TIME AND CONSTRUCTION STUDY
ON THE
DIMONDALE HIGHWAY BRIDGE

THESIS FOR DEGREE OF B. S.

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1932

Bridges

Title Dimondale highway
bridge

Time and Construction Study
on the
Dimondale Highway Bridge

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By

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THESIS

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I

OBJECT

There has been a great deal written on time study, job analysis, and scientific management as they apply to industrial operations, but it seems that construction work has been slighted, particularly in reference to the time and motion study field. It is true that these principles are more easily applied to standard operations in a manufacturing plant, and will hold good over a number of years. However there are many jobs that are practically standardized in the construction field that can be timed and motion study applied with a view to cutting out waste time and lost efficiency.

Time study in general makes it possible to secure information concerning the amount of work which may be accomplished in a given time. It is often used in the determination of possible improvements in conditions or methods, but it is essentially a rate-setting device. Rate-setting, however, also involves motion study and standardized operation to a great degree. Therefore, due to the limited time available, it is the object of this thesis, not primarily to find a standard rate or "should-take" time, but rather to determine by actual measurement in the field the average length of time of operations which may be standardized to some degree. In some cases the "should-take" time has been estimated by the author and noted, but due to his limited experience and the comparatively short periods used, these must be regarded merely as a pure estimate based on the knowledge of the work and the statistics used.

The average length of time for certain work, plus information as to waste and delayed time, may be used by estimators or by those who desire to use these figures in checking their own production when carried out under the same or similar conditions. They could also be used to good advantage in a detailed motion study of certain work with a view to improving conditions or methods, or both.

A secondary object of this thesis is to point out certain features concerning the actual construction of the bridge, showing the practical side and the actual carrying out of the theoretical work of design. The close observation necessary for good time studies is put to an auxiliary use therefore, and such methods as are in everyday use and that are considered good practice are recorded for the benefit of others who may sometime use them.

It is the hope of the writer that this thesis may be the beginning of a series of time and motion studies with regard to construction work. There is certainly a wide field for study here, and such a series would gain in accuracy and value with each one written. Notes on construction methods in use in conjunction with the above mentioned study will prove to be of great value to the man who intends to go into such work in the future.

II

GENERAL DESCRIPTION OF THE JOB STUDIED

The job studied, as the title indicates, was a highway bridge under construction in Dimondale, Michigan, over the Grand River. It was built during the summer months of 1932, beginning about April 1st, and ending about October 1st - by Hudson, Coons, and Granum. Mr. O. M. Granum, the writer's father, was superintendent on the job.

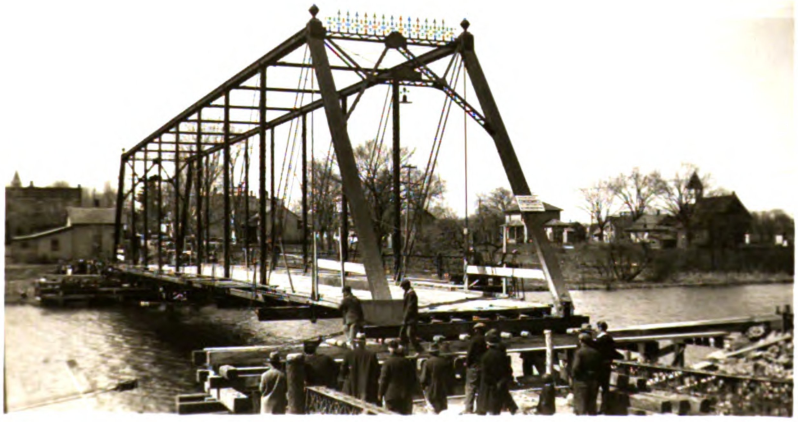
The bridge is 180 feet long, with three 60 foot spans of the deck girder type of regulation highway bridges, replacing an old 180 foot steel truss. As it was necessary to maintain traffic, the old bridge was moved up river 55 feet and placed on timber cribbing. This was the first job of its kind ever attempted in Michigan and was very successful. No time studies were taken on this part of the work, as it was unusual and the same conditions will probably never again be duplicated.

The abutments are of the counterfort wall type, approximately 65 feet wide. The building of the east abutment was the main project studied. This included ripping out the old abutment, placing and driving the sheet piling of the cofferdam, and bracing and pumping out the water from the dam. Excavation of the earth to the proper level, form and steel placing, and pouring of concrete were also studied, along with some of their adherent work.

The labor used was welfare labor - that is, the workers had to be employed from the list of unemployed in that township, since this bridge was one of many similar jobs to give unemployment relief. However five key men, including himself,

The necessity for a new bridge, showing rusted and cracked members on the old truss bridge.

The old bridge, built in 1894, showing old position, with fill for new (temporary) roadway in place.



Bridge being moved. Note timber cribbing at left.

were to be hired by the superintendent as he saw fit. Many of the laborers hired were inexperienced in such work, and therefore some of the time calculations may be too great. This can be proven by further study during a time when these men do not have to be hired. The work done by these laborers did not require a great deal of experience however; in the opinion of the superintendent they were good workers after being weeded out. By this was meant that the general effort was good and that inexperience did not detract a great deal, except insofar as a little more skilled work was required of them. The ability to direct these men in order to get the most work out of them is only to be acquired by practice and experience, combined with complete knowledge of the work to be done.

III

ELEMENTS OF TIME STUDY IN CONSTRUCTION WORK

Any portion of construction work, as well as any other work, entails three fundamental considerations: with what tools and machines it is to be performed; the method of doing the job; and the length of time required for doing it. It is the aim of the construction engineer to coordinate all work and manage each portion with efficiency so as to cut down the costs and still maintain quality. Economy is his watchword, and any methods whereby this can be gained will be welcomed.

Since the time of doing work is one of the three fundamentals, it follows that the engineer must always keep it down to a minimum within the limits set by efficient production of all those concerned with the work. This thesis is based upon the desire of the engineer to know what this time is, how it compares with other jobs, and how it may be improved upon. Time study in manufacturing plants is used to good advantage in rate-setting, but this is ordinarily done only on a piecework basis. In construction work, the hourly basis of payment for work is almost universally used, and hence we can think of rate-setting here only insofar as comparison with others is concerned. That is, if a man cannot keep up to the average time as determined by a series of studies of his job, it would be well to replace him with one who comes closer to this average. This of course tends to lower the average time and thus lower costs. It must be pointed out that there is a physical limit to the speed with which a man can work, and that it is more economical if he is not pushed too close to the limit, expecially if the job is a long one.

In order to be able to get intelligent studies, it is necessary to standardize work as far as possible. This is probably the most difficult thing to do with regard to building work as far as the time study man is concerned. He must pick out of the maze of detailed work to be done only those things which are more or less standard on every job, if his studies are to mean anything to others. It is the job of the time-keeper and cost clerk (if there is one) to keep track of the total time and costs for general work. It is the job of the time study man to separate such items as he can and determine the constituents of the general notations of the two former individuals. Therefore, the student must exercise his judgment as to standard work to be checked and decide whether or not the methods are standard. Such work has been studied by the author, and the detailed information is set down in a later part of this thesis.

The description of each operation must be rather complete in order that full information can be obtained by the user of such studies. If these times are to be of value, similar conditions must be had. This point emphasizes the fact that rate-setting can be but a minor item in the study, since it is difficult to have similar conditions even from day to day on the same job. What we want, for purposes outlined previously, is the average time, coupled with a "fair" or "should-take" time which will increase with importance as the experience of the observor and the number of trials made grow.

After the standard operation, or one which can be standardized by the use of time and motion studies, is decided upon, it must be separated into its elements. This predicates the fact that a cycle of repeated operations is found whereby the observer may make repeated trials. Strictly speaking, for average time alone, separation into elements would not be necessary, but since the studies are used for various purposes other than this, it is necessary to have the elements. Such fine work as the analysis of the technique of shoveling was not attempted, but rather the total time for a group of laborers to shovel a certain amount was determined, along with rest periods, delays, and crane operation. Enough description of the elements is necessary on the study sheet itself so that a person looking them over can get a good idea of what the operation is and under what conditions the work was done.

The sheets made up for the study were designed by the author to fit a small space. They do not carry a great number of elements, but if more elements are found than there is space for, the study is carried over to the next sheet which is then to be used simultaneously with the first. All the information required should be placed on the sheet in the spaces provided. The elements are placed along the top line, so that a complete trial reads from left to right. The last vertical column should be left for a "totals" column, but if six or more elements are required, it would be permissable to place the totals on a summary sheet, which has been done in several cases. The total at the bottom of each column is the sum total of the number of trials of each element indicated. A "delays" column on the right denotes each delay by letter, and leaves a space for description of the delay and for the time consumed.

A stop watch is needed - preferably one reading to decimals of an hour, although this was not obtainable by the author and so the next best (reading to hundredths of a minute) was used. It is best operated by procuring a regular time study board which has a watch holder and a clip for holding the sheet. This is convenient, easy to carry around, and allows good operation of the watch.

There are several methods of taking time studies, two of which are most common. In one method, the watch is re-set to zero after each reading. This makes calculations simpler, but is far less accurate. The best method and the one used here is that of allowing the watch to run all the time, only resetting occasionally. Each successive reading at the end of an element is marked down in the column marked "R". Then by later subtracting the previous reading at the end of the last element from the reading at the end of the next element, the total time for that element to be completed is found. In case of delays or waste time, the procedure is as follows: at the point where the delay starts, the time is noted and placed both in the column marked "R" under the element which is interrupted, and in the space provided in "delay" column.

The chief difficulty in making good time studies in construction work is the varied character of the work which the common labor does. They are seldom called upon to work long enough at some assignment to become very skilled in the procedure. Of course there are exceptions such as bricklayers, steel men tying steel mats, and others who hardly come under the class of common labor. In carrying out the day's work, many different things have to be done by common labor which are seldom, if ever, done again in the same manner and under similar conditions. Nevertheless, men who can be worked up to, or do better than the average in such work as we have time studies of, can be expected to put the same amount of effort and brains into other work which cannot be timed. Therefore in using these comparative values on other jobs, a basis can be formed upon which to judge an opinion of a man's effort and skill to show whether or not he is doing a "fair" day's work.

A. Clam-shell operation.

In order to place the sheet-piling it was necessary to take out the old abutment of the previous bridge. The old abutment was composed of large boulders cemented together with some sort of cement grout. Its condition was poor, and it was not difficult to demolish. The clam picked off much of the abutment above the surface, but that portion below the surface had to be blasted out, and the rabble therefore had to be picked off the bottom. This was the portion of clam-shell operation studied. The fact that the clam was grabbing blindly in the water, sometimes digging in for a good load and sometimes slipping over the surface of the rocks without picking them up, made large variations in the second item of this study - "grab load". This is especially true because more than one grab was often made since the first one might not have picked up a load. The swings of the crane can be easily checked, as they vary but little in comparison. However, this part of the placing of a cofferdam is no doubt encountered on other work, and since the same difficulties will probably airse, the average time for each swing and grab should prove to be a fairly representative cross-section of such work.

It is necessary to show that, although the bucket is marked as $\frac{3}{4}$ yard, $\frac{3}{4}$ of a yard was seldom taken out, and that the average excavation was probably something less than $\frac{1}{2}$ yard. Boulders encountered often kept the jaws from closing fully, thereby preventing a full load, and some timbers as well as rocks were removed by the teeth on the clam without removing any dirt at all.

The "swing up" and "swing back" items include only the turning of the crane from grab position to dump position, and the "grab load" item includes the dropping and raising of the bucket about 20 to 25 feet.

Statistical study on the clam-shell operation

1. Study of the elements

Trial #1	Total time	Trials	Av. time	Best time
1. Swing up 90°	2.65	13	.20	.14
2. Grab load	4.64	13	.44	.17
3. Swing back 90°	2.45	13	.19	.13
Trial #2				
1. As above	2.75	13	.21	.15
2.	6.31	13	.49	.11
3.	2.29	13	.18	.15
Trial #3				
1. As above	2.52	13	.19	.16
2.	5.21	13	.40	.12
3.	2.56	13	.20	.14

Element 1.

A. Average of average times for each trial = .20 min.
B. Average of best times for each trial = .15 min.
C. Fair time (average of average and best) = .175 min.

Element 2.

A. As above .443 min.
B. .133 min.
C. .288 min.

Element 3.

A. .19 min.
B. .14 min.
C. .165 min.

If all abnormal times, which are those times which are more or less than 50% of the average above or below the average, are discarded, and new averages drawn, it is interesting to note how much these changes affect the average times and fair times of the first study. All abnormal values are shown in red on the study sheet. Abnormal values for this study:

Element 1 - .30, .10
2 - .66, .22
3 - .28, .09

	Total time	Trials	Av. time	Best time
Trial #1				
Element 1	2.32	12	.19	.14
2	2.97	7	.42	.22
3	2.17	12	.18	.13
Trial #2				
Element 1	2.44	12	.20	.15
2	2.74	6	.46	.35
3	2.29	13	.18	.15
Trial #3				
Element 1	2.52	13	.19	.16
2	2.49	6	.42	.26
3	2.23	12	.19	.14

	Element 1	Element 2	Element 3
A	.193	.433	.183
B	.15	.276	.14
C	.171	.355	.16

This changes the average time for the first element by only .007 min.; for the second, .01 min.; for the third, .007 min. This shows that a few large abnormal times are balanced by several small ones, and so the average time given is accurate, even though the spread between greatest and least values is large. But since we have more smaller values, throwing out abnormal times tends to raise the best time, as is shown in the second element, the one with the largest variation of time due to character of work performed. Therefore this will raise the fair time for the second element to .355 min., a difference of .07 min., which may possibly be considered fair to do under the circumstances. At any rate, the difference is so little as to be hardly noticeable.

It has often been said that, while methods of time study are or can be scientific, the rate or fair time is largely a matter of experience and judgment on the part of the observer.

Since we are not using this study for wage payment, but for an actual determination of prevailing amounts of time necessary to do the work, the average time should be sufficient. The fair time is based on a mathematical average and discards all judgment of the observer, although this method of obtaining the fair time is personal judgment. But this judgment is agreed to by several authors, and is given here as being something to work toward and to maintain if possible.

The latter part of the previous statistical study of the elements is given in order to prove that the average time of all elements combined should give a fair average of time in which to do this work. This, of course, includes all the excessively great and small times; but these can be expected on the job and should be included. Discarding abnormal values is largely a matter of judgment of the observer and the use to which the studies are to be put. Therefore, in the further development of these time studies, the first method will be followed throughout.

2. Study of the total times for each trial:

		Trials
Trial 1	= 9.74	13
2	= 11.35	13
3	= 11.39	13
Totals	32.48	39

Average time for 1 operation is .833

(This of course can be found also by the average of all the elements added together)

Average time = .833

Best time = .47

Fair time = .65

3. Study of the total delayed time:

Total amount of delayed time = .45 & 1.45 = 1.90 min.

Total time consumed = 34.38 min.

% of delayed time = 5.5%

This delay proved to be necessary delay, and therefore should be allowed in the total time.

COMMENTS

It must be realized that this is only the study of the time consumed in actual operation. Preparation, such as loosening the old abutment, building trestle to allow the crane to operate, etc., can never be accounted for except in a general cost and time analysis of the whole bridge when completed. These things must be pro-rated according to their value on different parts of the job. If it were possible to have an observer on the job at all times, he could make such a study and find all the data on the prerequisites necessary for operations such as are considered in this thesis.

An improvement could easily be made in this and all other portions of the work requiring excavation, by the use of an orange-peel bucket which would do the job much more satisfactorily than the clam shell. The contractor recognized this, but as is often the case, a clam shell was available while an orange-peel was not; and so the equipment available is often the controlling factor rather than that which should be used. The state required most of the excavation to be done by hand instead of machinery; otherwise it might have been cheaper in the long run to buy an orange-peel bucket particularly for the occasion.

Time started 2:49

Time finished 3:25

Sheet No. 1 of

No. of men involved Crane Op.

Name of Operation

Clam-shell Operation

3/4 yd. bucket

Conditions. Weather - fair & warm

Boulders & Dirt in water - 2 grabs often req'd.
3 sometime

	#1						#2						Delays		
Elements	Swing up 90°		Grab load - boulders & dirt		Swing back 90° - Dump								No.	Cause	
No	1		2		3		1		2		3				
Triol	T	R	T	R	T	R	T	R	T	R	T	R			
1	.20	0.00 0.20	.18	.38	.19	.57	.25	0.00 0.25	.60	.85	.19	1.04	A	Move crane forward	.35 .80 .45
2	.16	.73	.49	1.22	.18	1.40	.31	.35 .80 A	.11	.91	.15	1.06	B		
3	.20	1.60	.50	2.10	.18	2.28	.21	1.27	.39	~~[illegible]~~ 1.66	.19	1.85	C		
4	.17	2.45	.46	2.91	.19	3.10	.15	2.00	.15	2.15	.17	2.32	D		
5	.15	3.25	.17	3.42	.18	3.60	.16	2.48	.35	2.83	.17	3.00	E		
6	.14	3.74	.80	4.54	.21	4.75	.20	3.20	1.10	4.30	.15	.45	F		
7	.21	4.96	.49	5.45	.17	5.62	.22	.67	.39	5.06	.16	.22	G		
8	.18	5.80	.17	5.97	.20	6.17	.18	.40	.67	6.07	.16	.23	H		
9	.33	6.50	.27	6.77	.13	6.90	.21	.44	.13	.57	.17	.74	I		
10	.22	7.12	.54	7.66	.19	7.85	.23	.97	.51	7.48	.22	.70	J		
11	.22	8.07	.18	8.25	.21	8.46	.20	.90	.13	8.03	.18	.21	K		
12	.27	8.73	.22	8.95	.28	9.23	.22	.43	.50	.93	.20	9.13	L		
13	.20	9.43	.17	9.60	.14	9.74	.21	.34	1.28	10.62	.18	.80	M		
T	2.65		4.64		2.45		2.75		6.31		2.29		N		

Time started 3:35:30

Time finished 3:41:30

No. of men involved Crane Op

Sheet No. 2 of

Name of Operation

Conditions.

Same as sheet 1

Elements #3

Delays

No	1		2		3									No.	Cause	
Trial	T	R	T	R	T	R	T	R	T	R	T	R				
1	.21	0.00 0.21 1.80A	.70	2.50	.17	2.67								A	Instruction + Cigarette	0.35 1.80 1A5
2	.18	2.85	.40	3.25	.20	.45								B		
3	.16	.61	.70	4.31	.19	.50								C		
4	.18	.68	.15	.83	.16	.99								D		
5	.19	5.18	.16	.34	.14	.48								E		
6	.20	.68	.62	6.30	.15	.45								F		
7	.23	.68	.42	7.10	.18	7.28								G		
8	.20	.48	.39	.87	.33	8.20								H		
9	.16	.36	.26	.62	.18	.80								I		
10	.21	9.01	.12	.13	.19	.32								J		
11	.20	.52	.40	.92	.22	10.14								K		
12	.21	.35	.73	11.08	.24	.32								L		
13	.19	.51	.16	.67	.21	.88								M		
T	2.52		5.21		2.56									N		

Totals

Time started

Time finished

No. of men involved

Sheet No. of

Name of Operation

Clamshell operation

Conditions.

No Trial	Elements #1 T	R	#2 T	R	#3 T	R	T	R	T	R	T	R	Delays No.	Cause
1	.57		1.04		1.08								A	
2	.83		.57		.78								B	
3	.88		.79		2.05								C	
4	.82		.47		.49								D	
5	.50		.68		.49								E	
6	1.15		1.45		.97								F	
7	.87		.77		.83								G	
8	.55		1.01		1.02								H	
9	.73		.51		.60								I	
10	.95		.96		.52								J	
11	.61		.51		.82								K	
12	.77		.92		1.18								L	
13	.51		1.67		.56								M	
T	9.74		11.35		11.39								N	

B. Placing steel sheet piling.

After the bottom was freed from boulders as much as possible as determined by sounding along the proposed line of the cofferdam, the steel sheeting was placed. The cofferdam walls consisted of Lackawanna steel sheet piling 20 feet long and 14 inches wide. This type of sheeting is the double claw type of interlock rather than the claw and ball of the U. S. Steel Company. The sheeting had been used several times and was again to be pulled after the abutment was in, hence it was in a rather battered condition requiring the use of a torch to cut some of the ends or claws and otherwise make it suitable for driving. The sheeting was all piled up in the old roadway leading to the bridge, and the crane was between them and the river, as the diagram of the layout shows. This necessitated a 180 degree swing which might have been improved upon had there another place been available for the piling. Only 8 or 10 piles were placed at one time, as more would cause too much bending out of line. After placing this number, the hammer was hooked on and that sheeting driven down a few feet to hold the next group of sheeting to be placed.

The first element - hook on - is the time necessary to run the cable through the hole in the end of the piling and hook it on, attach the tag line (rope held by a workman in order to guide and keep the pile from swinging), and hoist the pile clear of the ground ready to swing the crane carrying the pile through 180 degrees (on the average) to approximately near its position. There was a workman sitting on top of the piles already placed, ready to guide the end of the swinging pile held by the cable into mesh with the interlock of the

last sheet placed. This constitutes the third element. The fourth, called "set in", is the time necessary to drop and pick up the pile into and up from the bottom several successive times, the pile merely sliding up and down in the interlock of the one already placed. This is done in order to set the pile into the bottom so that it will stand there and form a guide for the next pile until it is driven. The time is quite variable in this element, since a comparatively soft spot in the bottom might be hit, in which case the weight of the sheeting will carry itself down each time it is picked up and dropped. Therefore it is good practice to allow the crane operator to do this until penetration is small - probably an inch or less. This may be done several times, or in case of hard ground, only once or twice, leaving the rest for the hammer. In the last element, the workman unfastens the hook, and the crance swings back to pick up another pile, during which time the workman should hitch his saddle forward to the pile just put in and be ready to guide the next one into place.

In the two following sheets of study, it will be observed that the elements are slightly changed in order. The above explanation applies to the second study sheet as being the better of the two. The first (taken at 2:00 PM) differs from the second in the following manner: the study starts with the swing rather than the hook-on, no time is given for lining up, and the item of unhooking is placed there. The second sheet starts the sequence more logically than does the first; since lining up is an important item, it should be included; and the item of unhooking is relatively small and unimportant as can be seen by the time for it on the first sheet. The total

time of course can be compared, as can the individual elements alike on both sheets, but the other elements have been combined or broken apart into their components as the following study indicates.

Driving sheet-piling

Close view of pile-driving with steam hammer. Pile at the right of hammer is used to hold the guide timber.

Excavation.

Note plumbness of cofferdam sheeting.

Statistical study on placing sheet piling

1. Study of the elements

Trial #1	Total time	Trials	Av. time	Best time
1. Swing up 135° (with pile)	4.34	10	.43	.18
2. Set in piling (including lining up)	8.47	8	1.06	.60
3. Unhook	.96	8	.12	.07
4. Swing back	2.00	9	.22	.15
5. Hook on	7.30	10	.73	.30

Trial #2				
1. Hook on (#5 in #1)	9.52	7	1.36	.77
2. Swing 180 degrees	2.98	7	.43	.35
3. Line up	7.21	7	1.03	.30
4. Set in	6.95	7	.99	.62
5. Unhook & swing back	4.46	7	.64	.53

Average of like elements in these two studies:

#1 in trial #2, #5 in trial #1

A. Average of average times for each trial = 1.05 min.

B. Average of best times for each trial = 0.54 min.

C. Fair time = 0.79 min.

#2 in trial #2, #1 in trial #1

A. As above .43 min.

B. .27 min.

C. .35 min.

By combining or separating, as the case may be, averages, based on trial #2 elements, may be arrived at. Element 2 in trial #1 is composed of 3 & 4 in trial #2; while 5 in trial #2 is composed of 3 & 4 in trial #1. It seems reasonable to divide the element 2 into its proportional parts and to place it in elements 3 & 4 in trial #2, and to combine 3 & 4 in trial #1 into element 5 in trial #2. The proportional parts are to be arranged according to their % value.

In trial #2, element 3 = 51%, and element 4 = 49% of the two taken together. Therefore element 2 in trial #1 can be divided in elements 3 and 4 in trial #2 as follows respectively: 51% x 1.06 = .54; 49% x 1.06 = .52. Elements 3 and 4 in trial #1 may be combined to equal .34 for element 5 in trial #2.

#3 in trial #2:

A. Average of average times for each trial = .79
B. Average of best times for each trial = .30
C. Fair time = .55

#4 in trial #2:

A. As above = .76
B. = .46
C. = .61

#5 in trial #2:

A. As above = .49
B. = .38
C. = .44

2. Study of the total times for each trial.

	Trials	Average
Trial #1 = 19.97	8	2.49
2 = 31.12	7	4.45

Average of both trials = 3.47 min.
Average of best times = 2.27 min.
Fair time = 2.87 min.

As can be noted, the average time for each trial is quite different in the two trials. These statistics were taken on different days, but under similar conditions. It would seem that these averages should be closer together, but there is an explanation of the difference between the two days, and that is that on the second sheet beginning at 3:33 the piling that was being placed was further away from the center. This necessitated a flat boom which made the lining up and setting in more difficult. When the piling is being placed at the limit of the boom it is necessary for the man guiding the pile into place to take more time to swing it into position. These studies show this difference very well. It will be further noted that the average of the "hook-on" times is larger in the later study. This is due to the fact that the sheeting on top of the pile was easier to hook on, and as the pile went down, some were under others or placed cross-ways, and in general were more difficult to snake out and hook on.

While there is this difference between the two, nevertheless this should provide a good average of time according to reasons outlined under the previous operation.

3. Study of the delayed time.

Trial #1:

Necessary delay = 2.64 min., or 11% of the total time
Unnecessary " = 1.70 min., or 7% of the total time

Trial #2:

Necessary delay = 2.30 min., or 6% of the total time
Unnecessary " = 3.40 min., or 9% of the total time

Average percentage of necessary delay = $8\frac{1}{2}$%
Average percentage of unnecessary delay = 8%

The percentage of unnecessary delay is the part that needs attention of the observer. In trial #1, delay B was unnecessary as it was the job of the helper at the pile of sheeting to see that the piling was ready for placing, and to choose the next pile so that there would be no delay as in A, B, and D in trial #2. Delay E in trial #2 was the fault of the man on the sheeting already in place, as he should not have left his position. Since only 8 or 10 piles are placed at one time before driving, there was no need for him to leave until the set was completed. Here then is one place to speed up the operation - by requiring that man to be a little more alert in supplying this sheeting to the crane.

Time started 2:00 P.M.

Time finished

No. of men involved

Sheet No. of

Name of Operation

Placing sheet piling

Conditions.

Weather - warm + fair

Elements	swing up 135° (with pile)		set in piling		Unhook		swing back		Hook on		Total		Delays		
No	1		2		3		4		5				No.	Cause	
Trial	T	R	T	R	T	R	T	R	T	R	T	R			
1	.18	0.00 0.18	.70	.88	.07	.95	.22	1.17	.91	2.08	2.08		A	Set pile for guide	4.38 5.62 1.4[illegible]
2	.38	.46	.68	3.14	.15	.29	.20	.49	.66	4.15	2.07		B	Poor pile take back	10.70 12.40 1.10
3	.31	.46	.81	5.[illegible]0	.01	.37	.20	.51	.13	6.30	2.15		C	Tap with sledge	14.00 15.40 1.40
4	.35	.65	1.05	7.10	.10	.80	.19	.99	.16	8.15	2.45		D		
5	.65	0.00 0.65	2.10	2.75	.20	.95	.15	3.10	.82	.92	3.93		E		
6	.46	4.38 A	→			5.62	.33	5.95	.73	6.68			F		
7	.32	7.00	1.90	8.40	.07	.97	.25	9.22	.84	10.06	3.38		G		
8	.64	.70	B →						.95	12.40 13.35			H		
9	.65	14.00 15.40 C	.60	16.00	.13	.13	.27	.40	.60	11.00	2.25		I		
10	.40	.40	.60	18.00	.11	.17	.19	.36	.30	.96	1.66		J		
11													K		
12													L		
13													M		
T	4.34	8.47 (8) →			.96 (8)		2.00 (9)		7.30		19.97 (8)		N		4.34

Time started 3:33 P.M.

Time finished 4:08"

Sheet No. 1 of

No. of men involved #1 + 4

Crane ~~[illegible]~~ op.

_ helpers.

Name of Operation Placing steel sheet piling

Conditions. After placing — Drive in about 6-7 ft. Hard bottom.

(for driving see later sheet)

Elements	Hook on		Swing 180°		Line up		set in		Unhook & swing back		Total		Delays		
No Trial	T	R	T	R	T	R	T	R	T	R	T	R	No.	Cause	
1	1.10	0.00 1.10	.50	1.60	.30	1.90	1.15	3.05	.55	3.60	3.60		A	Looking for pile	0.00 0.45 .45
2	1.03	0.00 A 0.45 1.48	.39	1.87	.83	2.70	.70	3.40	.65	4.05	3.60		B	"	4.05 4.80 .75
3	1.07	B 4.80 5.81	.35	6.22	3.93	10.15	.85	11.00	1.05	12.05	7.25		C	Pull pile out-reset	5.10 7.40 2.30
4	1.80	4.00 5.10 C 7.40 8.10	.43	8.53	.45	9.15 9.60 D 11.30	.70	12.00	.53	12.53	3.91		D	Get rope out of pile	9.60 11.30 1.70
5	1.75	0.00 1.75	.35	2.10 E 2.60	.55	3.15	.88	4.03	.47	4.50	4.00		E	Nobody There	2.10 2.60 .50
6	.77	5.27	.43	.70	.48	6.18	.62	.80	.58	7.38	2.88		F		
7	2.00	0.00 2.00	.53	2.53	.67	3.20	2.05	5.25	.63	5.88	5.88		G		
8													H		
9													I		
10													J		
11													K		
12													L		
13													M		
T	9.52		2.98		7.21		6.95		4.46		31.12		N		5.70

C. Driving steel sheet piling.

The next operation after placing the sheet piling is to drive it down into the bottom approximately 5 or 6 feet. This is done by a 5000# steam hammer carried by the crane. The work is done in series with the placing - that is, after 8 or 10 piles have been placed, the hammer is hooked on and the piles driven in order to provide a guide for the rest of the piling. The sheeting is driven two at a time, as the hammer is large enough to do this.

The bottom was hard blue clay, and the driving therefore rather difficult as the piles went into hard ground which later developed into a shale formation mixed in with and underlying the clay. However these studies treat only of the first part - that is, through the clay only, not into the shaly mixture. Occasionally a boulder was hit which necessitated leaving the piling sticking up until some on the other side were driven, and then the piling on top of the boulder was driven if possible. Very often this expedient was sufficient to force the stone to one side, or perhaps the pile was bent a little out of line, but not harmfully so. Again it was necessary to pull the piling and attempt to get the rock out and then replace the piling.

Of course it was necessary to keep the line of sheeting as straight as possible. To do this, it was sometimes necessary to put a set of rope falls on the piling to pull it into the proper position while hammering was going on. The piling was set against a floating frame which formed the general line of the cofferdam and later became the first set of walers.

In the study sheet, the first element consists of lifting the hammer off one group of piling and resetting on the next two. Occasionally this took a little more than a minute due to difficulty in getting the hammer set on just right to accomplish the most work. The next element shows the time taken for the actual driving of the sheeting to the depth shown. This did not remain the depth as they were driven down deeper later on to take care of a bad sand-boil which occurred, and also because the design of the abutment was changed, after the bottom was disclosed, requiring the foundation to be two feet lower than originally planned. The original plans called for caissons under the footing, but the bottom was discovered to be so hard that these were not necessary. The reason for lowering the foundation was to be sure that no scour would occur around or under it in case a dam about 400 yards downstream should ever go out.

Statistical study of pile driving.

1. Study of the elements:

		Total time	Trials	Av. time	Best time
1.	Lift off and set on	9.76	13	.75	.25
2.	Drive 5 to 6 feet	38.29	11	3.48	2.00

Element #1 - Fair time = av. of average & best times = .50 min.
2 - Fair time ditto 2.74 min.

In these figures, the two groups of piles left standing high were eliminated, as they were not yet completed and could not be compared to the rest.

2. Study of the total times:

The total time less the two not completed was 46.48 min., with 11 trials. The average time was 4.22 min., and the best time being 2.70, and therefore a fair time is set at the average of the two, and is 3.46 minutes.

3. Study of the delayed times:

The delays as noted were all necessary ones, since they had to do with lining up the piling, and one in which the crane had to lower the boom in order to reach the piling. Hence these delays should all be expected in the course of driving a cofferdam and should be added in. The amount of time consumed was 13.62 min., or a total time of 53.39 plus 13.62 or 67.01 minutes, of which the delayed time is 20%.

It would be advisable to cut down this delayed time, of course, but the result of the delays was to get a very straight wall and one which lined up very well. Therefore these delays no doubt made up for themselves in saving trouble later on in the closure. There should be no delays for fatigue, etc., because the two men who are charged against this operation have nothing to do as long as everything goes smoothly, other than to signal the crane operator as to the position of the hammer. They are there to place the falls and hold the lines if needed.

It may seem like a waste of time to set in only 8 or 10 piles, attach the hammer, drive then, take hammer off, and repeat the process - since it usually takes about 15 minutes to put on and take off the hammer. The writer noticed this delay, and thought that it would be more economical if several guide piles were placed along the framework, with the walers and another set of parallel timbers hooked on to these piles to act as guides for the sheeting. In this way, all of the sheeting along one side could be placed at once and then driven without the necessity of spending so much time taking the hammer off and on. However the author was assured by the contractor that it would take much more time to place the guide timbers and piles than would be saved in doing away with the necessity of changing the hammer. This is purely a question of time which might be settled at some future time by some sort of time studies intended to show the difference between the two. It may be that the method is impractical and that no one uses it, but if it is in use a comparison could be made between the time necessary for placing by this method, which would be the average time of the set in sheet, plus about 15 minutes for every 8 or 10 piles, plus the average time of the driving sheet (divided by 2 for 1 piling), plus the delays shown, as compared to the time per pile for the other method.

Time started ____________

Time finished ____________

Sheet No. ______ of ______

Name of Operation

Drive steel sheet piling

No. of men involved #1 + 2 Crane + steam ops. 2 men

Conditions. Hard Blue clay plus some boulders. Drive 2 at a time.

Elements	Lift hammer off + set on		Drive about 6'				Total						Delays		
No Trial	T	R	T	R	T	R	T	R	T	R	T	R	No.	Cause	
1	.67	0.00 0.67	5.80	3.47 7.90 A 10.90			6.47						A	Put falls on pile	3.47 7.90 4.43
2	.25	B 11.49 11.79	3.01	14.80			3.26						B	Boom out	10.90 11.49 .59
3	.50	15.30 C 20.50	4.13	24.63			4.63						C	change lines + pull up	15.30 20.50 5.2
4	1.00	0.00 1.00	3.00	4.00	← about 3' only		4.00						D	Put falls on	4.30 7.40 3.10
5	.65	4.65	4.60	9.25			5.25						E	Pull up	7.85 8.15 .30
6	.25	9.50	5.23	14.73			5.48						F		
7	.57	15.30	2.34	1264	← about 4' only		2.91						G		
8	1.27	0.00 1.27	2.38	365			3.65						H		
9	.90	0.00 0.90	3.00	3.90			3.90						I		
10	.40	4.30 D 7.40 7.85 E 8.15	3.0 :2	10.00			2.70						J		
11	1.08	0.00 1.08	3.60	4.68			4.68						K		
12	.60	5.28	2.24	7.52			2.84						L		
13	1.62	0.00 1.62	2.00	0.00 3.62			3.62						M		
T	9.76		38.29 (11)				53.39						N		

D. Study of wet excavation.

The wet excavation is started after the cofferdam is completed and braced sufficiently to allow the water to be pumped out. After leveling off, the second set of walers and struts was placed about six feet below the first set, and after further excavation, the third set was placed about five feet under the second and the excavation carried down about three feet below this level. The bottom of the footing is about 14½ feet below water level and the toe hold of the 20 foot piling is about 3 feet.

Perhaps the term "wet excavation" should be explained. This does not mean that the excavation is done under water by clam-shell, but rather means all excavation within the walls of the cofferdam. Ordinarily this, too, is done by clam-shell, but due to the unemployment situation, the contract called for hand excavation of the material. This could be done either by shoveling out in stages, or by filling the clamshell by hand and hoisting out and dumping. The latter was done as it was by far the easiest and cheapest method. Great care was necessary to see that the bucket in going up and down between the struts did not touch or jam any of them, as it could have easily knocked out one of the struts which might have caused a cave-in of the cofferdam.

In the study of any excavation, the character of the ground is of course the most important consideration. After going through the first few inches of top soil over which the river had been flowing, the ground encountered was a hard blue clay which kept getting harder as it went down, finally

developing into an underlying bed of shaly clay and actual blue shale which required quite a little picking to get loose. The hole was a remarkably dry one however, and it was kept that way by digging a trench clear around the outside edge of the cofferdam to lead off the water seeping through the walls and to collect the water from two or three small sandboils whose flow was led into the side ditches which led to a sump where the water was pumped out. The pumps used for emptying the cofferdam were two 5 inch centrifugal pumps powered by gas engines. After emptying, the hole was kept dry by a 1 cylinder, 2 inch force pump. This pump was bought for the purpose of filling the tank on the concrete mixer, and thus did double duty and reduced operating expense of the large pumps to quite an extent. A dry hole is much better to work in, and it should be kept as dry as possible to provide a good bottom.

The next important consideration in a study of excavation is the method of doing it, which has already been outlined, and the effort and experience of the men doing the excavation. This welfare labor, while willing, nevertheless varied quite a little in their ability to shovel this dirt. The difference between a man who takes large shovelsfull and keeps it up steadily all day long, and the one who is erratic in his effort and in the amount carried in by his shovel, is easily discernable. Here the contractor was forced to take good and bad, and although the worst ones were discharged, there were still some who could have been improved upon but who had to be kept on to get the work done. Hence the average time per man is probably somewhat lower than the average during normal times when the best men available can be hired. A certain degree of intelligence is also required in that the hole must be kept higher in the center in order to allow good drainage of any water towards the edges. Men tend to work in the center of the hole, and the foreman must keep them on the edges if they do not do it themselves. As the excavation nears the grade care must be taken to see that no one digs below this level, as it must be filled with concrete, and not backfilled with clay to the proper level.

There was not a constant number of men engaged in filling the bucket at all times, as study of the observation sheet shows. Some men were instructed to cut out the ditch at the side, and if the bucket came down near them they would throw their dirt into it; otherwise it would be piled up on the bottom of the hole. Occasionally one would pick instead of shovel during the time the clam was lowered. When a man worked half the time without throwing any clay into the bucket, but during the other half did his share of filling, this fact is accounted for by noting a "$\frac{1}{2}$" man at the side showing the number of men actually engaged in filling.

The character of the ground was sometimes variable also, as the softer clay top might be peeled off and shaly clay struck underneath. These variables make it difficult to determine exactly the time needed to fill the clamshell, but the average of all the times should be a good indication of the time nexessary for filling and depositing, according to the principle illustrated under "Clamshell operation."

The first element "Load bucket" is merely the time necessary for the indicated number of men to fill the clamshell with about ½ yard of excavation. Although the clamshell was of ¾ yard capacity, the voids of the shoveled material brought it down. In order to bring the time for each trial to a common average it was necessary to find the number of "man-minutes" (number of men multiplied by number of minutes) required to load the clamshell. Therefore in the analysis to follow, the first element has been divided in this way. The total number of man-minutes is summarized at the end of the observation sheets on this operation. This shows only the actual time necessary for loading as shown in the summary of statistical data under element 1. The total time for each yard given in the total number of man-minutes including the time for the bucket to be dumped is found at the end of the statistical data under "study of total times".

The distinction between these two is that the first shows the time it would take one man to shovel a yard of this sort of excavation, averaging soft and hard, with no rest periods in between, while the second shows the actual number of man-minutes consumed on this job per yard, including all time except the noted delayed times. This data should apply as a general rule since the study was conducted throughout one whole day, thus averaging the results of early morning and late afternoon work.

The next group of elements comprise the mechanical portion of the operation. The second element - raise 25' - is the time necessary to raise the full bucket from the bottom up to a height sufficient to be dumped on the pile. This time included a stop or two necessary to stop the swinging of the bucket so that it could be hoisted without danger of hitting a strut. The next two elements are self-explanatory: swing back 90°, and dump and swing back. The last (lower) is similar to the second, the bucket being guided by someone standing on the top strut. The men all have a chance to rest a short ime while the bucket is being dumped, as shown in the statistical study. This is no doubt a saving factor in the results of fatigue as is also shown in the study.

Statistical study of wet excavation.

1. Study of the elements:

Element 1

Trial #1 (started at 2:30) :

A. Total number of man-minutes = 453.85
B. Total amount of excavation = 6½ cu. yds.
C. Average man-minutes/yard = 69.75 min.
D. Best time/yard
(sum of 2 best trials) = 58.45 min.
E. Fair time
(av. of best & av. times) = 64.10 man-min.

Trial #2 (started at 7:16):

A. As above 427.20
B. 6.5
C. 65.60
D. 53.30
E. 59.50

Trial # 3 (started at 11:05):

A. As above 234.90
B. 3.0
C. 78.30
D. 68.10
E. 73.20

- Other elements -

Trial #1	Total time	Trials	Av. time	Best time
Element 2 (Raise 25 feet)	5.70	13	.44	.25
Element 3 (Swing 45° & empty)	2.07	13	.16	.08
Element 4 (Swing back)	2.38	13	.18	.10
Element 5 (Lower)	5.49	13	.42	.25
Trial #2				
Element 2	6.25	13	.48	.30
3	2.22	13	.17	.13
4	2.56	12	.21	.16
5	8.13	12	.68	.47

Trial #3	Total time	Trials	Av. time	Best time
Element 2	2.00	5	.40	.25
3	1.15	5	.23	.13
4	1.16	5	.23	.17
5	2.65	5	.53	.33

Summary of elements:

Element 1 - throughout a day

A. Average man-minutes per yard = 71.25
B. Average of best times = 59.95
C. Fair time = 65.60

Element 2

A. Average of av. times for each trial = .44 min.
B. Average of best times = .26 min.
C. Fair time (av. of A & B) = .35 min.

Element 3

A. As above .19
B. .11
C. .15

Element 4

A. As above .21
B. .14
C. .18

Element 5

A. As above .54
B. .35
C. .45

The action of workmen as the day progresses is strikingly illustrated in this study. If the element of manual labor, #1, is studied according to hour of the day the studies were made, it will be noticed that the fastest progress was made during the early morning from about 7-9 AM, both in average time and in the best time. The second best occured in the afternoon between 2:30 and 4:23. The least productive time in this study was between 11 and 12. Unfortunately there was no opportunity to get data between 5 and 6 which might have proved that this was the slowest time. With more data it would be interesting to show how the production varied with time due to fatigue of the laborers, but that is beyond the scope of this thesis.

2. Study of the total times.

This study must be conducted in a little different manner than in the former cases. To get an equitable average, the average time multiplied by the average number of men is determined in order to get an average number of man-minutes for each ½ yard. To get a fair "best time", the best times of each number of men are averaged together according to the above method. Study of the average and best times according to the time of day is made in a summary of the results for each trial immediately before the day's average is made up. The totals for each trial are then made into a grand average covering a whole day's work, and shows what may be expected on a job of this kind.

Trial #1 (2:30 - 4:23)

Total time 86.29 min.
No. of trials 13
Average time 6.64 min.

Total number of men 85
Average " " " 6.54

Average number of man-minutes =6.54 x 6.64
=43.40

Best times:

No. of men	Least time	Trials	Weighted times
7	5.45	8	43.60
6	5.56	4	22.20
5	10.97	1	10.97
		13	76.77

Average best time = $\frac{76.77}{13}$ = 5.90 min.

Best time = 5.90 x 6.54 = 38.60 man-min.

Fair time (average of best and average times):

Fair time = 41.00 man-min./½yd. (1 clamshell)

Trial #2 (7:16 - 9:05) (Excluding trial #9)

Total time 94.51 min.
No. of trials 12
Average time 7.88 min.

Total no. of men 64
Average " " " 5.33

Average no. of man-minutes = 5.33 x 7.88 = 42.00

Best times:

No. of men	Least time	Trials	Weighted times
7	4.98	2	9.96
6	6.47	1	6.47
5	7.13	7	49.91
4½	8.86	2	17.72
		12	84.06

Average best time = 84.06/12 = 7.00 min.

Best time = 7.00 x 5.33 = 37.33 man-min.

Fair time = 39.86 man-min.

Trial #3 (11:05 - 12:02) (Excluding trial #6)

Total time	45.66 min.
No. of trials	5
Average time	9.13 min.

Total no. of men	25.5
Average " " "	5.10

Average no. of man-minutes = 5.10 x 9.13 = 46.60

Best times:

No. of men	Least time	Trials	Weighted times
6	8.69	1	8.69
5	8.08	3	24.24
4½	9.22	1	9.22
		5	42.15

Average best time = 42.15/5 = 8.43 min.

Best time = 8.43 x 5.10 = 43 man-min.

Fair time = 44.80 man-min.

Trial #4 (2:00 - 3:27) (This trial shows total times only as the author was busy taking notes, and could only determine the time by recurrence of an element.)

Total time	94.30 min.
No. of trials	13
Average time	7.25 min.

Total no. of men	87.5
Average " " "	6.74

Average no. of man-minutes = 6.74 x 7.25 = 49.00

Best times:

No. of men	Least time	Trials	Weighted times
9	6.35	2	12.70
8	6.40	3	19.20
7	7.70	1	7.70
6½	7.15	1	7.15
6	6.95	3	20.85
5	6.85	2	13.70
4	8.75	1	8.75
		13	90.05

Average best time = 90.05/13 = 6.92 min.

Best time = 6.92 x 6.74 = 46.60 man-min.

Fair time = 47.80 man-min.

Summary of trials by time of day:

Time of day	Average time in man-minutes	Best time in man-minutes	Fair time in man-minutes
7:16 - 9:05 (#2)	42.00	37.33	39.86
11:05 - 12:02 (#3)	46.60	43.00	44.80
2:00 - 3:27 (#4)	49.00	46.60	47.80
2:30 - 4:23 (#1)	43.40	38.60	41.00

This summary shows how fatigue of the worker tends to increase from morning to noon through the early part of the afternoon, and evidently decreases again in the latter part of the afternoon. These last two studies overlap a bit, but the last one extends over an hour beyond number 4. However this is not entirely a good case to base such a statement on, as shown in "Study of delayed time".

An average for the day can now be found by averaging all of the above times. A criticism may be found in doing this in that not all trials were the same length of time, and that they should be weighted to find a true average. However, the author does not believe that this is necessary here because each trial is a representative one. Therefore we have total times, given in man-minutes, to excavate ½ yard of the previously described soil. To this must be added the time of 2 men in digging ditches, or picking, 1 crane operator, and 1 superintendent.

Average	45.25 man-minutes
Best	41.38 man-minutes
Fair	43.31 man-minutes

3. Study of the delayed time. (All necessary)

Trials	Total delayed time	% of total time
#1	23.15 min.	21%
2	1.10	1%
3	1.81	4%

In order to get a good idea of the amount of rest the shovellers had, the difference between the total amounts of element 1 and the total amount of "total" times for each trial is shown here. To this time must be added the time for delays. The men then got a chance to rest a little between each loading when the bucket was being dumped. It has been mentioned that the fatigue seemed to lessen the latter part of the afternoon, as the average time was smaller. However it can be observed now that during this time there was a large amount of delay (21%) during which the men had a chance to rest and freshen up for the next loading.

Amount of rest allowed:

Trial #1

86.29 - 70.66 = 15.63 min. plus 23.15 = 38.78 min.

Average of 38.78/13 = 2.98 min. per load of ½ yd.

(It must be kept in mind that this is excessive due to the large amount of delayed time. The extra rest shows up plainly in the increased speed of the men during loading in this period, but should not be regarded as a general rule.

Trial #2

94.51 - 84.98 = 9.53 plus 1.10 = 10.63 min.

Average of 10.63/13 = 0.82 min. per load of ½ yd.

(In spite of this handicap of a smaller amount of rest, this period shows the best time for loading as it is early in the morning.)

Trial #3 (Except #6)

45.66 - 38.70 = 6.96 plus 1.81 = 8.77

Average of 8.77/5 = 1.75 min. per load of $\frac{1}{2}$ yd.

(This increased rest period does not overcome the fact that this is later in the day and therefore the production becomes slower.)

COMMENTS

While primarily this study was undertaken to show the actual time and labor consumed, yet we have here a problem which could, with sufficient data carried out in the same manner, be continued in the building field for all forms of labor.

A study of fatigue of the laboring man in heavy, outdoor work might prove of value in scientific management of such labor. This is never done in the field - experience being the best guide. But it has worked out in industrial plants, and the author is of the opinion that this study might someday be removed from the field of the theoretical, and be given practical consideration.

Trial #1

Time started 2:30

Time finished 4:23

Sheet No. 1 of

Name of Operation

Loading wet excavation & Dumping - ~~[illegible]~~ 1/2 yd. ex.

No. of men involved 1 Crane Op.
7 ~~8~~ shovelers -welfare

Conditions. Wet and hard Blue clay
Men load bucket by hand
Weather - warm - cloudy
Occasional Boulders

	Elements	Load buckets		Raise 25'		Swing 45° & empty		Swing back		Lower		Total time		Delays		
	No Trial	T	R	T	R	T	R	T	R	T	R	T	R	No.	Cause	
7	1	5.50	0.00 5.50 A	.41	5.80 6.27	.08	6.35	.17	6.52	.78	7.30 B	~~7.30~~ 7.00		A	Get Crane op. on job.	5.50 5.80 .30
"	2	5.90	11.85 ~~16.75~~ 17.75	.50	~~16.75~~ 18.25	.10	18.35	.10	18.45	.35	18.80	6.95		B	Bucket took up boulders & part shovel fill	7.30 11.85 4.5
"	3	4.90	23.70	.50	24.20	.13	.33	.20	.53	.37	24.90	6.10		C	Untwist Bucket	36.0 36.9 .9
"	4	4.50	29.40	.45	29.85	.14	.99	.19	30.18	.42	30.60	5.70		D	Get rocks under bucket	23.70 24.7 1.0
"	5	4.55	35.15	.50	.65	.13	.78	.22	36.00 C 36.90	.34	37.24	~~[illegible]~~ 5.74		E	Same as B	25.20 ~~28.40~~ 36.00
6 men	6	4.66	42.90	.25	43.15	.17	.32	.14	.46	.34	43.80	5.56		F	Op. stringing cable	11.8
7 "	7	4.60	0.00 4.60	.52	5.12	.15	.27	.23	.50	.25	5.75	5.75		G	Same as ~~B~~ total time	0.0 5.3
"	8	4.35	10.10	.40	.50	.12	.62	.18	.80	.40	11.20	5.45		H		
6	9	5.10	16.30	.44	.74	.16	.90	.22	17.12	.50	17.62	6.42		I		
7	10	5.23	22.85	.48	23.33	.15	.48	.22	.70 D 24.73	.47	~~24.20~~ 25.20 E F G	6.58		J		
6	11	6.25	0.00 6.25	.35	.60	.20	.80	.17	.97	.41	7.38	7.38		K		
6	12	5.42	13.80	.44	14.24	.36	.60	.15	.75	.35	15.10	6.72		L		
5	13	9.70	24.80	.40	25.20	.18	.38	.18	.56	.51	26.07	10.97		M		
85	T	70.66		5.70		2.07		2.38		~~5.02~~ ~~(12)~~	5.49	~~[illegible]~~ 86.29		N		

Note: Man could use pick while bucket is unloading, instead of during loading time.

Trial #2

Time started 7:16 A.M.

Time finished 9:05 "

Sheet No. 1 of

Name of Operation

Wet excavation - 1/2 yd.

No. of men involved

Conditions. Fair - cool

Hard & Wet blue clay

with occasional rock

	Elements	Load Bucket		Raise 25'		swing 90°		Dump & swing back		Lower				Delays		
	No	1		2		3		4		5				No.	Cause	
	Trial	T	R	T	R	T	R	T	R	T	R	T	R			
6 men	1	5.10	0.00 5.10	.40	5.50	.15	.65	.35	6.00	.47	6.47	6.47	Softer top	A	Haul up line	9.00 10.10 1.10
5 "	2	5.43	11.90	.39	12.29	.14	.43	.17	.60	1.00	13.60	7.13		B		
"	3	6.00	19.60	.50	20.10	.20	.30	.20	.50	.60	21.10	7.50		C		
5 men	4	7.20	28.30	.55	.85	.15	29.00	~~.22~~ .22	.22	.68	.90	8.80		D		
"	5	6.10	0.00 6.10	.60	.70	.20	.90	.21	7.11	.74	7.85	7.85		E		
"	6	6.95	14.80	.46	15.26	.21	.47	.28	.75	.85	16.60	8.75		F		
"	7	6.60	23.20	.50	.70	.20	.90	.25	24.15	.61	24.76	8.16		G		
"	8	5.71	30.47	.65	31.12	.17	.29	.21	.50	.50	32.00	7.24	Softer top	H		
4 men	9	9.00	0.00 9.00 A	.48	10.10 .58	.15	.73	Delay to take off line					Hard	I		
(4+5) 4 1/2 "	10	11.80	0.00 11.80	.37	12.17	.18	.35	.18	.53	1.02	13.55	13.55	Into shale	J		
4 1/2	11	7.31	20.86	.69	21.55	.20	.75	.16	.91	.50	22.41	8.86	Soft top	K		
7	12	4.05	0.00 4.05	.30	.35	.13	.48	.11	.65	.57	5.22	5.22	"	L		
"	13	3.73	8.95	.36	9.31	.14	.45	.16	.61	.59	10.20	4.98	"	M		
68	T	84.98		6.25		2.22		2.56 (12)		8.13 (12)		94.51 (12)		N		1.10

Trial # 3

Time started 11:05 A.M.

Time finished 12:02 Noon

Sheet No. 2 of

Name of Operation

No. of men involved

Conditions. Ditto

	No	1		2		3		4		5		Total	Descr.	Delays		
	Trial	T	R	T	R	T	R	T	R	T	R	T	R	No.	Cause	
6 men	1	6.75	0.50 6.75	.46	7.21	.13	.34	.23	.57 A 9.38	1.12	10.50	8.69	½ soft ½ hard	A	Walk cat ahead	7.51 9.38 1.81
5 "	2	6.65	17.15	.48	.63	.26	.89	.31	18.20	.38	18.58	8.08	fairly soft	B		
4 ½	3	7.75	26.33	.51	.84	.26	27.10	.25	.35	.45	27.80	9.22	average	C		
5	4	8.35	0.00 8.35	.15	.50	.30	.80	.11	.97	.35	9.30	9.30	hard	D		
5	5	9.20	18.50	.40	.90	.20	19.10	.20	.30	.31	19.67	10.37	"	E		
4	6	9.63	29.30		Stop									F		
	7													G		
	8													H		
	9													I		
	10													J		
	11													K		
	12													L		
	13													M		
29½	T	48.33		2.00 (5)		1.15 (5)		1.16 (5)		2.65 (5)		45.66 (5)		N		

Trial #4

Time started 2:00 P.M.

Time finished 3:21 "

Sheet No. 3 of

Name of Operation

Ex.

No. of men involved 6

Conditions. Total Time Only

Hard Blue Clay

	Elements	Total Time only													Delays	
	No Trial	T	R	T	R	T	R	T	R	T	R	T	R		No.	Cause
6 men	1	7.50	0.00 7.50											A		
"	2	6.95	14.45											B		
"	3	8.40	22.85											C		
5 men	4	6.85	0.00 6.85											D		
4 "	5	8.75	0.00 8.75											E		
5 "	6	7.55	16.30											F		
8 "	7	7.10	23.40											G		
6½	8	7.15	30.65											H		
8½	9	6.60	0.00 6.60											I		
8	10	6.40	13.00											J		
7	11	7.70	0.00 7.70											K		
9 men	12	7.00	14.70											L		
9 "	13	6.35	0.00 6.35											M		
87.½	T	94.30												N		

Summary - element 1

Time started

Time finished

No. of men involved

Sheet No. of

Name of Operation

Wet excavation

Conditions.

Element #1 - Load Bucket

Total Man-minutes

Elements	2:30-4:23		7:16-9:05		11:05-12:02								Delays	
No	1		2		3								No.	Cause
Trial	T	R	T	R	T	R	T	R	T	R	T	R		
1	38.50		30.60		40.50								A	
2	41.30		27.10		33.20								B	
3	34.30		30.00		34.90								C	
4	31.50		36.00		41.80								D	
5	31.85		30.50		46.00								E	
6	32.20		34.80		38.50								F	
7	30.45		33.00										G	
8	36.60		28.60										H	
9	28.00		36.00										I	
10	30.60		53.10										J	
11	37.50		32.90										K	
12	32.55		28.40										L	
13	48.50		26.20										M	
T	453.85		421.20		234.90								N	

E. Study of Concrete Pouring.

All preliminary work necessary has been done. The cofferdam has been made, the proper level of excavation has been reached, and forms and steel have been placed in readiness. The concrete gang is ready and the observer is ready to start observation. This portion of the work was the footing which is 2 feet thick, about 65 feet long and about 12 feet wide.

The layout is shown in a diagram in this thesis and was considered as an ideal layout by the contractor. It was so designed as to permit a steady flow of materials through the mixer without any delay or without particularly long hauls. The mixer used was a 21 S paver which was too large for this type of job, but as it was lying idle at the time, it was used in place of buying a 10 S mixer which was the proper size to use here. In order to get a good, even, and constant mix, it is necessary to run a concrete mixer to somewhere near its full capacity. It was impossible to do this, as the space available for placing was limited, necessarily limiting the number of men who could place and distribute the concrete. Only 9 men were used here - 3 to handle the concrete in the chutes, 2 to strike off to the proper level, and 4 to handle, distribute, and spade. Therefore the batch was limited to a 4 sack batch instead of 6 sacks, the regular capacity of the mixer. It should have been less than 4 but this was the least the mixer could handle efficiently.

The batch as designed by the engineer was: 4 bags of cement, 138# (16.6 gallons) of water, 4 wheelbarrows of stone (each to weigh 297#), and 3 wheelbarrows of sand (each to

weigh 266#). This produced about 16 cubic feet of concrete with a 3 inch slump, instead of the 21 cubic feet regular capacity. The concrete was very uniform, but rather stiff to place around all the reinforcing steel. It would have been permissable to allow a little more water, making the placing easier, as subsequent tests on sample beams showed a breaking point of 750 pounds per square inch at 7 days, which was better than required at 28 days. This proportion of sand to gravel presented a problem. Gravel is harder to shovel than sand, and one more barrow was required. So 3 men were placed on the gravel and 2 on the sand. Later on, as it became apparent that the gravel was slow in getting to the mixer, another man was added. The balance of time must be maintained between the two so that the men work continuously and yet have time enough between batches to load the skip. It will be seen that most of the delay due to the skip not being loaded was due to the gravel being a little late. This delay was eliminated when the 4th man was put to work on the gravel pile. The time of mix was set at 1½ minutes. This presumably meant that the first part of the batch was not to be discharged for 1½ minutes. However, even though an automatic timing device was on the mixer, this time was often short, although the average of the first and last parts of the batch out was usually over 1½ minutes. It is to the advantage of the contractor if he can cut the mixing time short a little, and as the inspector was present and did not object, and further since the test beams showed high strength, it seems that this was permissable.

It was necessary to weigh each wheelbarrow full of aggregate, so a man was added soon after the start whose sole job was to check the weight and adjust. It may seem that each man wheeling a barrow could do this for himself, but as the observer noted some delay and confusion in doing this, the extra man was put on, which decreased the delay very considerably. This fact is especially noticeable on the first and second sheets of observations. Immediately after the weight adjuster was added, the delayed time due to the skip not being loaded was nearly eliminated, but near the bottom of the first sheet, this man was sent on another errand, and immediately delay due to this cause was noticeable and continued until the man came back (on the second sheet). There is one criticism which may be made of this analysis, and that is the fact that the time between the raising of the skip and the batch emptied seemed to be shorter than usual during the time the weight adjuster was gone. This did not allow the average time for loading the skip and naturally would cause some delay in itself. However it is the opinion of the writer, formed on the few cases where this man was not present and on personal observation, that the weight adjuster was necessary and added to the speed of the work.

In the concrete gang were also included one mixer operator, two men to wheel the buggies about 75 feet and back, and one man to put in the cement. He was later augmented by another man to bring the cement nearer the mixer as the pile grew smaller. The men wheeling the aggregate only had to go an average distance of about 10 feet to the scales, and another 6 feet into the skip. There was one superintendent and one foreman whose job was the placing of the concrete. Thus there was

a total of 10 men making and wheeling the concrete and 9 handling and placing it, not including the foreman and the superintendent.

In sheet 1 of the observations the first element is called "Load - skip up and down". After further study, it was decided that the difference between this time and the time the first batch was discharged would not give the true mixing time. This is because the load leaves the skip, and the operator holds it up for some little time waiting for all of the material to slide in, and perhaps he jerks it two or three times, and it is then dropped for a new load. Of course the concrete is being mixed before the skip comes down, so in the statistical study the element 1 on the first observation sheet (beginning at 8:00) has been divided into two parts according to data procured on the second and following sheets. That is, in this study, trials on sheets 2, 3, 4, and 5 are analyzed first, and the data procured on element 1 and 2 is used to divide element 1 on sheet 1 into two parts.

The third element (on all except first sheet) shows the difference in time between the time that the skip was down ready to be re-filled and the time of the first part of the batch out of the mixer into the concrete buggies. The times of element 2 and element 3 added together give the true mixing time of the least mixed concrete, while element 4 shows the length of time between the first and last batch out. This is quite large due to the fact that only 2 buggy men were used and they required some time to travel that 75 feet to the chutes. More could have been used for faster operation, but this was as fast as the handlers could place it.

For efficient mixer operation, there should be no delay between the emptying of the last batch and the raising of the skip with the new one. Observation showed that there was very often a delay which could be put down to one of two causes; the most important being that the skip was not yet loaded, and the second being due to the operator not quickly enough raising the skip. Because one of these things usually occurred, this time was inserted as an extra element, with a letter designating the reason and a subscript classifying the delay due to sand or gravel not being ready.

General layout.

Detail of pouring layout. Note extra mixer for breakdowns.

Pumps.

2--5"
1--2"

Statistical study of concreting operations.

1. Study of the elements:

Trial #2 (Sheet 2 of trial beginning at 8:00)

	Total time	Trials	Aver. time	Best time	Fair time
Element 1 (First load in)	2.35	12	.20	.15	.18
Element 2 (Skip down)	2.64	12	.22	.12	.17
Element 3 (First batch out)	15.00	13	1.15	1.00*	1.08
Element 4 (Last batch out)	17.05	13	1.31	1.10	1.20
Element 5 (Delay)	2.70	13	.21	.00	.10

Trial #3 (Sheet 1 & 2 of trial beginning at 10:45 added together)

Element 1	3.35	17	.20	.17	.18
2	2.82	17	.17	.12	.14
3	10.82	15	.72	.54*	.63
4	20.84	16	1.31	1.10	1.20
5	12.53**	16	.78**	.00	.39

Trial #4 (Sheet beginning at 1:00)

Element 1	1.05	6	.18	.10	.14
2	1.08	6	.18	.15	.16
3	6.87	6	1.15	1.00*	1.08
4	5.72	5	1.14	1.02	1.08
5	5.85**	5	1.17**	.00	.58

* -The best time of this element should not be considered as the least time. This is the main part of the mixing time and should be at least a minute. Nothing can be done in the way of improving methods or getting better workers to shorten this period. Therefore this time has been left out of calculations for fair time. The fair time has been calculated by subtracting from 1½ minutes (supposedly the least mixing time) the fair time of element 2 which is the other part of the true mixing time.

** -These totals show excessive delays due to the time needed

for changing direction of the concreting chutes. They do not show the average of delays for each trial, although computed as though they did. Rather these times show an average distribution of delay over the whole period. More will be said on this subject under "Study of the delayed time".

A summary of elements 1 & 2 of the preceding trials will now be made to determine a suitable percentage of division these two combined in trial #1. It will be noted that trials #2 & #3 are given a weight of 2 to 1 since they are about twice as long as the other one.

Element 1	Aver. time	Fair time	Weight
Trial #2	.40	.36	2
3	.40	.36	2
4	.18	.14	1
	.98	.86	5
Aver. time in min.	.20	.17	
Element 2			
Trial #2	.44	.34	2
3	.34	.28	2
4	.18	.16	1
	.96	.78	5
Aver. time in min.	.19	.16	
Percent of total of E1	51%	51%	
E2	49%	49%	

For purposes of division of elements 1 & 2 in trial #1, 50% for each will be taken.

Trial #1 (Sheet 1 of trial beginning at 8:00)

	Total time	Trials	Aver. time	Best time	Fair time
Element 1	2.79	13	.21	.15	.18
2	2.79	13	.21	.15	.18
3	12.66	13	.97	---*	---
4	16.26	13	1.25	1.06	1.16
5	6.90	13	.53	.00	.26

Summary of elements

Element 1	Average time	Best time	Fair time
Trial #1	.21	.15	.18
2	.20	.15	.18
3	.20	.17	.18
4	.18	.10	.14
	.79	.57	.68
Average for run	.20	.14	.17

Element 2			
Trial #1	.21	.15	.18
2	.22	.12	.17
3	.17	.12	.14
4	.18	.15	.16
	.78	.54	.65
Average for run	.195	.135	.16

Element 3	Average time only
Trial #1	.97
2	1.15
3	.72
4	1.14
	3.98
Average for run	1.00

(This element shows a great variation which should not be present under the circumstances as explained. The average of this time, added to that of element 2 is 1.20 minutes, and is the average time of mix for the first part of the batch.)

Element 4	Average time	Best time	Fair time
Trial #1	1.25	1.06	1.16
2	1.31	1.10	1.20
3	1.31	1.10	1.20
4	1.14	1.02	1.08
	5.01	4.28	4.64
Average for run	1.25	1.07	1.16

2. Study of the total times.

	Total time	Trials	Aver. time	Best time	Fair time
Trial #1	42.50	13	3.27	2.75	3.01
2	40.18	13	3.09	2.70	2.90
3*	44.08	15	2.94	2.25	2.60
4**	10.80	4	2.70	2.48	2.59
			12.00	10.18	11.10

* Including sheet 2, omitting #3 on sheet 1
** Omitting #2

Average time for 1 batch = 12.00/4 = 3.00 min.
Average of best times " " = 10.18/4 = 2.55 min.
Fair time for 1 batch = = 2.78 min.

These times are exclusive of large delays such as occured in those trials omitted above. These were usually due to changing the chutes and, while necessary, should not be included in the batch time. The above averages do include the delays of operation and of loading which are not necessary.

3. Study of the delayed time. (Element 5)

	Total time	Trials	Aver. time/batch
Trial #1	6.90	13	.53
2	2.70	13	.21
3	14.53	16	.91
4	5.85	5	1.17
			2.82

Average time/batch for all runs = 2.82/4 = .705 min.

This is high, including as it does all delays, necessary and unnecessary. If the delays due to change of chutes are eliminated, the following is shown:

Trial #1	6.90	13	.53
2	2.70	13	.21
3&4	5.88	19	.31
			1.05

Average time of actual unnecessary delay per batch equals 1.05/3 = .35 min.

Since the average time per batch is 3.00 minutes, the unnecessary delay proves to be .35/3.35 x 100 = 10.5%
This percentage should be as small as possible as it is waste time. This cannot be cut out entirely, but a comparison of this percentage with some other study, making due allowances for difference in conditions, will indicate the relative efficienty of the organization. This organization on this job can be considered good, as a good effort was put forth, the layout was good, and other conditions as noted before.

Other items of interest to the contractor and time study man can be found from these figures. The contractor will no doubt be more interested in the number of batches which he has put out in a certain elapsed time, regardless of divisions for study purposes. This information is given here. The sum of all the total times = 42.50 plus 40.18 plus 45.22 plus 8.31 plus 19.50 = 155.70 minutes, elapsed time during the studies. The number of batches was 47. Therefore the average time per batch was 3.32 minutes, and each batch constituted approximately 16 cubic feet of dry mix.

Another thing interesting to the contractor in the interests of better proportioning of men is the percent of delay due to the lateness of sand or of gravel. Therefore the delays due to these causes can be separated. The sum of the delays due to lateness of gravel in all the trials is 8.45 minutes. The delay due to lateness of the sand is 3.09 minutes. In percent of the total due to these causes, the gravel was 73% of the time behind. Whether another man should be put on to cut down this time is problematical. A little harder work on the part of the gravel workers would often have cut this delay down, and another man would probably have added disproportionately to the cost, since the concrete was coming then about as fast as those placing it could handle it.

Trial 1

Time started 8:00 A.M.

Time finished

Sheet No. 1 of

No. of men involved
2 - sand
3 - gravel
~~1 - cement~~
1 - mixer op.
2 - buggy men

9 men handling & placing + foreman + superintendent

Name of Operation

Concrete Batches

Mix:
4 bgs. cement (=6.6 bgs./yd.); 138# (16.6 gal. water

Conditions. 4 barrows stone @ 297#
3 " sand @ 266#
1½ min. in mixer.
Buggy haul = 75'
Weather - Cool & Fair

Elements	Load-Skip up & down		1st Batch out		Last batch out		Delay between Last & raise skip				Totals		Delays	
No	1&2		3		4		5						No.	Cause
Trial	T	R	T	R	T	R	T	R	T	R	T	R		
1	.34	0.00 .34	.60	.94	1.06	3.00	.34	3.34	A	Extra man to adjust wt. added here.	2.34		A	Operator
2	.31	3.75	.80	4.55	1.45	6.00	.75	6.75	B_G		3.31		B	Skip not loaded due to B_S - sand late
3	.38	7.13	.59	7.72	1.13	8.85	1.90	10.75	B_G		4.00		C	B_G - stone "
4	.45	11.20	.84	12.04	2.01	14.05	.25	14.30	B_G		3.55		D	
5	.45	14.75	1.42	16.17	1.13	17.30	.34	17.64	A		3.34		E	
6	.41	18.05	1.29	19.34	1.16	20.50	.50	21.00	B_S		3.36		F	
7	.41	21.41	.99	22.40	1.20	23.60	.45	24.05	B_G		3.05		G	
8	.60	24.65	1.15	25.80	1.20	27.00	.40	27.40	A		3.35		H	
9	.35	27.75	1.08	28.83	1.17	30.00	.35	0.00 0.35	B_G		2.95		I	
10	.45	0.80	1.20	2.00	1.20	3.20	.05	3.25	A	Wt. adjuster missing	2.90		J	
11	.45	3.70	1.20	4.90	1.10	6.00	0	6.00	—		2.75		K	
12	.58	6.58	.87	7.45	1.35	8.80	.42	9.22	A		3.22		L	
13	.40	9.62	.63	10.25	1.10	11.35	1.15	12.50	B_S		3.28		M	
T	5.58		12.66		16.26		6.90				42.50		N	

Trial 2

Time started ____________

Time finished ____________

Sheet No. 2 of ____

Name of Operation

Same

No. of men involved Same

Conditions.

Same

Elements	Load in		Skip down		1st batch out		Last batch out		Delay between last + raise		Totals			Delays	
No	1		2		3		4		5						
Trial	T	R	T	R	T	R	T	R	T	R	T	R		No.	Cause
1	—	[illegible]	.37	12.87 0.00	.70	0.00 0.70	1.30	2.00	1.00	3.00	B 3.37		A		
2	.20	3.20	.25	3.45	1.20	4.65	1.25	5.90	0	5.90	2.90		B	B,	- cement not in
3	.26	6.16	.25	6.41	1.19	7.60	1.30	8.90	.95	9.85	C 3.95	st. adj. back.	C		Instructions to operater
4	.15	10.00	.30	10.30	1.20	11.50	1.10	12.60	0	—	2.75		D		shift chute ← 1.0 buggies held up
5	.18	12.78	.25	13.03	1.41	14.50	1.20	15.70	0	—	3.10		E		
6	.15	15.85	.15	16.00	1.17	17.17	1.23	18.40	0	—	2.70		F		
7	.27	18.67	.21	18.88	1.22	20.10	1.25	21.35	.35	21.70	B,	3 30	G		
8	.15	21.85	.20	22.05	1.20	23.25	1.19	24.44	0	—		2.74	H		
9	.21	24.65	.22	24.87	1.06	25.93 26.00 27.00 D	1.90	28.90	0	—		3.46	I		
10	.20	29.10	.12	29.22	1.11	30.33	1.42	31.75	.05	31.80	A	2.90	J		
11	.20	32.00	.21	32.21 0.00	1.00	1.00	1.30	2.36	.20	2.50	A	2.91	K		
12	.18	2.68	.24	2.92	1.26	4.18	1.37	5.55	.05	5.60	A	3.10	L		
13	.20	5.80	.24	6.04	1.22	7.26	1.24	8.50	.10	8.60	A	3.00	M		
T	2.35 (12)		2.64 (12)		15.60		17.05		2.70			40.18	N		

Trial 3

Time started 10:45 A.M.

Time finished

Sheet No. 1 of

Name of Operation Same

No. of men involved Same + 1 more to bring up cement. & tie sacks

Conditions.

3 buggy loads - full

Elements No Trial	Load in		skip down		1st batch out		Last batch out		Delay between last & raise		Totals		Delays	
	T	R	T	R	T	R	T	R	T	R	T	R	No.	Cause
1	.17	0.00 0.17	.14	.31	.94	1.25	1.20	2.45	.16	2.61	A	2.61	A	Operator
2	.19	2.80	.15	2.95	.75	3.70	1.10	4.80	1.00	5.80	B_G	3.19	B	Skip not loaded
3	.18	5.98	.22	6.20	1.20	7.40	1.20	8.60	6.65	15.25	B_G & C	9.45	C	change chute
4	.20	15.45	.15	15.60	.80	16.40	1.60	18.00	0	—		2.75	D	
5	.25	18.25	.20	18.45	.60	19.05	1.45	20.50	0.63	21.13	B_G	3.13	E	
6	.17	21.30	.21	21.51	.64	22.15	1.25	23.40	.65	24.05	B_G	2.92	F	
7	.17	24.22	.17	24.39	.71	25.10	1.45	26.55	.40	26.95	B_G	2.90	G	
8	.23	27.18	.17	27.35	.65	28.00	1.40	29.40	.65	30.05	B_G	3.10	H	
9	.17	30.22	.12	.34	.58	30.92	1.23	32.15	.60	32.75	B_S	2.70	I	
10	.17	32.92	.16	33.08	.62	3.70	1.30	5.00	0	—		2.25	J	
11	.27	5.27	.13	5.40	.71	6.11	1.64	7.75	.37	8.12	B_S	3.12	K	
12	.21	8.33	.15	8.48	C 3.47	11.95	.60	12.55	0	—		4.43	L	
13	.17	12.72	.23	12.95	.65	~~14.15~~ 13.60	1.20	14.80	.42	15.22	B	2.67	M	
T	2.55		2.20		8.85 (12)		16.62		11.53			45.22	N	

Trial 3 (cont.)

Time started

Time finished

Sheet No. 2 of (10:45)

Name of Operation

Same

No. of men involved Same

Conditions. Same

Elements	1		2		3		4		5		Totals			Delays	
No Trial	T	R	T	R	T	R	T	R	T	R	T	R		No.	Cause
1	.20	15.42	.13	15.55	.80	16.35	1.30	17.65	0	—		2.43	A		
2	.25	17.90	.22	18.12	.63	18.75	1.50	20.25	.47	20.72	B_s	3.07	B		
3	.18	20.90	.14	21.04	.54	21.58	1.42	23.00	.53	23.53	B_c	2.81	C		
4	.17	23.70	.13	23.83		Dinner							D		
5													E		
6													F		
7													G		
8													H		
9													I		
10													J		
11													K		
12													L		
13													M		
T	.80		.62		1.97 (3)		4.22 (3)		1.00 (3)			8.31	N		

Trial 4

Time started 1:00 P.M.

Time finished

Sheet No. of

No. of men involved
2-sand
4-Gravel
weigher
Cement man
Mixer op.
2 buggy men

Name of Operation

Pour concrete

Conditions.

Elements No	1		2		3		4		5		Totals		Delays No.	Cause
Trial	T	R	T	R	T	R	T	R	T	R	T	R		
1	.10	0.00 0.10	.18	.28	1.49	1.75	1.20	2.95	0.10	—		2.95	A	operator
2	.17	3.12	.18	3.30	1.30	4.60	1.20	5.80	5.85	11.65	C	8.20	B	Skip not loaded
3	.15	11.80	.20	12.00	1.15	13.15	1.02	14.17	0	—		2.52	C	change chute
4	.28	14.45	.15	14.60	1.00	15.60	1.05	16.65	0	—		2.48	D	
5	.17	16.82	.18	17.00	1.25	18.25	1.25	19.50	0	—		2.85	E	
6	.18	19.68	.19	19.87	.68	20.55	Last Batch waited for instructions						F	
7													G	
8													H	
9													I	
10													J	
11													K	
12													L	
13													M	
T	1.05		1.08		6.87		5.72 (5)		5.85 (5)			19.50	N	

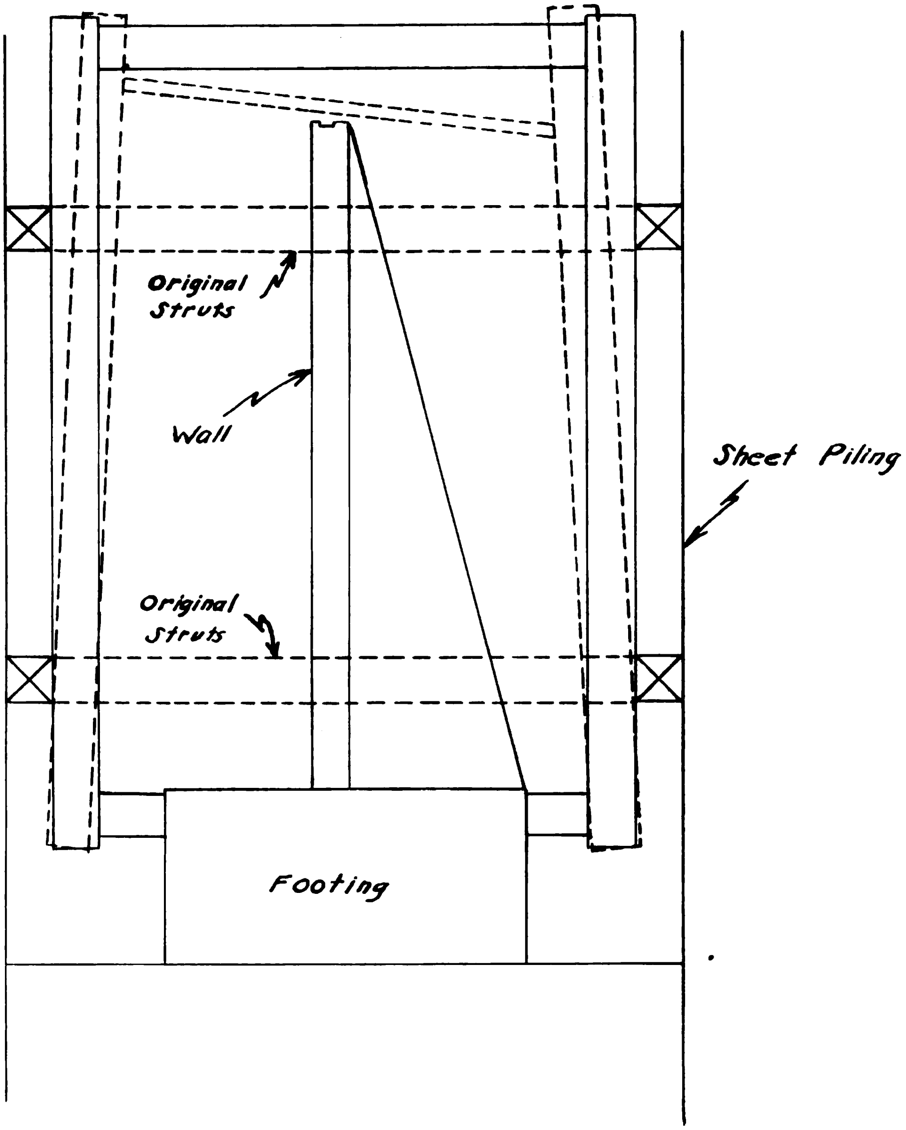
IV

SOME DETAILS OF CONSTRUCTION

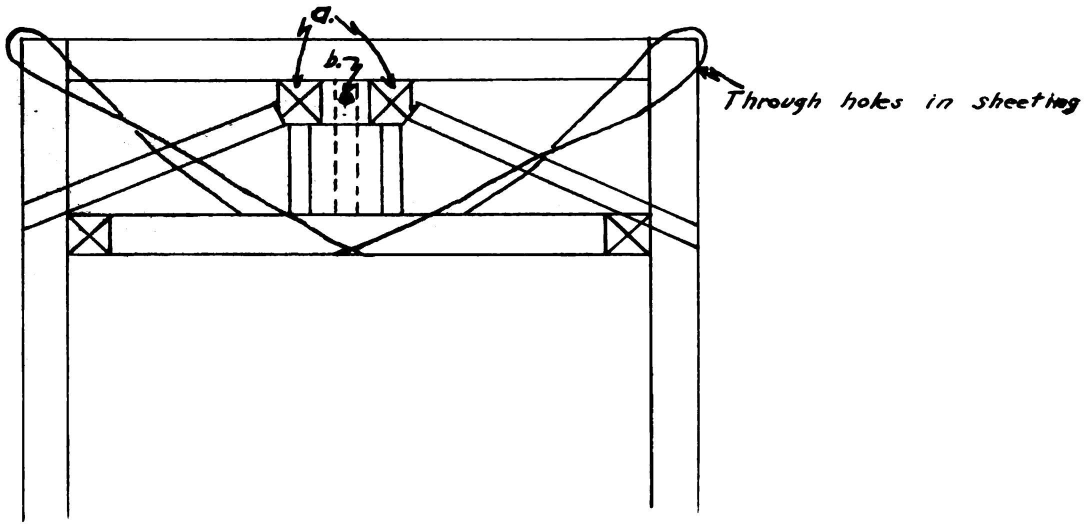
The cofferdam construction was of the usual type of bracing (walers and struts) for the pouring of the footing. The counterforted wall extended higher than the piling, and since the state would not allow the struts to be boxed through the wall while it was being poured, another method had to be chosen to reinforce the cofferdam walls. Therefore' the method to be described was used. (See drawing A)

After the footing was poured, the change of bracing was begun. The scheme was to carry the pressure of the cofferdam by upright posts amounting to vertical beams supported laterally by short braces on either side of the poured foundation and at the upper end a timber between the two opposite posts high enough to clear the height of wall to be poured. These vertical posts then carry the pressure through the walers which give the posts two comparatively concentrated loads. Since the greatest pressure comes on the lower set of walers, extreme care must be taken to see that a good full bearing is had by the walers on the post. To obtain this, the vertical posts are set in at a small angle leaning in from the top, and held in place by a piece of 2 x 4 between opposite posts. The piece of 12 x 12 timber was then cut to the proper length to be placed between the footing and the lower end of the post. Then the heavy cross timber between opposite posts was forced into place with blows of a sledge hammer. This timber forced the vertical posts against the walers and assured a good bearing on the lower set.

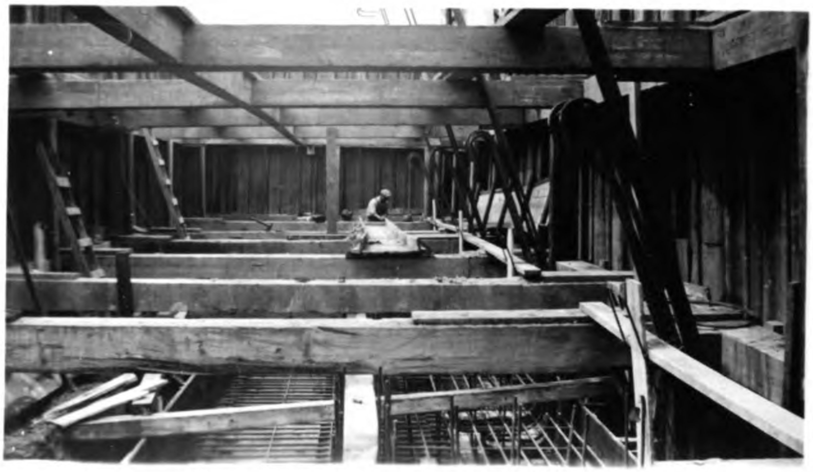
"A"


Original Struts
Wall
Sheet Piling
Original Struts
Footing

"B"


a.
b.
b.
Through holes in sheeting

Regular method of bracing.



Struts and walers plus some reinforcing steel.

New method of bracing end of coffer. Note upright posts.

The corners and ends of the cofferdam were secured by two vertical posts "a" (in drawing B), and separated by a short block B about 2 feet long in order to leave the original strut (shown in dotted lines) in until the new bracing was erected. These were braced at their lower end in a manner similar to the other vertical posts, but differently at the upper ends. One strut was left in near the end of the cofferdam, as it was not interfering with the wall construction. The two verticals were braced by short timbers to this strut, and the strut held in turn by a $\frac{3}{4}$" steel cable pulled tight by a turn-buckle. The manner of placing the cable is shown in the drawing. In addition, these center timbers were braced for any possible sidewise motion by means of two lateral timbers placed at an angle and set against the sheet piling as shown.

Another detail of interest is in the anchoring of the vertical posts on one side of the cofferdam. On this side due to a change in design, there was no room to place the posts down between the walls of the cofferdam and the footing, and some other system of supporting the lower end had to be devised. It was done by the use of angles and bolts as shown in drawing C. The vertical posts were set down on top of the footing as shown. Then two angles about two feet long were attached to the back side of the timber by 2 bolts which carried through to a face plate on the front side of the timber. The angles extended beyond the timber about a foot and had their bearing on the footing. All dimensions for the angles and bolts are shown on the drawing.

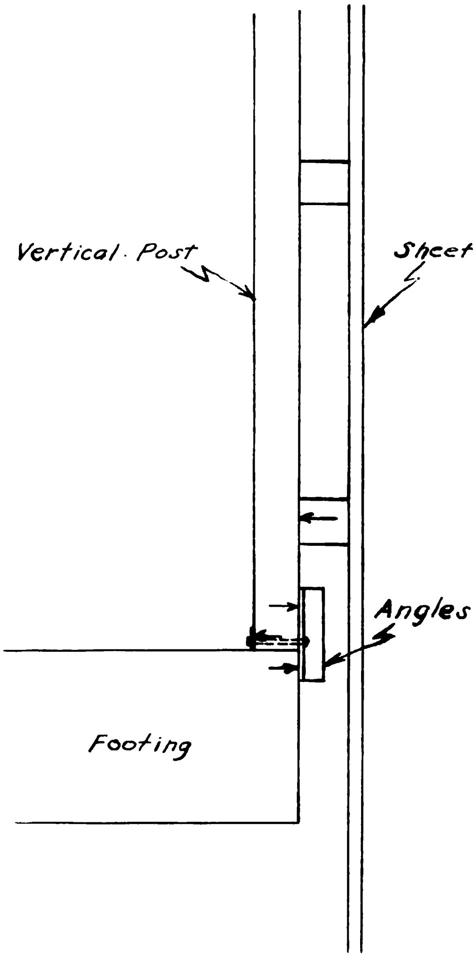
The working trestle for carrying the 32 ton crane and its

loads is also of interest. It consisted of a series of 4 pile bents spaced 13 feet apart with sway bracing and a 12 x 12 cap. The stringers were 12 x 12 and 10 x 12 timbers with a 12" I-beam under each tread. It requires only two sets of these heavy stringers, as they can be moved ahead as necessary. Of course lighter stringers and floor boards are used to form a runway for concrete and other materials. Longitudinal sway bracing was used on every fourth bay only, the trestle being held together by this bracing and two of the 12 x 12 stringers bolted to the cap for every bay. This is an item of importance as trestles are often built with lengthwise bracing in every bay, which is costly and unnecessary.

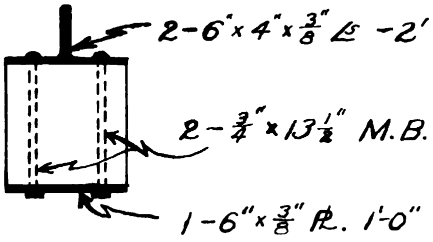
All forms used for concrete were built in sections so as to be re-used later on in other parts of the work. Universal form clamps with ½" bars were used to tie the forms together. The wall was 18" thick, and the number of clamps necessary was figured on a pouring rate of about 4 feet per hour. While the pressure is greatest at the bottom of the wall and is increased by the impact of the concrete falling 15 feet, the number of clamps to be used per square foot can be less than the number called for by considering the full height of the wall because the concrete acquires an initial set long before the whole height is poured, thereby taking the strain off of the forms.

In tying reinforcing steel, it is necessary to hold it in place while doing so. An experienced hand can easily hold it in place and tie it at the same time, but on this job this was not the case, as only one man had ever done this work before.

"C"



Elevation



Cross-section of post at bolt plate

So a simple method was used for holding the horizontal steel in its proper position against the vertical steel while being tied. Pieces of 2 x 4 were marked off with the proper spacing of the steel, and spikes driven at these markings. The 2 x 4's were then placed vertically at intervals along the line of steel, and each bar laid across the respective spikes which held it accurately until tied.

On this job, during the excavation a large sandboil started in the middle of the night. This boil was a stream of water evidently coming through a gravel seam just under the lower edge of the sheeting, while the top of the sheeting was still six or seven feet above the water level. The pumps couldn't keep up with the stream of water, and the sides of the dam were apt to give way due to the loss of bearing around this seam, so the cofferdam was allowed to fill up, the piling was driven several more feet along that side, and the hole plugged with sandbags. This adequately cared for the emergency, and no further trouble was encountered.

The last item of general interest to be inserted is that a gas operated crane should never by used for this type of work, or any other industrial work. It lacks the smoothness of operation of steam, depending as it does upon the brake for control of the load, while steam would give power control of the load. Smoothness and ease and accuracy of control are essential, since it would be highly dangerous to knock any strut out of a cofferdam, or to lose control of any heavy object with men below.

New method of bracing with vertical posts and overhead struts. Note bracing against footing.

Reinforcing steel. Large rods at an angle are for counterforts.

Building up the trestle.

V

CONCLUSION

The author has attempted to branch into a new field for the time study man. This thesis makes no attempt to inquire into rate-setting which is the chief value of industrial time studies. Rather it shows the actual time values of as many construction operations as time permitted, and only of those which were apt to be repeated again in approximately the same manner. The detailed setting forth of each operation has been given partly for use in the time study and partly as a construction methods study. Every effort has been made to give the best averages - those which come closest to the actual facts, and to give explanations and suggestions concerning the use of the studies.

The close observation necessary to take these times force upon the observer an excellent opportunity to see details and to study methods which otherwise might be missed. The greatest value therefore lies in the experience gained by the observer, concerning how much work men can do and the methods of doing it.

It is sincerely hoped that someone will take up this idea and carry it on by further investigation in the construction field, or comparison of these results to results on a similar job. It is felt that a series of theses such as this one will prove of real value both in time comparisons and job methods.