

KING FAHAD UNIVERSITY OF PETROLEUM & MINERALS
CONSTRUCTION ENGINEERING AND MANAGEMENT

CONSTRUCTION PRODUCTIVITY
CEM - 513

PRODUCTIVITY STUDY ON
A SELECTED CONSTRUCTION SITE

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MAY 2007

I. INTRODUCTION

Productivity is considered as one of the key factor in the construction industry. On other words, the more efficient productivity, the more success of the project in both time and money. Construction productivity performance improvement is one of the major issues that all parties enrolled in this industry aspire to accomplish.

In order to achieve our study goals, about some techniques for studying the construction productivity and suggesting the improvement, we selected the new main center of Arab national Bank which is located on Al-Khobar.

The project is owned by group of investors. Zuhair Faiz Parteners handles the design and the project management .The main contractor is Alhashmiah Co (HATCO). The initial budget for the total project cost is SR 100,000,000.

The bank consists of the following buildings:

1) Car parking building:

a. Three floors building

2) Main center Arab National bank:

a. Administration Building.

b. Mosque

c. Male section

d. Female section

II. OVERVIEW

This paper is written by group number consisting of three students, Mohammed Al-Barout (ID 968067), Abdulrahman Al-Ghamdi (ID 000000) and Nasser Al-Hatilah (ID 981326).

We selected a project with many repetitive activities in order to conduct the productivity studies most efficiently. The project consists of an car parking and administration building os Arab National Bank in Al-Khobar (Eastern Province), Saudi Arabia at King Abdulaziz Road. It will be the main center bank of Arab national bank in eastern province. The average total built up area of approximately **70,000 sqm**.

III. METHDOLOGY

The approach for our study is based on the techniques and knowledge learned through the course. The sequences of this study are as follows:

- Identification and selection of the operation through looking at the whole project in order to consider those available major repetitive jobs by choosing task with less constraints and limitations for improvement.
- Applying work sampling techniques using tour approach by selecting random time and route for observations, to determine the relative portion of the time spend on activities associated with the performance of the task for three categories: effective, essential contributory and ineffective work.
- Performing Five-minuet rating technique for chosen repetitive activities (plaster work), and support it by a video film, in order to recommend for productivity improvements
- Crew Balance Chart (CBC) for repetitive construction operation is applied on, for recommending improvement.
- Studying the existing operation method of material flow.
- Focusing on the safety aspects by the help of the check-lists, and safety officer input, to assess the adherence of HATCO to the safety requirements and suggest improvement in order to reduce the accidents on the entire site.

IV. WORK SAMPLING TECHNIQUE

Work sampling involves observing and classifying a small percentage of some whole to get a representation of that whole and to statistically determine how the different types of craftsmen's time have been utilized for the entire job site.

The overall project productivity is to be measured by three classifications:

1. Effective Work:

Activities directly involved in the actual process of putting together or adding to a unit being constructed, such as placing bricks, scaffolding, fabricating and plastering.

2. Essential Contributory work:

Work not directly Adding to put essential to finishing the unit, such as: handling material at work station, receiving instructions or reading planes.

3. Non-effective:

Not useful or idle.

All the required data were collected on May 10, 2007.

The following rules have been taken into consideration during the observation to assure random sampling:

1. Sample size: minimum number of observations to be selected should not be less than 384 observations. This will reflect a confidence level of 95% limit of error of +_5%. This condition is adopted to provide a reasonable indication of the overall effectiveness of the result by taking 403 observations.
2. Every craftsman should have the same probability of being observed at any time.
3. Observations must have no sequential relationship. This condition was fulfilled by selecting random observation intervals using random tables which prepared before collecting data with ignoring the break times. Likewise floors have been selected in advance on a random basis with equal percentage of probability every time.
4. The basic character of the work situation must remain the same.

The observer made 80-90 percent of the evaluation using tour approach before the workers are aware of his presence to avoid workers modify their behavior or react adversely to the presence of the observer.

PRODUCTIVITY RATING FOR SEVERAL CONSTRUCTION TRADES

Craft	Effective	Contributory	Ineffective
Carpenter	54	24	20
Helper	61	55	43
Steel fixer	60	19	17
Masonry	11	1	9
Equipment Operator	6	0	2
Fabricator	10	2	5
Electrician	0	0	2
Total	204	101	98

Data Analysis:

Number of sampling rounds	4
Total number of observations	403
Number of observations classified as effective	204
Number of observations classified as essential contributory	101
Number of observations classified as ineffective	98

Effective work = $201/403 = 49.87\%$

Essential contributory = $101/403 = 25.06\%$

Ineffective work = $98/403 = 24.32\%$

$b = x/n = 0.4987$

Limit of error for effective work (95% confidence)

$$b - 1.96\sqrt{\frac{b(1-b)}{n}} \leq P \leq b + 1.96\sqrt{\frac{b(1-b)}{n}}$$

$$0.449883 \leq P \leq 0.547517$$

P: Population portion

x: Number of observations classified as effective

n: total number of observations

b: productivity in effective work

The results indicate that it can be assumed in every 95 samples out of 100; the craftsmen spend 45% to 54.7% of their time in effective work.

No.	Effective	Contributory	Infective	No.	Effective	Contributory	Infective	No.	Effective	Contributory	Infective
1	S			56			OP	111	H		
2			H	57			SC	112	H		
3		H		58	SC			113		H	
4	SC			59	SC			114			H
5		H		60			SC	115	SC		
6			H	61		SC		116	SC		
7	S			62	SC			117	SC		
8	S			63	SC			118	SC		
9	H			64			SC	119	H		
10		S		65			SC	120	H		
11			S	66	S			121	H		
12		S		67			S	122		H	
13	S			68		S		123		H	
14	S			69			F	124		SC	
15	H			70			F	125	OP		
16	H			71	F			126	H		
17		H		72		S		127	H		
18		S		73	S			128		H	
19	M			74	S			129		H	
20		M		75	S			130			H
21			M	76	F			131		H	
22			M	77	H			132		H	
23			S	78	H			133			SC
24			H	79		H		134			SC
25		H		80		H		135			H
26	H			81			H	136			M
27	S			82		H		137			M
28		S		83			H	138		SC	
29	S			84			H	139	OP		
30	S			85		H		140			SC
31	H			86			S	141			S
32		H		87	SC			142	SC		
33			H	88	SC			143	SC		
34			S	89		SC		144	H		
35		H		90		H		145	S		
36	S			91			OP	146	H		
37			H	92			H	147	S		
38		H		93	S			148	S		
39	H			94		S		149	S		
40	S			95	S			150			S
41	S			96	S			151			H
42		S		97	S			152		H	
43			S	98	F			153	H		
44	SC			99	F			154	SC		
45	SC			100	S			155		SC	
46	H			101		S		156		SC	
47			H	102		H		157		H	
48	SC			103			S	158		H	
49	SC			104		H		159	H		
50		S		105	S			160	H		
51		SC		106	S			161	H		
52	M			107	H			162	SC		
53			M	108	OP			163	S		
54	M			109		SC		164			SC
55			M	110	SC			165			H

166	SC			221		H		276	SC		
167	SC			222			H	277	SC		
168		SC		223		H		278		SC	
169			SC	224		H		279	H		
170	H			225	S			280		H	
171	H			226	S			281			H
172	SC			227	S			282	SC		
173		SC		228	S			283			H
174		SC		229	H			284	S		
175	H			230		H		285	S		
176			H	231	S			286			S
177			H	232		S		287		H	
178		H		233			H	288	SC		
179	SC			234			H	289		SC	
180	SC			235		H		290	SC		
181	SC			236	H			291	H		
182	H			237	S			292			H
183	F			238	S			293	H		
184	SC			239		S		294		SC	
185		SC		240			F	295	H		
186	S			241			F	296		H	
187	S			242	F			297		H	
188	SC			243		F		298			SC
189		SC		244	F			299			H
190		SC		245	S			300			H
191		H		246	M			301	H		
192	M			247	M			302	H		
193			M	248			H	303	SC		
194			M	249		H		304	SC		
195	F			250		H		305			EL
196		F		251		S		306	S		
197	F			252	S			307	S		
198			F	253	S			308			H
199	H			254	SC			309			SC
200	H			255		H		310		SC	
201	M			256			H	311	S		
202	M			257	SC			312	H		
203	S			258	SC	H		313	H		
204	S			259	S			314		S	
205	S			260	OP			315		S	
206			S	261		H		316	SC		
207			S	262	H			317	H		
208	H			263			SC	318		H	
209			H	264			SC	319		H	
210	M			265			H	320		H	
211			M	266	H			321		H	
212	H			267	H			322	F		
213	S			268	S			323	F		
214		S		269		S		324		S	
215	SC			270		H		325	S		
216	SC			271	S			326	S		
217		H		272	H			327	H		
218			H	273			S	328			EL
219		H		274			H	329			SC
220		H		275			H	330		SC	

No.	Effective	Contributory	Infective	No.	Effective	Contributory	Infective	No.			
331		SC		386	H			441	SC: Scaffolder; EL: Electrical; F: Steel Fabricator; Steel Fixer; Masonry H: Helper; OP: Operator; S: M:		
332			H	387	H			442			
333	SC			388			H	443			
334	H			389	SC			444			
335	SC			390	H			445			
336		H		391			SC	446			
337		H		392	S			447			
338	OP			393			S	448			
339			SC	394	S			449			
340	S			395		H		450			
341	H			396	H			451			
342		S		397		H		452			
343	S			398		SC		453			
344			S	399	SC			454			
345			S	400	SC			455			
346	SC			401			SC	456			
347	SC			402			H	457			
348	H			403			H	458			
349	H			404				459			
350			H	405				460			
351	H			406				461			
352			H	407				462			
353			SC	408				463			
354	OP			409				464			
355		S		410				465			
356		SC		411				466			
357	SC			412				467			
358	H			413				468			
359	H			414				469			
360	SC			415				470			
361		SC		416				471			
362			H	417				472			
363	S			418				473			
364			H	419				474			
365	S			420				475			
366			S	421				476			
367	S			422				477			
368	H			423				478			
369		H		424				479			
370	M			425				480			
371	M			426				481			
372	H			427				482			
373		H		428				483			
374			H	429				484			
375	SC			430				485			
376	SC			431				486			
377		SC		432				487			
378	H			433				488			
379			SC	434				489			
380	SC			435				490			
381	SC			436				491			
382			SC	437				492			

383			H	438				493			
384	H			439				494			
385		H		440				495			

V. FIVE MINUTES RATING TECHNIQUE

The 5- minute rating technique is a quick and less accurate assessment of activity than is that of the productivity rating method discussed above. However, it is an effective method for making a general evaluation. The purpose of conducting such a technique is to provide a sign to the management about any delay could happen due to the low indication of the crew productivity.

The rule for this technique is to create the observation equal to the number of the selected crew size or more, but not less than 5 minutes. Our selected observed crew consists of five workers performing installing beam activity. The observation has been recorded on a video film for approximately 19 minutes continuously. The results are extracted by viewing the film and indicating the status of all crew members for every minute.

COLLECTED DATA:

TIME (Start)	Scaffolder 1	Scaffolder 2	Helper 1	Helper 2	Helper 3
10:07	x	x			
:08			x		
:09	x		x	x	
:10	x	x			x
:11			x		x
:12	x	x		x	
:13	x	x	x	x	x
:14	x	x			
:15	x	x			
:16	x	x			
:17	x	x			
:18	x	x			
:19	x	x			
:20	x	x	x		x
:21	x	x			
:22	x	x	x		x
:23	x	x	x		x
:24	x	x	x	x	
:25	x	x			
:26	x	x	x	x	x
TOTAL	17	16	9	5	7

Legend

X : EFFECTIVE WORK

DATA ANALYSIS:

Total Man Unit = 95
Effective = 54
Effectiveness = $54/95 = 57\%$

In our opinion, the main reasons for the ineffective work are:

- 1) The crew may need one more Scaffolder to help them since hot weather and hard work for installation. Therefore, the crew spend some of their effort on doing work which will be considered as ineffective work.
- 2) Portion of the worker time wasted on shifting scaffolding set from an area to another.
- 3) In spite of this activity was performing at hot time, that caused an adverse affect on the workers productivity.

IV- CREW BALANCE CHART (CBC), FLOW DIAGRAM, AND PROCESS CHART

The crew balance chart (CBC) allows the observer to compare interrelationships among the tasks assigned to the various members of the crew and the equipment and to appraise the amount of non productive time of each .By rearranging work assignments among various members of the crew, non effective time can be reduced and productivity increased.

Flow diagram and process chart implement graphical presentation of the selected cyclic operation to aid in improving and developing work. The most obvious savings found by analyzing flow diagrams and process charts generally involve excessive transportation. Rearranging the positions of the operations can often greatly reduce the need for ineffective movement.

Video recording is used to record our selected repeated operation in order to help for detailing the existing cycle. As mentioned before, the selected operation is the erecting scaffolds to support the construction beam This operation will be used in both techniques CBC and FD.

The transportation off the material to the site and the removal of the used material from the ground floor , as well as, is not considered as a part of the selected cycle

Crew Balance Chart

A- Methodology

For the crew balance chart (please see attached) , an observations and the calculations were conducted for Construction/Erection of Formwork. The observation was focussed on this activity since the movement of the group could be properly monitored for they are only in one area.

The Group is composed of 2 Carpenters and 3 Helpers. The 2 Carpenters were on the elevated position to install support/trusses for Formwork while one (1) of the Helpers was on the lower level and the two (2) Helpers were on the Ground. The work of the helpers are to raise/pass Formwork support to the Carpenters Fig 1.

The activity was filmed to get a realistic observations. The observation completed in a period 25 minutes

B- Results

A chart was developed with a bar representing each of the 5 Workers activities for the duration of 25 minutes or equivalent to 125 minutes. It was noticed during the observation that the pace of work is quite slow considering the difficulties of the 2 Carpernters in installing a support causing the 3 helpers who are raising materials for them to become idle. Within the 25 minutes period, the 2 Carpernters are considered productive or effective as they worked 24 minutes or a total of 48 minutes which is equivalent to 96%, whereas the 3 helpers are idle for a combined time of 56 minutes. This means that the helpers are only effective for 23 minutes or 31%.

For the whole Group which is equivalent to 125 minutes required working time, only 71 minutes or 57% is considered effective or productive.

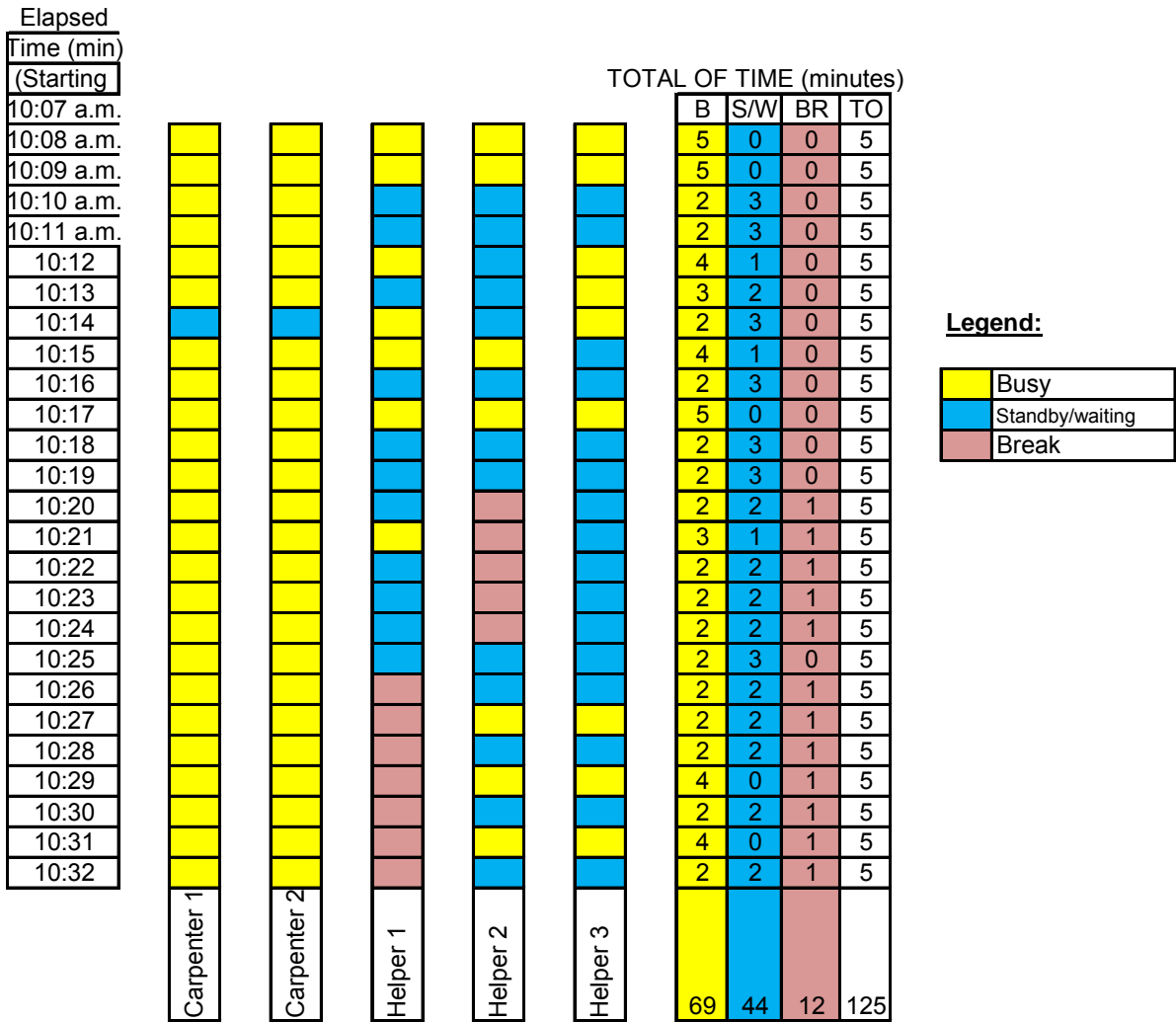
C- Interpretation:

The Crew Balance Chart shows that the activities need to be improved particularly in reducing the working time while output or production is not affected. In view of above findings the following are suggestions:

- Since the Formwork support/truss is not heavy, this could be raised using a handline or rope. This activity can be done by one (1) helper on the Ground, to prepare and tie the support; whereby the two (2) Carpenters can raise the support by pulling the rope Fig 2. This means removing the two helpers can save 50 minutes or from 125 minutes for five (5) workers this will reduce to 75 minutes for the same activity.
- One the Carpenters could be also replaced by a helper, since it was noticed that one of them was only assisting the other while fixing/installing the support. The Carpernter to be replaced by a helper could be utilized in other Carpentry activities.

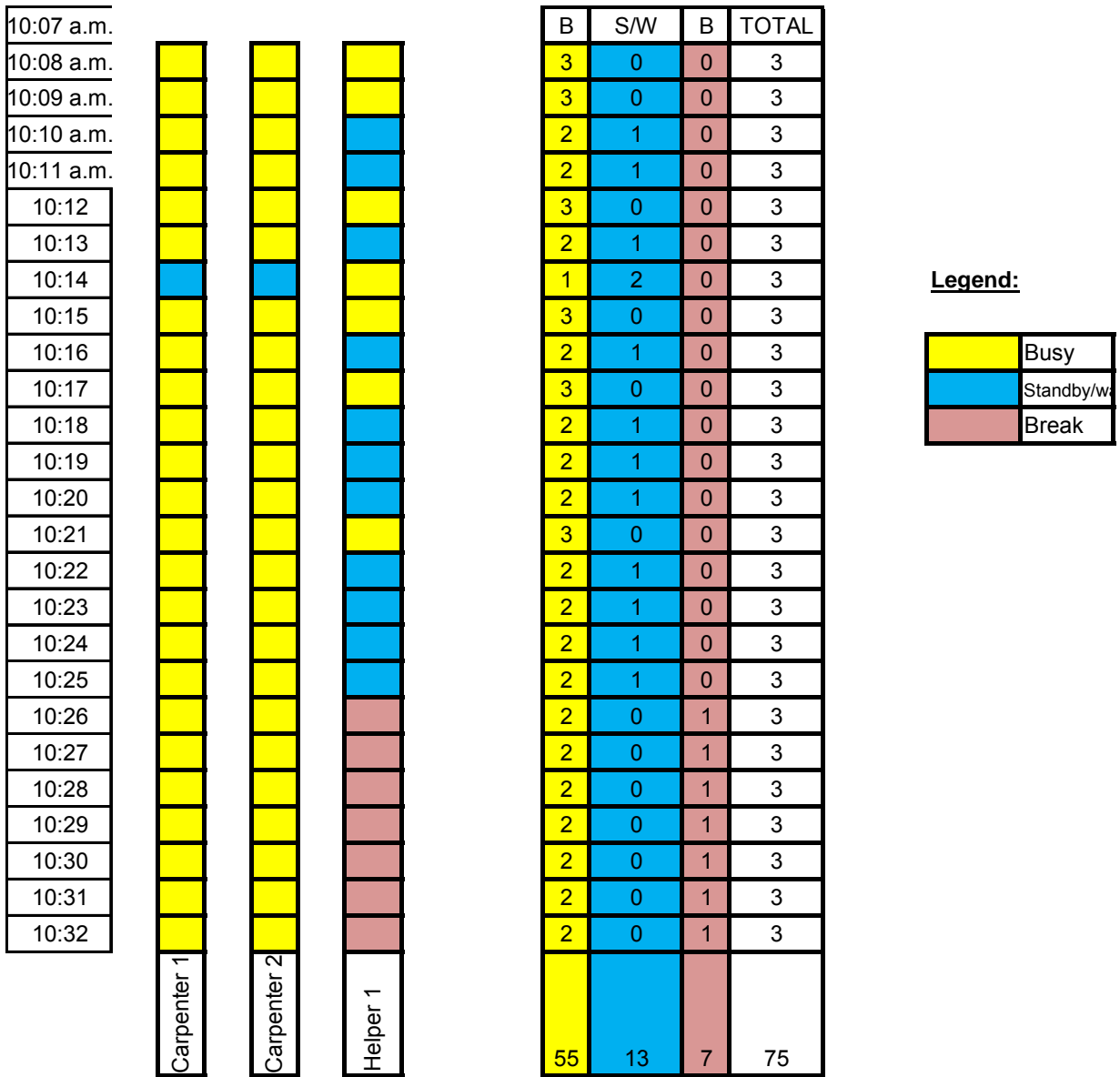
D- Conclusion

By adhering with the above recommendations, for sure we can save working time. The save working time can be utilized to other activities.



Activities: Fig1
Carpenters - Installing/fixing Formworks
Helpers - Passing Formwork Materials to Carpenters/ Assiting Carpenters

Crew Balance Chart for Construction Formwork



Legend:

Busy	Standby/w	Break
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Activities:

Fig2

Carpenters - Installing/fixing Formworks

Helpers - Passing Formwork Materials to Carpernters/ Assiting Carpenters

Crew Balance Chart for Construction Formwork

Flow Process Chart				Man	Material	Equipment	Type		
Chart no. 1		sheet no. 1 of 1		Date:		May-10			
Project:				Activity	Present	Proposed	Saving		
Arab National Bank				Operation	5				
				Transport	5				
Job:				Delay	1				
Errect Scaffolding				Inspection	3				
				Storage	5				
Method: Present / Proposed				Distance	10				
Workers 2				Time					
Observers 3									
Description	Qty.	Distance (m.)	Time (min.)	Symbol				Remarks	
Beam (B), Positioned (P), Worker (W)				○	⇒	□	□	▽	
Beam (B) from stage								▽	
B to Worker (W)	1	2			⇒				
B Positioned				①					
Temp delay						□			
Beam (B)								▽	
B to W	1	2			⇒				
B Positioned				②					
Beam								▽	
B to W	1	2			⇒		1		Inspection
B Positioned				③					
Beam								▽	
Beam to W	1	2			⇒				
B Positioned				④			2		Inspection
Beam								▽	
B to W					⇒				
B Positioned				⑤			3		Quality inspection
				End of Cycle					
Total		10		5	5	1	3	5	

IV. PROJECT SAFETY

Project Safety

As we are all aware, safety precautions on site are quite critical due to their impact on the extra cost in cases of accidents and progress time delay. Plus other impact on the site labor moral and the negative effect of their productivity and job quality in case the safety precautions are not considered in a proper way. On the basis of above a site tour has been conducted and below is a list of comments / precautions that to be taken to enhance site safety precautions to overcome the safety impact on the progress / refer to what have been stated previously.

OBSERVATIONS:

1. Majority of the workers have no head protections (Safety Hat).
2. Almost all of the workers have no Eye Protections (Safety Glasses); some are only wearing ordinary sun glasses.
3. Most of the workers have no hand gloves and some are only wearing cotton gloves which are not acceptable in construction work particularly Steel works.
4. Workers in high noise area have no hearing protection
5. Workmen working @ heights have no fall protection (Guardrail or Fall Arrest system-harness)
6. Two workers exposed to fall hazard; they are standing at the edge of an opening where hoisting of materials is being carried out without fall protection (full body harness)
7. People are passing underneath of workers erecting Formwork/platforms and without head protections.

8. Poor housekeeping will be observed throughout the area whereby materials are scattered posing tripping hazards, fire hazards, etc.
9. No proper barricade below of overhead and lifting activities.
10. No Fire fighting equipment (Fire extinguishers) at the work area.
11. Two (2) workers are sharing in one water bottle (unhygienic).
12. Scaffold/Structures being used to support Formwork/platform are considered sub-standard due to no proper support, braces, ledgers, etc.
13. A worker was climbing on the post of a temporary platform instead of using ladder.
14. Noticed a sub-standard homemade wooden ladder.
15. No tag line to control the load being hoisted by Crane.
16. A bunch of shuttering materials was improperly rigged; they secured the materials by a choker hitch single wrap instead of double wrap; possible materials to fall down.
17. Riggers are giving signal to the Crane Operator at the same time. One rigger shall only give signal to the Crane Operator
18. Rigger are also using oversized sling.
19. A worker was using a material as a hammer.
20. Most the overhead activities have no access ladders.
21. The belt and pulley of the equipment being used to level the fresh concrete has no guard.
22. No shields for welding activity exposing workers from welding arch.
23. No safety signs posted in the work area.

RECOMMENDATIONS:

It seems that the Management is not committed on the safety of his workers, likewise the workers apparently unaware of the safety requirements. The following are safety recommendations based from the above observations:

1. Fall Protection :

- The Management shall establish a program to protect his workers from falling while working @ heights, i.e. guardrail system or fall arrest system.

Some of the things that require fall protection:

- ✓ Unprotected sides & edges
- ✓ Leading edges
- ✓ Holes
- ✓ Hoist areas
- ✓ Form work and reinforcing steels
- ✓ Walkways & ramps
- ✓ Wall openings, etc.

2. Personal Protective Equipment:

- It is very obvious that workers and their management is not so concern on the use of PPE particularly basic PPE. This requires a competent safety man to assess the hazards and implement the use of Personal Protective Equipment with respect to the activities of the workers.

3. Lifting / Rigging activities:

- A competent Rigging Supervisor shall supervise all lifting/rigging activities to ensure proper planning and proper implementation of all safety requirements particularly on the basic rigging requirements, i.e. to determine the weight of the load to ensure proper sizes of lifting/rigging equipment will be used, rigging technique, to ensure all lifting/rigging equipment are in good condition, etc.

4. Housekeeping & Hygiene:

- In general, the housekeeping condition of the work areas is very poor. Since the work area is wide and there are many activities, the Management should provide a housekeeping group, maybe composed of three (3) workers including one leader. Their activities are to arrange materials, remove materials from walkways, provide/install barricades, provide drinking water, ensure trash/garbage are collected to proper container, de-nailed all wood with protruding nails, maintain the cleanliness of toilets, rest areas and tea rooms, etc.

5. Formwork / working platforms erections/ ladders:

- Suggest a qualified person to monitor these activities to ensure that the Formwork/platforms are properly designed, erected, supported, braced and maintained so that it will be capable supporting without failure all vertical and lateral loads.
- Ensure workers @ heights are provided with standard ladders.

6. **Fire Prevention/Protection:**

It is the responsibility of the employer to develop a Fire Protection Program throughout all phases of the construction, and shall provide for the firefighting equipment. The following shall be observed:

- ✓ Designated smoking area should be provided as the work areas are with combustible materials, i.e. wood, etc.
- ✓ Electrical wirings and equipment for light shall be installed in a standard manner.
- ✓ Portable fire extinguisher shall be provided at conspicuously accessible locations.
- ✓ Materials shall be piled to permit convenient access for firefighting.
- ✓ It is also the responsibility of the employer to train his employees on how to use a Fire Extinguisher.

7. Welding/Grinding /Cutting Activities:

- Welding/Grinding/Cutting activities shall be shielded to protect workers from flying sparks, arch rays, etc.
- Workers doing the work shall wear the required special PPE, i.e. Welding mask, cutting goggles, earplug, dust or fume mask, faceshield.

8. Tools & Equipments:

- Guards shall be provided and shall not be removed or modify.
- Power tools should be grounded otherwise protected with Ground Fault circuit Interrupter to prevent electric shock or electrocution.
- An Inspection program should be developed to ensure that tools & equipment are regularly inspected.

9. Safety Signs/barricades:

- Safety Signs are excellent materials to remind employees and shall be installed at the strategic areas.
- All overhead activities particularly rigging/lifting activities shall be roped-off to prevent workers from passing underneath.

10. Management to consider providing a Competent Safety Officer to develop and implement Safety Programs. The Management shall be committed and shall support his Safety Officer 100% to ensure effectiveness of the Safety Program.