DW1	10020	14400	4380
	NVAT3	14400	18000	3600
	IW4	18000	23070	5070
	Boring	23070	33080	10010
	DW1 WW3 WW4 WW5 WW9 IW1	33080	38280	5200
A4	Depth checking	38280	39720	1440
	WW6 OPG1	38280	39370	1090
	Depth checking	39370	39720	350
A5	Inserting reinforcement cage	39720	49260	9540
	Dinner	39720	42840	3120
	MW1	42840	43560	720
	Inserting 1st cage	43560	43860	300
	Lifting 2nd	43860	44160	300
	DW2	44160	44530	370
	NVAT4	44530	45060	530
	Two welder	45060	45900	840
	IW2 WW7	45900	46200	300
	Inserting 2nd cage	46200	46260	60
	lifting 3rd cage	46260	46620	360
	DW2	46620	46920	300
	NVAT4	46920	47520	600
	Two welder	47520	48480	960
	Inserting 3rd cage	48480	48600	120
	Tie hook	48600	48790	190
	WW9	48790	48960	170
	Welding for hook	48960	49080	120
	Fixing cage	49080	49260	180
A6	Installing trimie pipe	49260	54540	5280
	WW10	49260	49680	420
	Trimie pipe 1	49680	49860	180

	Trimie pipe 2	49860	50280	420
	Trimie pipe 3	50280	50520	240
	Trimie pipe 4	50520	50820	300
	Trimie pipe 5	50820	51120	300
	Trimie pipe 6	51120	51300	180
	Trimie pipe 7	51300	51660	360
	Trimie pipe 8	51660	51960	300
	Trimie pipe 9	51960	52260	300
	Trimie pipe 10	52260	52560	300
	Trimie pipe 11	52560	53040	480
	Trimie pipe 12	53040	53400	360
	Trimie pipe 13	53400	53940	540
	Trimie pipe 14	53940	54480	540
	Removal hook	54480	54540	60
A7	Concreting & Removing Trimie pipes	54540	65880	11340
	Auguring & Fixing bin	54540	55500	960
	WW12	55500	55920	420
	Fixing mud pump	55920	56280	360
	WW13	56280	56700	420
	Transit mixer 1	56700	57420	720
	WW13	57420	58020	600
	Transit mixer 2	58020	58860	840
	Hopper	58860	59340	480
	Trimie pipe 1	59340	59520	180
	Trimie pipe 2	59520	59700	180
	Trimie pipe 3	59700	59760	60
	Trimie pipe 4	59760	59820	60
	Hopper	59820	60060	240
	WW13	60060	60300	240
	Transit mixer 3	60300	61140	840
	Hopper	61140	61440	300
	Trimie pipe 5	61440	61560	120
	Trimie pipe 6	61560	61740	180
	Trimie pipe 7	61740	61980	240
	Hopper	61980	62220	240
	Transit mixer 4	62220	63180	960
	Hopper	63180	63300	120
	Trimie pipe 8	63300	63480	180
	Trimie pipe 9	63480	63600	120
	Trimie pipe 10	63600	63720	120
	Hopper	63720	63840	120
	WW13	63840	63960	120
	Transit mixer 5	63960	64380	420

	WW13	64380	64980	600
	Transit mixer 6	64980	65100	120
	Hopper	65100	65400	300
	Trimie pipe 11	65400	65580	180
	Trimie pipe 12	65580	65700	120
	Trimie pipe 13	65700	65760	60
	Trimie pipe 14	65760	65880	120
A8	Removal & cleaning	65880	66660	780
	WW11	65880	66420	540
	Casing	66420	66660	240

Piling Data 2

Table 2: - Pile Data-02

Act	Description	From (S)	To (S)	Dur. (S)
A1	Point & level	0	1800	1800
	Marking	0	1800	1800
A2	Auguring	1800	12200	10400
	NVAT3	1800	5400	3600
	WW9	5400	7800	2400
	WW2	7800	8820	1020
	Auguring	8820	9900	1080
	Casing	9900	11720	1820
	WW9	11720	11780	60
	Bucket Fixing	11780	12200	420
A3	Boring	12200	35720	23520
	Boring	12200	26570	14370
	IW3 WW3 WW9 WW8	26570	34510	7940
	Bucket Removing/changing	34510	35720	1210
A4	Depth checking	0	0	0
A5	Inserting reinforcement cage	35720	43800	8080
	MW1	35720	36120	400
	Inserting 1st cage	36120	36600	480
	Lifting 2nd	36600	36720	120
	DW2	36720	37960	1240
	NVAT4	37960	40200	2240
	Inserting 2nd cage	40200	40380	180
	Setting 3rd cage	40380	40500	120
	Welding	40500	42900	2400
	Inserting 3rd cage	42900	42910	10
	Welding for hook	42910	43780	870
	Fixing cage	43780	43800	20
A6	Installing trimie pipe	43800	48100	4300
	WW10	43800	44200	400

	Trimie pipe 1	44200	44346	146
	Trimie pipe 2	44346	44670	324
	Trimie pipe 3	44670	44887	217
	Trimie pipe 4	44887	45234	347
	Trimie pipe 5	45234	45484	250
	Trimie pipe 6	45484	45732	248
	Trimie pipe 7	45732	45898	166
	Trimie pipe 8	45898	46247	349
	Trimie pipe 9	46247	46590	343
	Trimie pipe 10	46590	46868	278
	Trimie pipe 11	46868	47173	305
	Trimie pipe 12	47173	47394	221
	Trimie pipe 13	47394	47557	163
	Trimie pipe 14	47557	47820	263
	Chute	47820	48100	280
A7	Concreting & Removing Trimie Pipe	48100	56930	8830
	WW13	48100	48210	110
	Transit mixer 1	48210	49490	1280
	WW13	49490	49590	100
	Transit mixer 2	49590	50650	1060
	WW13	50650	50750	100
	Transit mixer 3	50750	51710	960
	WW11	51710	51790	80
	Hopper	51790	52010	220
	WW11	52010	52090	80
	Trimie pipe 1	52090	52260	170
	Trimie pipe 2	52260	52370	110
	Trimie pipe 3	52370	52470	100
	Trimie pipe 4	52470	52640	170
	Trimie pipe 5	52640	52780	140
	Trimie pipe 6	52780	52910	130
	WW11	52910	52930	20
	Hopper	52930	53020	90
	WW13	53020	53070	50
	Transit mixer 4	53070	54090	1020
	Hopper	54090	54200	110
	WW11	54200	54210	10
	Trimie pipe 7	54210	54340	130
	Trimie pipe 8	54340	54510	170
	Trimie pipe 9	54510	54660	150

	Trimie pipe 10	54660	54800	140
	WW11	54800	54820	20
	Hopper	54820	54930	110
	WW13	54930	55180	250
	Transit mixer 5	55180	56110	930
	WW11	56110	56170	60
	Hopper	56170	56270	100
	WW11	56270	56280	10
	Trimie pipe 11	56280	56480	200
	Trimie pipe 12	56480	56650	170
	Trimie pipe 13	56650	56840	190
	Trimie pipe 14	56840	56930	90
A8	Removal & cleaning	56930	57400	470
	Mud pump	56930	57260	330
	Casing	57260	57400	140

Waste Reasons

Table 3: - Waste Reasons

Waste Type	Waste Code	Waste Reason
Defective Waste	DW1	Polymer not properly mixed which unable to use
	DW2	Facing some issues in welding machine
Inventory Waste	IW1	Bucket hook was not working properly
	IW2	Take away welding machine to get started the work
	IW3	No space for excavated soil
	IW4	Trimie pipe sucks at other site and stops the current site boring activity
Moving Waste	MW1	Reinforcement cage is placed far from Mait machine
NVAT	NVAT1	Surveyor getting disturbed and unable to mark due to uneven ground, that's why labor is levelling the soil as per requirement
	NVAT2	Waiting for client and its approval
	NVAT4	One welding machine is working but second is facing some issues
	NVAT3	Lunch or Dinner
Over Processing	OPG1	Measuring Depth more than one time
Waiting Waste	WW1	Bull dozer is setting the plate for boring machine
	WW3	Operator having a phone call and hold the work
	WW4	Fuel intake
	WW5	Talking to engineer for estimated time
	WW6	Waiting for bringing chain by labor
	WW7	Waiting for operator
	WW10	Preparing trimie pipe to use
	WW11	Unable to open trimie pipe or hopper
	WW12	Waiting for mud pump arrival
	WW13	Setting up transit mixer
	WW9	Doing nothing
	WW8	Shift change
	WW2	Positioning Mait

V. DATA ANALYSIS

Piling Data-01

Bar Chart of Pile Data-01

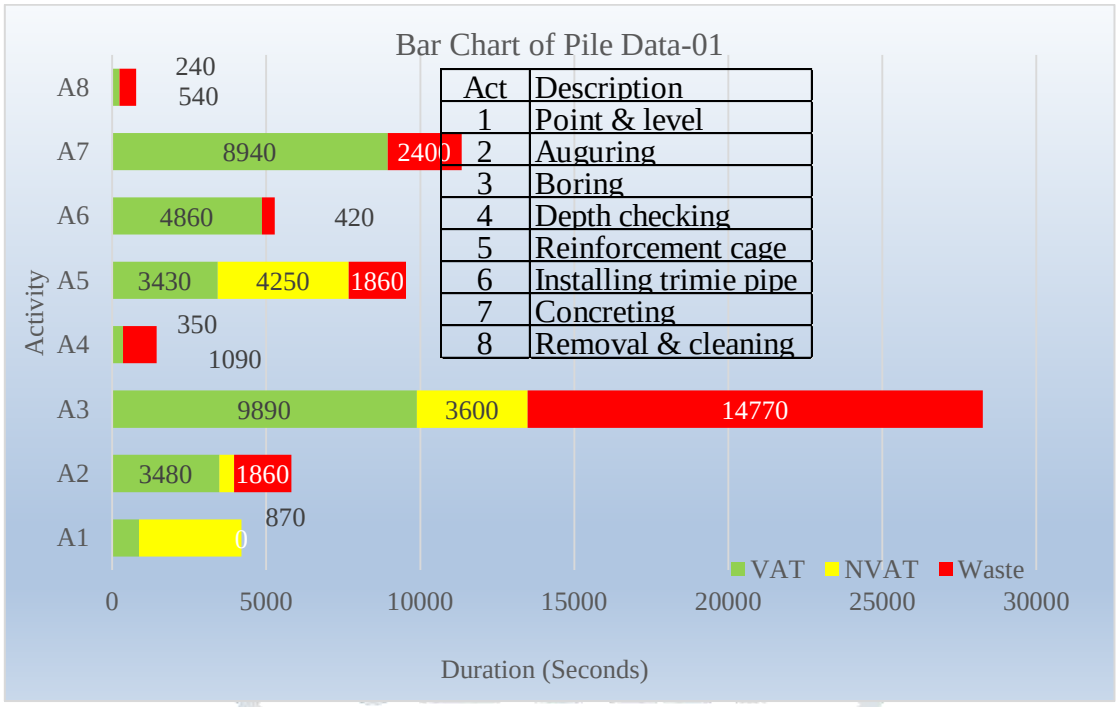

Figure 2: - Bar chart of Pile Data-01

VSM of Pile Data-01

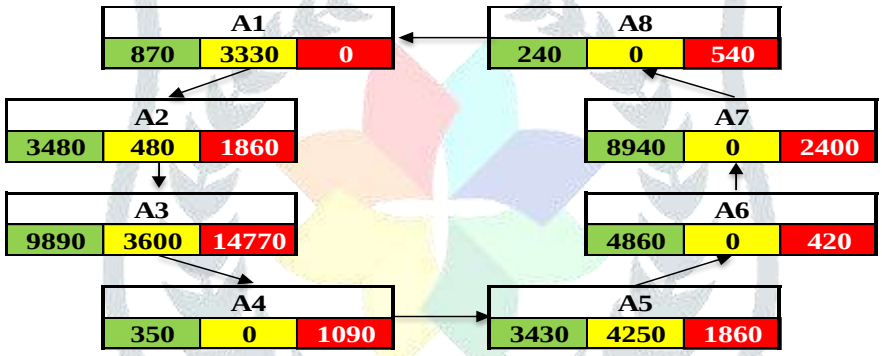

Figure 3: - VSM of Pile Data-01

Cardiogram of Pile Data-01

Figure 4: - Cardiogram of Pile Data-01

Analysis of Pile Data-01

Table 4: - Analysis of Pile Data-01

	Activity Time (s)				Activity Time (%)			
Act.	VAT	NVAT	Waste	Total	VAT	NVAT	Waste	Total
A1	870	3330	0	4200	1.31%	5.00%	0.00%	6.30%
A2	3480	480	1860	5820	5.22%	0.72%	2.79%	8.73%
A3	9890	3600	14770	28260	14.84%	5.40%	22.16%	42.39%
A4	350	0	1090	1440	0.53%	0.00%	1.64%	2.16%
A5	3430	4250	1860	9540	5.15%	6.38%	2.79%	14.31%
A6	4860	0	420	5280	7.29%	0.00%	0.63%	7.92%
A7	8940	0	2400	11340	13.41%	0.00%	3.60%	17.01%
A8	240	0	540	780	0.36%	0.00%	0.81%	1.17%
Total	32060	11660	22940	66660	48.09%	17.49%	34.41%	100%

As shown in above table highest waste occurs in construction of pile is boring activity (A3) 22.16% (14770s), which include waiting waste, inventory waste and defective waste. Major of these three waste, inventory waste consumes highest wastage because at that time trimie pipe sucks at other place and consultant having requirement that concreting have to finished within 6 hours after completing boring, so have to stop the boring activity which cause inventory waste.

Beside this other major waste in boring activity is waiting waste causes by fuel intake, operator attaining the phone while performing activity; operator is talking with engineer; taking of inappropriate break by machine operator during activity with no reason. And third major waste in boring activity is defective waste which caused due to inadequate properties using of polymer as per standard.

Second highest waste consuming activity in construction of pile is inserting reinforcement cage (A5), having 2.79% (1860s), which include moving waste and inventory waste. Moving waste is cause due to reinforcement cage was unloaded so far from require place, which consume more time to move at require place; inventory waste happens as welding machine was not placed correctly after its completing of work which indirectly create blockage in further process. Insertion of reinforcement cage also consists of 6.38% (4250s) non-value added time, which happens due to one workable machine out of two which consume extra time compare to estimated.

Third major waste consuming activity in construction of pile is concreting of pile (A7), having 3.60% (2400s) of waiting waste due to more time consumption in transit mixer setup and non-availability of mud pump on time.

Piling Data-02

Bar Chart of Pile Data-02

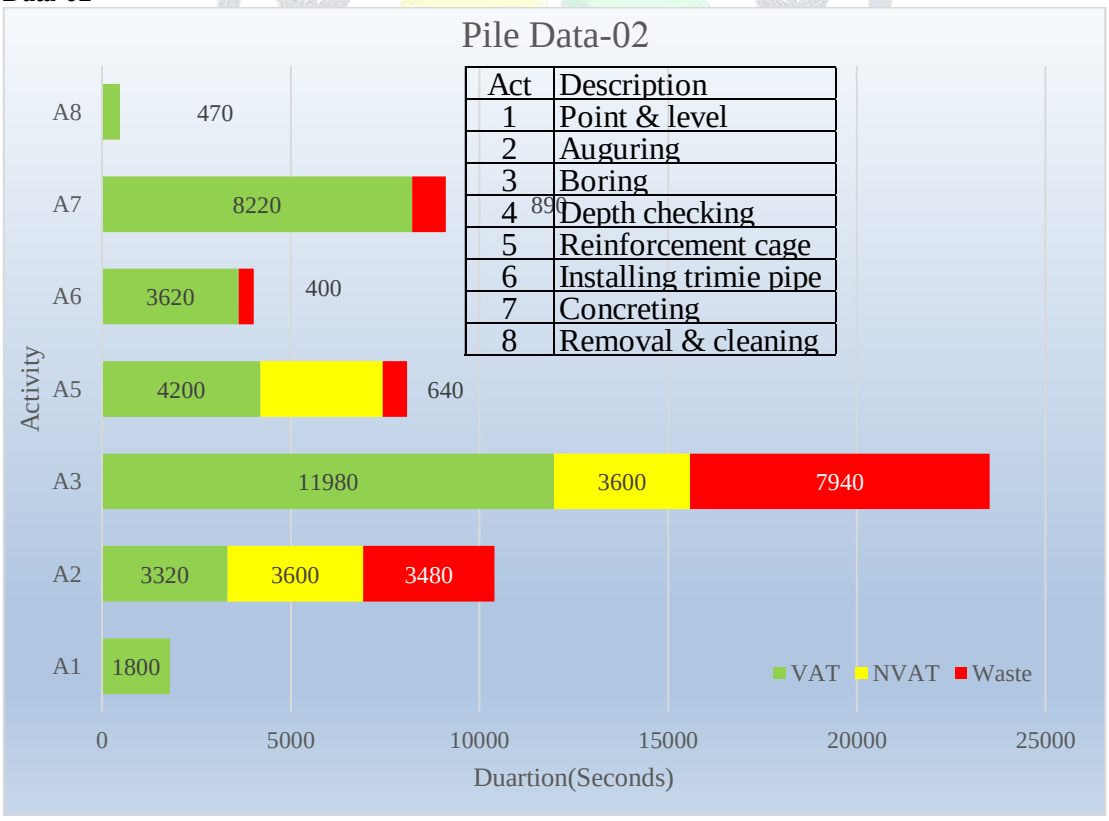

Figure 5: - Bar Chart of Pile data-02

VSM of Pile Data-02

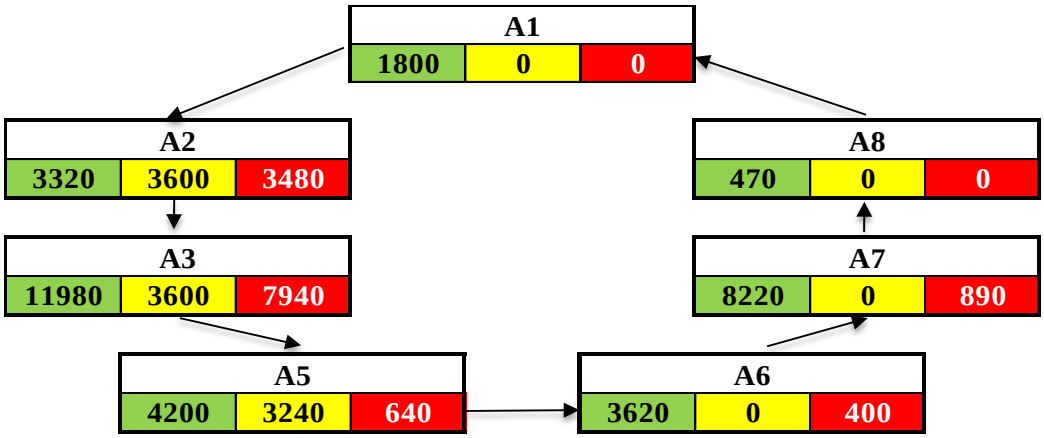

Figure 6: - VSM of Pile Data-02

Cardiogram of Pile Data-02

Figure 7: - Cardiogram of Pile Data-02

Analysis of Pile Data-02

Table 5: - Analysis of Pile Data-02

	Activity Time (s)				Activity Time (%)			
Act.	VAT	NVAT	Waste	Total	VAT	NVAT	Waste	Total
A1	1800	0	0	1800	3.14%	0.00%	0.00%	3.14%
A2	3320	3600	3480	10400	5.78%	6.27%	6.06%	18.12%
A3	11980	3600	7940	23520	20.87%	6.27%	13.83%	40.98%
A5	4200	3240	640	8080	7.32%	5.64%	1.11%	14.08%
A6	3620	0	400	4020	6.31%	0.00%	0.70%	7.00%
A7	8220	0	890	9110	14.32%	0.00%	1.55%	15.87%
A8	470	0	0	470	0.82%	0.00%	0.00%	0.82%
Total	33610	10440	13350	57400	58.55%	18.19%	23.26%	100%

As shown in above table highest waste consuming activity in construction of pile is boring activity (A3) which consumes 13.82% (7980s) waste in which main reason is waiting waste due to waiting for a machine operator during shift change. Along with this other reason for waiting waste are insufficient time for polymer filling and shifting excavated soil due to speedy of boring of pile; waste of time by operator for attaining the phone while performing activity; taking inappropriate break by machine operator during activity with no reason and many more, and it also consists 6.27% (3600s) non-value added time due to lunch/dinner.

Second highest waste consuming activity is auguring (A2), having 6.06% (3480s) of waiting waste as worker taking inappropriate break during activity with no reason and it also consists 6.27% (3600s) non-value added time due to lunch/dinner.

Third major waste consuming activity is inserting reinforcement cage (A5), having 1.11% (640s) of inventory waste like facing some unexpected issue in both welding machine and also consists 5.64% (3240s) non-value added time due to one workable machine out of two which consume extra time compare to estimated.

Comparison between Piling Data-01 & Piling Data-02

Analysis of both pile data shows that,

Productive time 32540s & 33610s simultaneously, which is almost same to each other, still productive % having 48.81% & 58.55% of total construction time, this difference shows that total time of pile construction increase as waste increases.

Pile construction consists of 20-30% Waste and 15-20% non-value added time, which ultimately increases the overall completion time of single pile.

Boring activity is highest waste consuming activity in both construction of pile is; 22.16% (14770s) & 13.83% (7940s) simultaneously.

Inserting reinforcement cage activity having non-value added time; 6.38% (4250s) & 5.64% (3240s) simultaneously.

VI. CONCLUSION

The highest problem of not staying advance which causes waiting waste. Second highest waste is defective waste which include polymer is not ready to use, machine getting some issue and etc.

Many other wastes are there like; moving waste, inventory waste and non-value added time.

VII. RECOMMENDATION

Stop waiting waste by employing skilled operator/driver for not to stop boring and set up transit mixer in minimum time.

Pilling is cast in situ site where all machinery, materials and man power have to work at site and move accordingly to the site change, that's why need very advance in planning of their requirement on site otherwise it stops the work.

Stay updated with machinery and resources that decreases defective waste and inventory waste. Proper planning of space and material decreases moving waste.

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