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FIELD STUDY OF THE HANDLING CHARACTERISTICS OF MC CONCRETE

R.B. KRUM, COMDR. (CEC) USN
THEODORE ROCKWELL III

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Technical Division

Section IV, Engineering Materials

F. Kerze, Section Chief

FIELD STUDY OF THE HANDLING CHARACTERISTICS OF MO CONCRETE

Problem Assignment No. TD-39

R. B. Krum, Comdr., CEC, USN

T. Rockwell, III

Period of Test: Aug. 16-19, 1948

Date Issued

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FIELD STUDY OF THE HANDLING CHARACTERISTICS OF MO CONCRETE

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FIELD STUDY OF THE HANDLING CHARACTERISTICS OF MO CONCRETE

ABSTRACT

A field study was made on the handling characteristics of MO concrete, a new type of concrete containing magnesium oxychloride cement with iron aggregate. Despite some difficulties which arose during the test, the material shows promise in the handling of large quantities by conventional methods. This work is being continued at the new ORNL shielding laboratory in Y-12.

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FIELD STUDY OF THE HANDLING CHARACTERISTICS OF MO CONCRETE

Introduction

There is very little information available on the batching, mixing and pouring characteristics of MO concrete, (magnesium oxychloride cement with iron aggregate) using conventional construction equipment on work involving field scale quantities. In an effort to find some of the answers the Oak Ridge National Laboratory initiated a field test project, the original scope of which is outlined in Appendix A.

Procedure and Equipment

For reasons of practicality or expediency several changes were made in Appendix A during the tests. Weight batching equipment was not used. Ordinary 55 gallon steel drums were used for magnesium chloride solution mixing and storage, rather than a stainless steel tank. Compression test samples were not made, nor were temperature measurements taken. Because of the possibility of the future use of MO concrete in Pumpcrete equipment it was decided to investigate its pumping characteristics. The horizontal pipes installed in the columns were spaced on eight inch centers vertically throughout instead of at two, four, six, etc. feet from the bottom. On the MO tremie column (Suggested Tests, c, Appendix A) the horizontal pipes were held accurately in position by two steel channel jigs.

A type No. 200 Pumpcrete, with a three cubic yard pugmill, and twin reciprocating pumps (only one of which was used) powered by a 50 HP electric motor was installed on a low-bed trailer at the foot of a bank. A single eight inch steel discharge line extended from the Pumpcrete for a distance of approximately 300 feet up the hill. The difference in elevation between the pump and the pipe discharge end was 45 feet.

In the batching yard the equipment consisted of one four cubic yard transit truck mixer, one 15 ton truck crane, two concrete pouring buckets and one portable electric agitator.

Batching and Mixing

Batching methods were relatively slow and crude since it was not feasible to establish a bulk batching plant. The steel punchings were premeasured into steel drums with approximately 1000 pounds of punchings per drum. The balance of the materials were bagged with manufacturers' weights indicated thereon. The punchings and shot were emptied into a concrete pouring bucket which in turn was emptied into the truck mixer. Bags of oxide were stacked and hoisted to the top of the truck mixer and there opened and dumped into the mixer. The chloride solution was mixed (by means of a portable electric agitator) in drums equipped with a valved spout near the bottom. Then the drums

[redacted]

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were hoisted to the top of the truck mixer and emptied.

Although the specific gravity of MO concrete is a little more than two and one-half times that of PC (Portland Cement) concrete, it was found that the truck mixer would not handle a volume of MO concrete determined by inverting this ratio. In other words, a four cubic yard PC concrete mixer would only mix one cubic yard of MO concrete. This was largely due to a concentration of the load in the drum at a greater-than-normal lever arm. The mix for one cubic yard of MO concrete was as follows:

780 lbs. MgO
4780 lbs. steel punchings, ca. 3/4" dia.
2160 lbs. steel shot 1/8"
1440 lbs. steel shot 1/20"
76.5 gal. $MgCl_2$ solution, Sp. G. 1.3 (33.5° Be)

Pumping

Following routine pumping practice for PC concrete, a small load (about 1100 lbs.) of magnesium oxychloride motar using fine shot, MgO and $MgCl_2$ solution was first placed in the Pumpcrete machine. This was followed by two, one cubic yard loads of MO concrete, the slump of which was 7-1/2" and 8" respectively. From time to time between loads the operator ran the machine for a few test strokes of the pump. The Pumpcrete appeared to be functioning properly. However, when the third cubic yard of MO was about to arrive and efforts were made to pump continuously it appeared that the machine was not developing sufficient power either to move the concrete or snap the flywheel shear pins. At this time the concrete, although somewhat stiff, was fairly workable. Much time was spent in an effort to obtain full power from the machine, ending in the unfortunate results set forth in more detail in Appendix C.

Vibration Tests

In order to investigate the action of internal vibration on MO concrete, one load of concrete was distributed among four forms. The forms were two-foot cubes. In addition to the above mentioned batching equipment, an internal air vibrator and an air compressor were used. Maximum vibration time was estimated visually as the time at which about 3/4" of neat cement had risen to the top of the form. The forms were later stripped and the cubes were fractured with a pneumatic pavement breaker. The concrete was then examined to determine the effect of vibration time on segregation and voids. The results are shown on the following pages.

[redacted]

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VIBRATION TIME - NONE

No voids or honeycomb evidenced on faces of cube except for about 2 sq. in. at two of the bottom corners. No internal voids apparent on breaking-up. This specimen was the most difficult to fracture.

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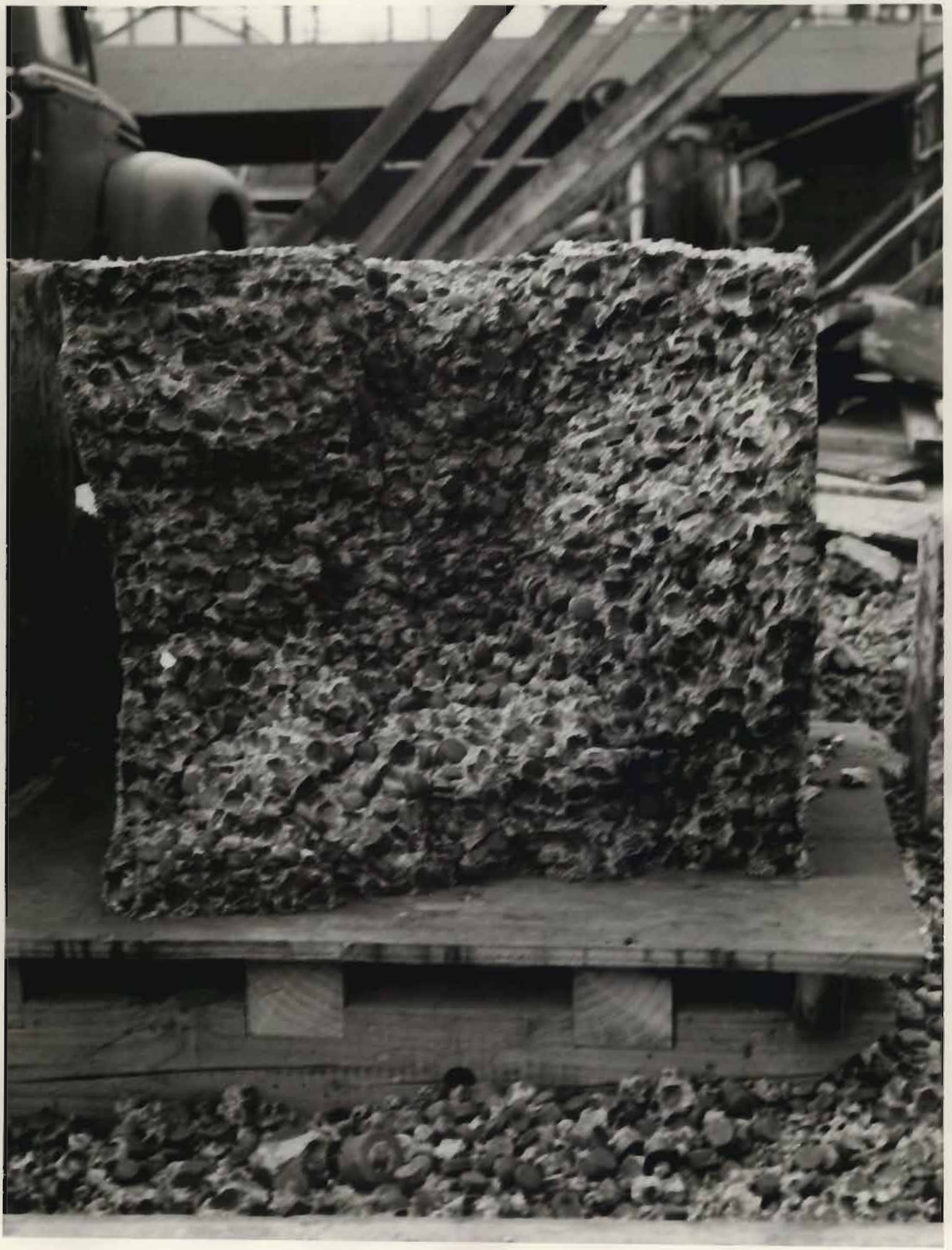

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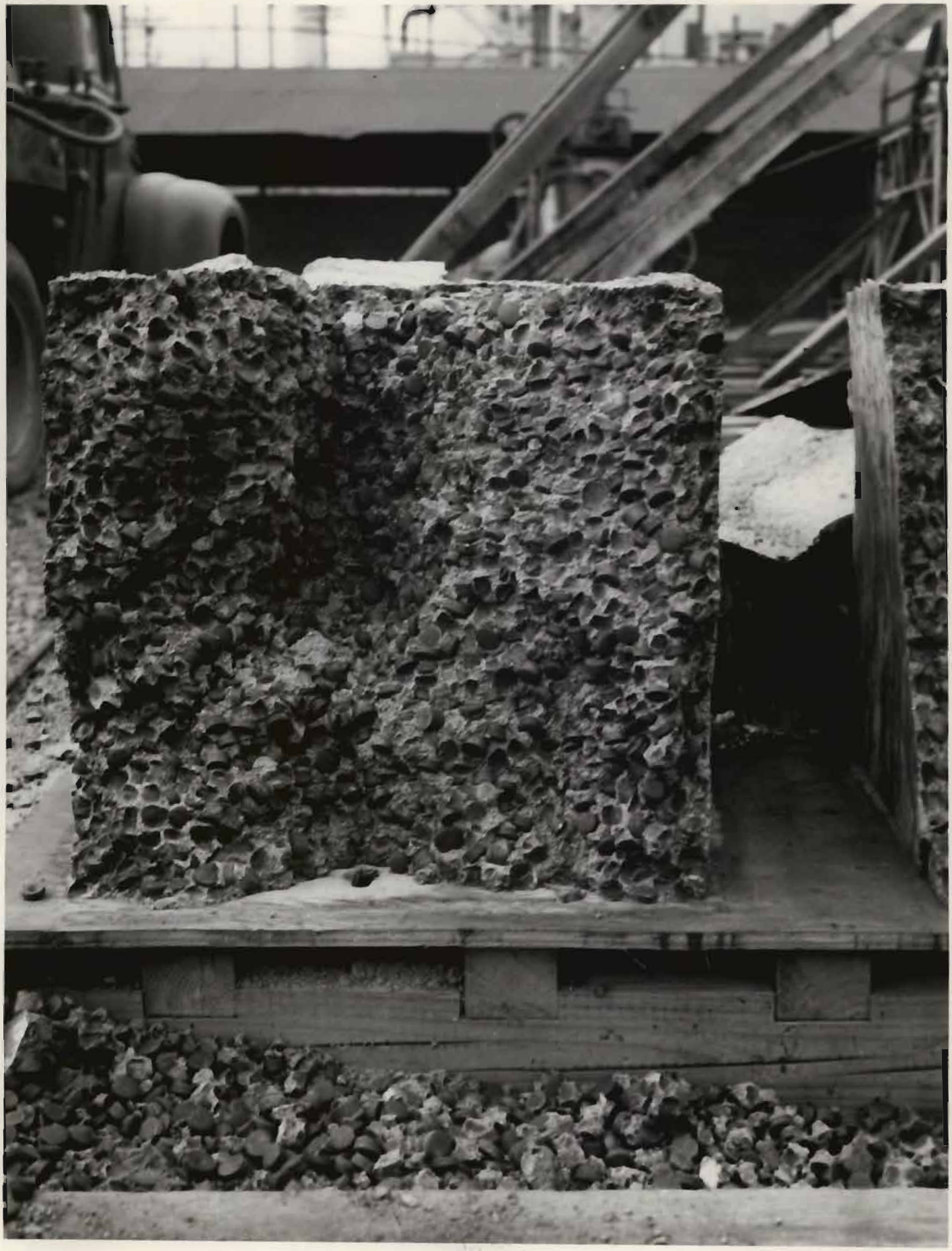
VIBRATION TIME - ONE MINUTE

No voids or honeycomb. No segregation of the coarse aggregate.

[redacted]



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VIBRATION TIME - TWO MINUTES

No voids or honeycombs. No appreciable segregation of the coarse aggregate except for a 1 to 1-1/2" layer at the top which contained no coarse aggregate.

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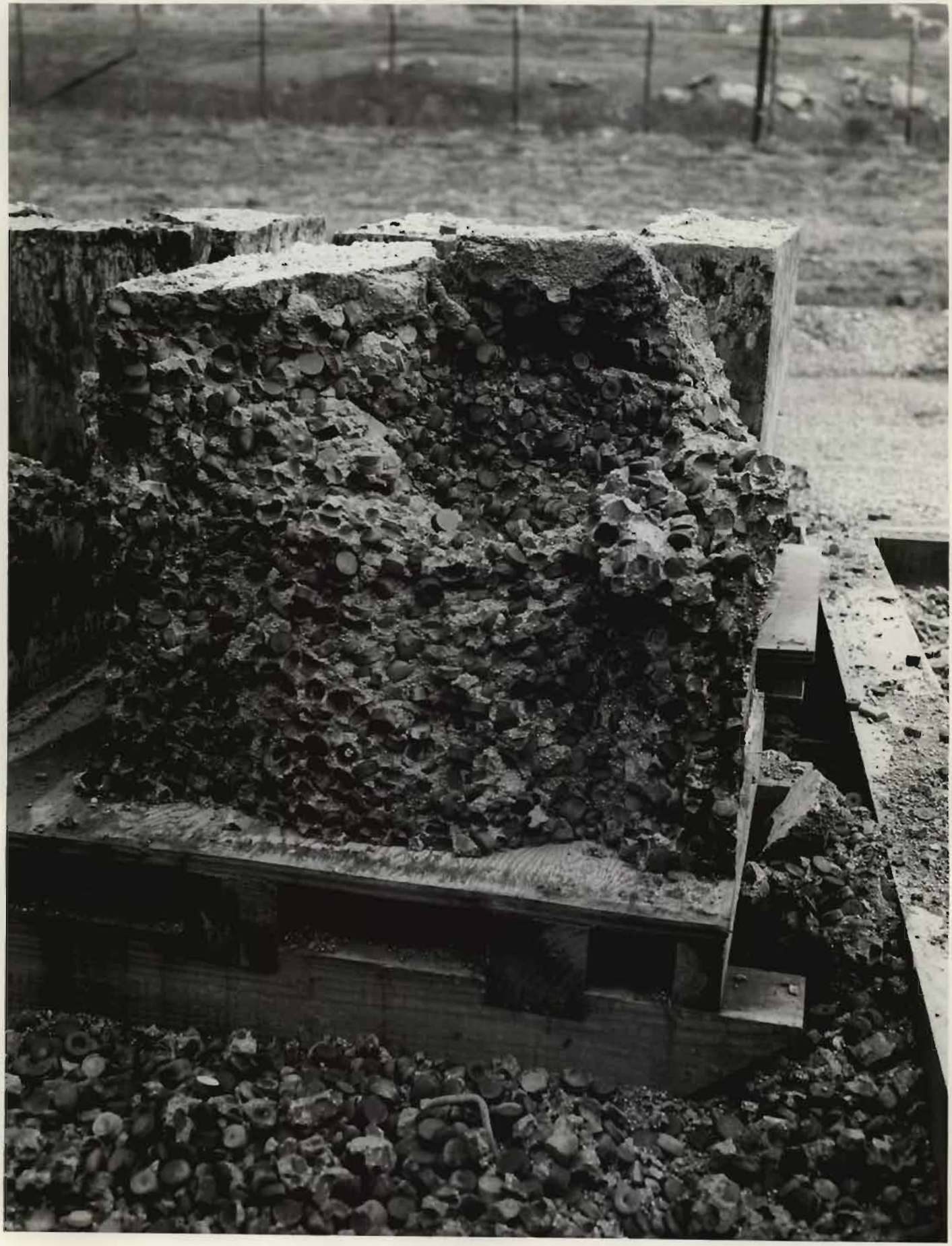


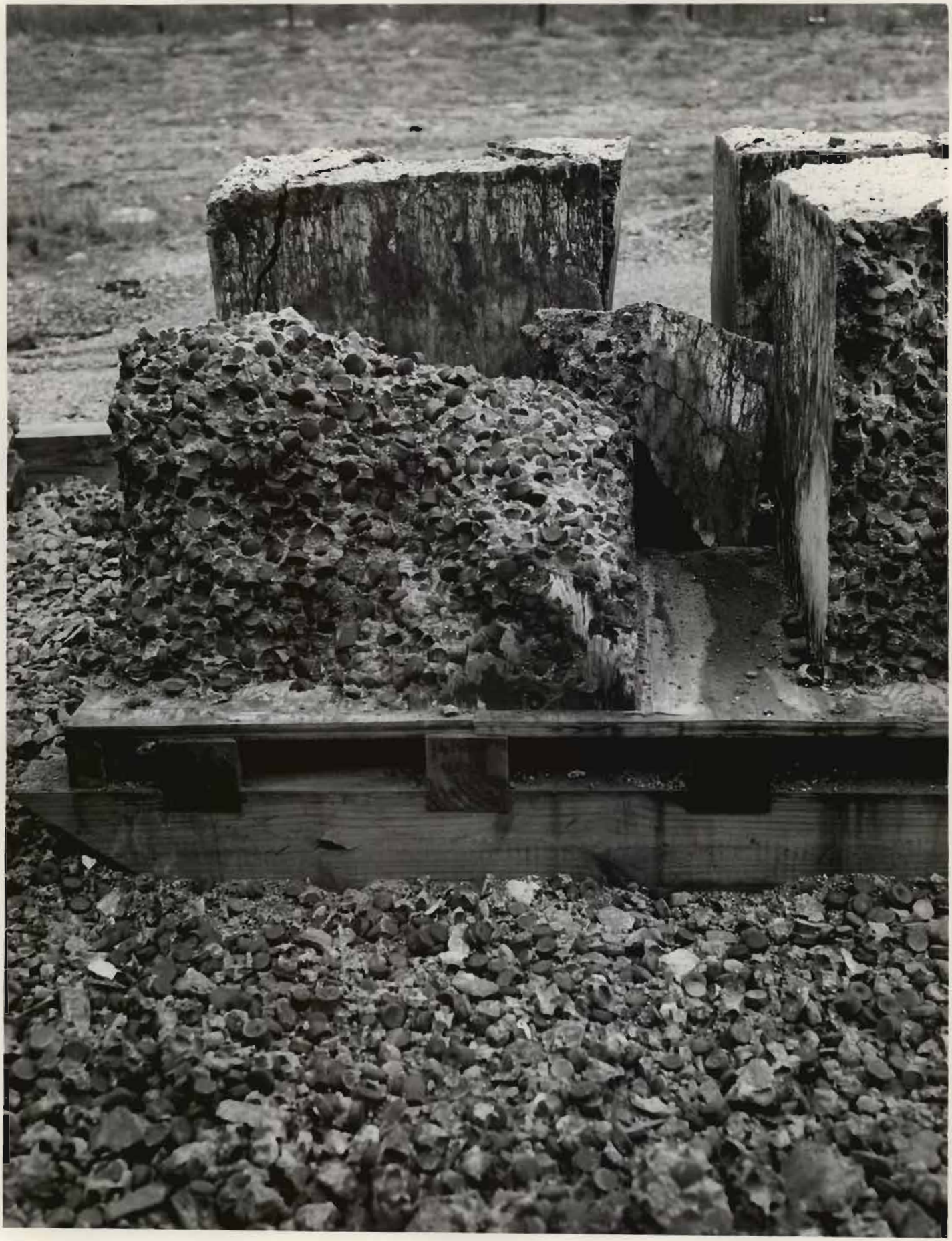
[redacted]

VIBRATION TIME - THREE MINUTES

No voids or honeycomb. No so-called "sandstreaks" on the faces of the specimen. No appreciable segregation of the coarse aggregate except for a 2 to 2-1/2" layer at the top which contained practically no coarse aggregate.

This specimen fractured more readily than the other three. The entire top portion broke off so that it was necessary to take two pictures in an attempt to show as much as possible of a vertical section. The first of the two following pictures shows the bottom portion of the cube. The second picture shows a top corner portion lying on its side on the ground.

[redacted]



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Column Tests

As indicated in Appendix A, plywood forms containing horizontal pipe sleeves were erected for four columns. Into the first column, PC concrete was poured, beginning with a free fall of eight feet and decreasing at two foot intervals to a free fall of one foot at the top of the column. On the next column PC concrete was poured by means of a tremie pipe. Internal vibration was used in these columns. The concrete was conventional PC concrete (approximately 3000 psi) with crushed stone and sand aggregate. These two columns were poured without unusual incident.

An attempt was made to pour the last two columns with MO concrete but in each case only about a quarter of the column was actually poured and the balance of the mixer loads had to be discarded. Between about 1/2 hour and 1-1/2 hours after adding $MgCl_2$ to the mix, the concrete became so stiff that it would not flow down a chute or through a pouring bucket. Neither was it sufficiently workable to flow into place around the pipe sleeves. However, the concrete was plastic and could be readily penetrated and worked by tools or even by hand. An internal pneumatic vibrator would punch a hole into the concrete but would not make it flow. The time at which this loss of workability occurred was so erratic that it was decided to postpone the completion of this test until a slower, more stable and more uniformly reacting magnesium oxide could be found. The Westvaco Chemical Corporation (one of the members of the Oxychloride Cement Association) is endeavoring to find a more suitable magnesium oxide for this work.

Conclusions

In spite of the apparently discouraging results of this study, it can be said that all the difficulties appear to be capable of solution, and once successfully solved the other more-favorable working characteristics of MO concrete mentioned later offer definite advantages.

In planning a field job with MO concrete, careful consideration must be given to the capacity limitations of the construction equipment. All personnel concerned should be indoctrinated in the working characteristics of a new material, especially since many will have inapplicable ideas ingrained from years of practical experience with conventional concrete. These precautions coupled with alert supervision should prevent losses from batches "setting up" in the equipment. However, the most important problem to be solved (and presently under investigation) is the provision of a reliable magnesium oxide which will have a sufficiently slow reaction time to give a reasonable and reliable working period for the mixed concrete. It appears that the provision of such an oxide is merely a matter of a moderate amount of further investigation.

[redacted]

[redacted]

During the workable period of MO concrete, the material has a good consistency and adequate flow characteristics. Despite an abnormally high slump compared to PC concrete there is practically no segregation of the aggregates. For these reasons MO concrete appears to be an excellent material for pumping in spite of the harshness of steel aggregates.

Although the number of specimens studied in the vibration tests are few in number, it appears that properly workable MO concrete requires very little vibration in placing. Prolonged vibration forced some mortar out through the joints in the form and displaced some mortar to the top of the form, thereby apparently weakening the specimen so that it was more readily fractured. However, prolonged vibration caused no "sand streaks" and produced considerably less segregation of the coarse aggregate than might be expected with PC concrete.

R. B. Krum

T. Rockwell

Approved by:

F. Kerze

[redacted]

[redacted]

ACKNOWLEDGMENTS

The writers wish to acknowledge the assistance and cooperation of the ORNL Engineering and Maintenance Division, particularly the field personnel who, on relatively short notice, willingly spent long overtime hours on the job.

The writers further wish to acknowledge the assitance and cooperation of the Oxychloride Cement Association of Washington, D.C., and The Martin Machinery and Supply Company, Knoxville, Tennessee.

[redacted]

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APPENDIX A

OAK RIDGE NATIONAL LABORATORY

INTER-COMPANY CORRESPONDENCE

July 1, 1948

To: J. C. Stewart

From: S. McLain

Subject: Pouring and Strength Tests of MO Concrete

It is requested that facilities be furnished and assitance be rendered the Technical Division in conducting pouring and strength tests on MO concrete.

MO concrete has been developed for use in shielding reactors, shipping containers, etc. It consists of magnesium oxychloride cement, or Sorel's cement, and iron punchings and shot as aggregate. A description of this concrete with its properties was given in ORNL Report No. 17, "Engineering Data on "MO" Shielding Concretes and Boron (Thermal Shield) Cement," by T. Rockwell and F. J. Roehrenbeck dated March 17, 1948. The concrete which we desire to have poured has the following composition:

MgO	162-1/2	lb.
Steel Punchings, 3/4" x 3/4"	1000	lb.
Steel Shot, 1/8"	450	lb.
Steel Shot, 1/20"	300	lb.
Saturated Solution $MgCl_2$(32° Be)	16	gal.

This concrete differs from normal concrete mainly in its specific gravity and time and manner of setting. Ordinary concrete has an initial set in two to four hours and a final set in twenty-four hours or more. MO concrete has an initial set in two to three hours and reaches full strength in twenty-four to forty-eight hours. The specific gravity of the MO concrete is 5.80 as compared with 2.3 for ordinary concrete.

Since small scale tests only have been made to date, there is no information available on the practical aspects of large scale pouring tests. We need additional information on all phases of such tests as listed in the following paragraphs:

a. Forms. All forms must be designed much heavier because of the higher specific gravity of the concrete. No special precautions need be taken in respect to stripping the forms as both wood and steel strip readily.

[redacted]

[redacted]

J. C. Stewart from McLain July 1, 1948

b. Raw Materials Handling. No difficulty is foreseen relative to raw materials handling.

c. Mixing. Batching, weighing, and dry mixing are expected to be similar to normal concrete except that the batch size must be cut down one half because of the greater density of the concrete.

d. Wet mixing. The addition of the magnesium chloride solution and wet mixing are expected to be similar to water addition in ordinary concrete mixing.

e. Slump tests. The slump of the MO concrete will be about three inches. The MO concrete is considerably more viscous than ordinary concrete. Slump tests should be made at each pouring.

f. Pouring. Smaller amounts must be handled than in ordinary work. We wish to obtain as much information as possible from this part of the test. We desire especially, information concerning the distance the raw concrete may be dropped without affecting segregation.

g. Vibration. We have no information concerning the amount of vibration necessary to obtain good concrete. In fact one of the tests requested is designed to evaluate this point.

h. Segregation. Considerable segregation is anticipated in the MO concrete dropped excessive distances or in the concrete given excessive vibration. This also is one of the most important items to be investigated.

i. Test samples. Test samples from each pour should be made for the standard compression tests.

j. Temperatures. Thermocouples will be placed in the center of the small scale tests to measure the temperature rise due to the heat of setting.

k. Working properties. Detailed data and visual observations on the working properties of the MO concrete in comparison with regular concrete are desired. The times required for mixing, ease of cleaning of the mixers and tools, ease of removal and appearance of the forms are desired.

l. Equipment. We would like to have the concrete mixed and handled in regular equipment in order to determine what difficulties will be encountered in practice. We suggest the use of batching and weighing equipment, a stainless steel storage tank for the magnesium chloride solution, a transit mix truck, a truck or crawler crane equipped with a suitable concrete

[redacted]

pouring bucket, suitable tremie piping, and an air vibrator. The pouring bucket should either have a small pouring mouth or be provided with a hopper and funnel. Information concerning the adequacy of this equipment is an important part of the test.

The following tests are suggested:

a. Prepare and pour four wooden forms with MO concrete for the purpose of carrying out vibration tests. The form sizes should be approximately two feet cubed. The first form should be poured without vibration and the next with sufficient vibration to produce visible segregation with the appearance of neat cement at the top of the form. The other two forms should be vibrated one-third and two-thirds of the time used on the second form.

b. Prepare the forms for and pour a column eighteen inches square and sixteen feet high. It is suggested that the form bracing and the scaffolding for the full height be prepared in advance with platforms for pouring and observation erected at eight foot lifts and with the form prefabricated in units eight feet long so that the units can be readily placed and quickly secured one on top of the other during pouring. Sections of standard two inch pipe should be placed in a horizontal position through two faces of the form on eight inch centers two, four, six, etc., feet from the bottom. This will allow two rows of pipes from the bottom to the top of the column. It is desired to pour the concrete by letting it fall freely a variable distance from as much as five feet to as little as one foot, decreasing the distance of free fall as the column is poured. No reinforcing steel will be used in this or the next test. The vibration time in this and the next test should be the optimum as determined by the small cube tests.

c. Prepare wooden forms for and pour a second column of the same dimensions as the first, including the same pipe spacing except that the form should be initially placed to full height before any concrete is poured. This form should be poured by tremie methods using a suitable size diameter pipe. Removable windows or panels may be used if desired.

d. Prepare and pour one wooden form with regular Portland cement concrete for the purpose of comparison of time and costs with the MO concrete. This concrete should be given the regular vibration used in regular work, slump tests, etc. The mix used should be a typical wall mix e.g., (3-2-1).

e. Prepare and pour one column eighteen inches square and sixteen feet high. Cross pipes should be placed as in the column in b above. The mix should be the same as (d) and slump tests, etc.

[redacted]

J. C. Stewart from McLain July 1, 1948

should be made. The pour should be made by regular tremie methods as in c above. Time and costs figures should be kept for comparison with the MO tests.

Forms may be removed one day and tests conducted five days after pouring.

The columns will be broken up into two foot sections. These sections and the two foot cubes will be broken and examined for segregation around the cross-pipes and from top to bottom. In addition the test samples poured at the same time as the cubes and columns will be tested for compression strength.

The Technical Division will furnish the raw materials. It is estimated that four cubic yards of concrete will be poured. Costs on the work should be charged to H415L.

Time studies and cost records of the work are desired in order that labor costs, equipment costs, and material costs may be accurately estimated on a unit basis. Photographs of all phases of the work are desired.

s/ Stuart McLain

SM:eg

Copies to: Blizard, Kyger, Lane, Peterson, Rockwell

[redacted]

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APPENDIX B

Photographs of Test

	Page No.
General View of the Test Site	24
Preparing the Batch	25-27
The Pumpcrete Test	28,29
The Vibration Test	30,31
Tremie Column Tests	32,33
Free Fall Column Tests	34-36

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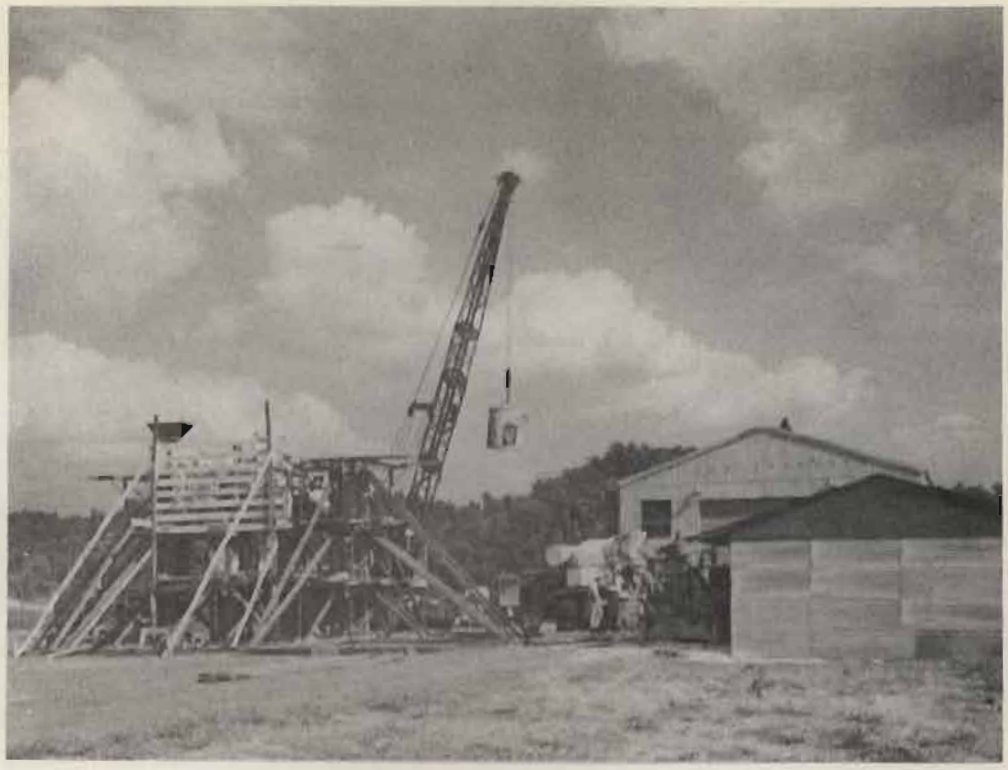
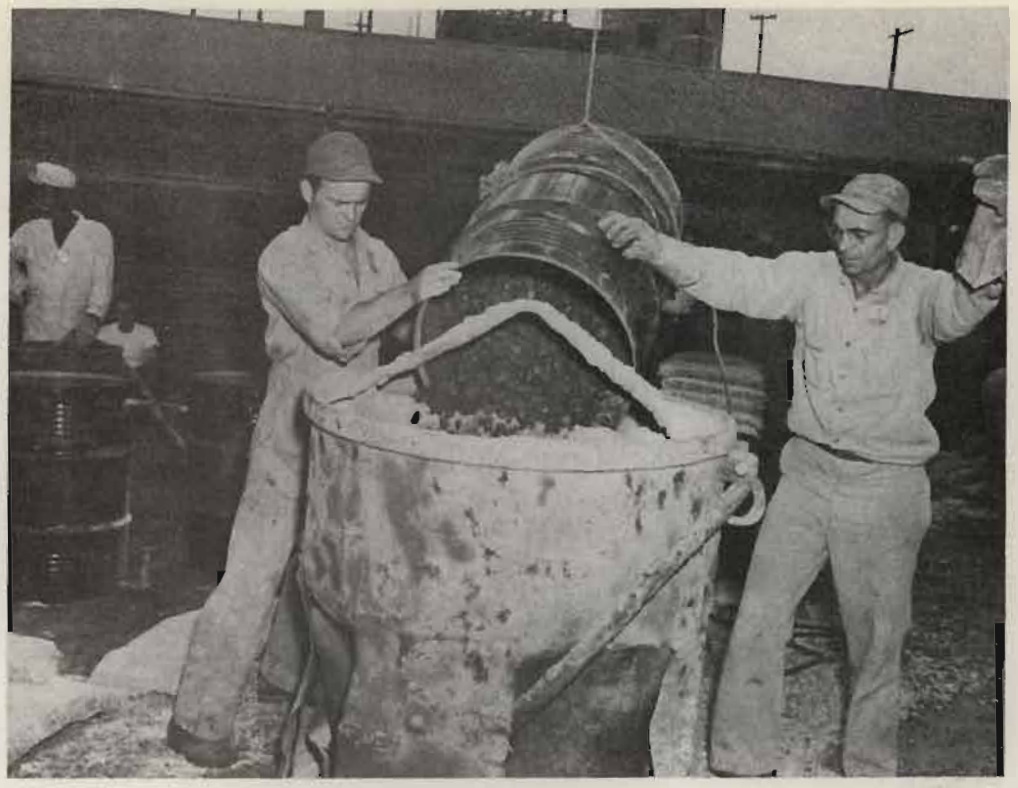


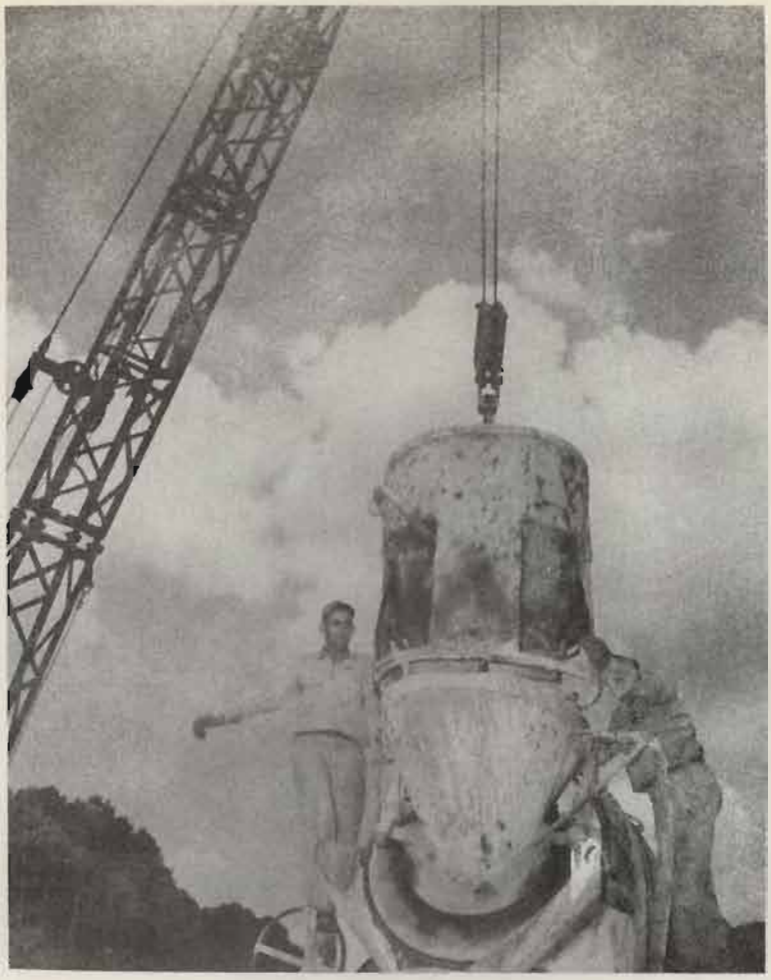
GENERAL VIEW FROM THE NORTH
SHOWING THE BATCHING SITE AND THE TEST COLUMNS

GENERAL VIEW FROM THE SOUTH
SHOWING THE BATCHING SITE AND TEST COLUMNS



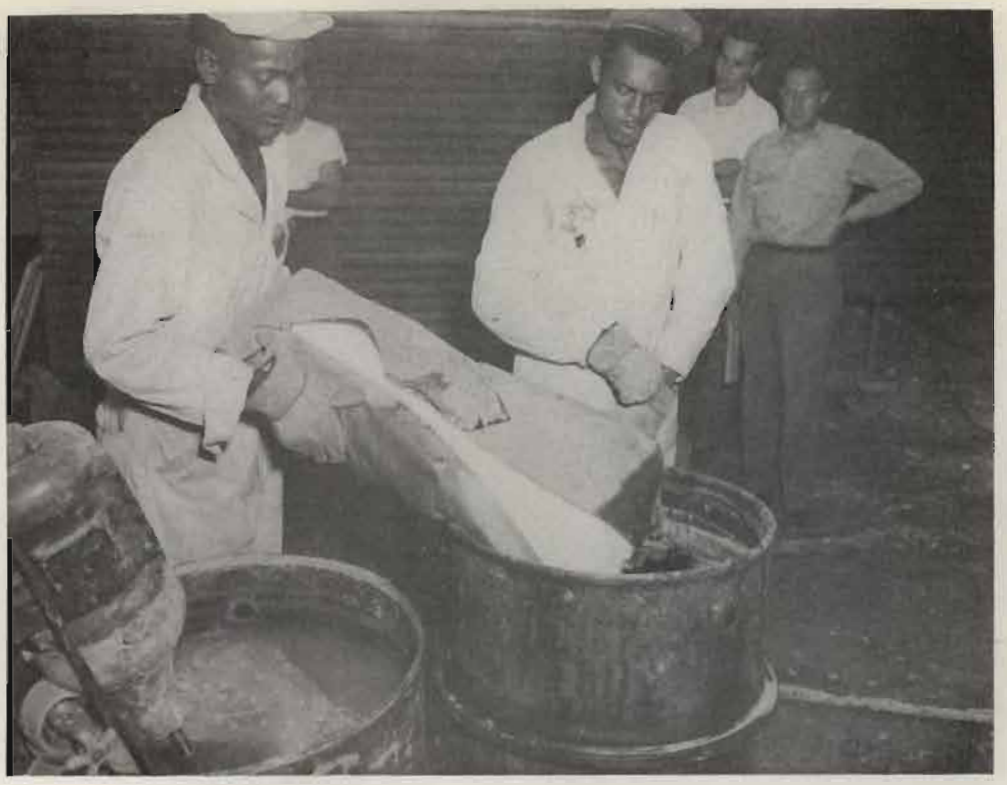
EMPTYING STEEL PUNCHINGS INTO A POURING BUCKET

ADDING STEEL SHOT



EMPTYING THE BUCKET INTO THE TRUCK MIXER

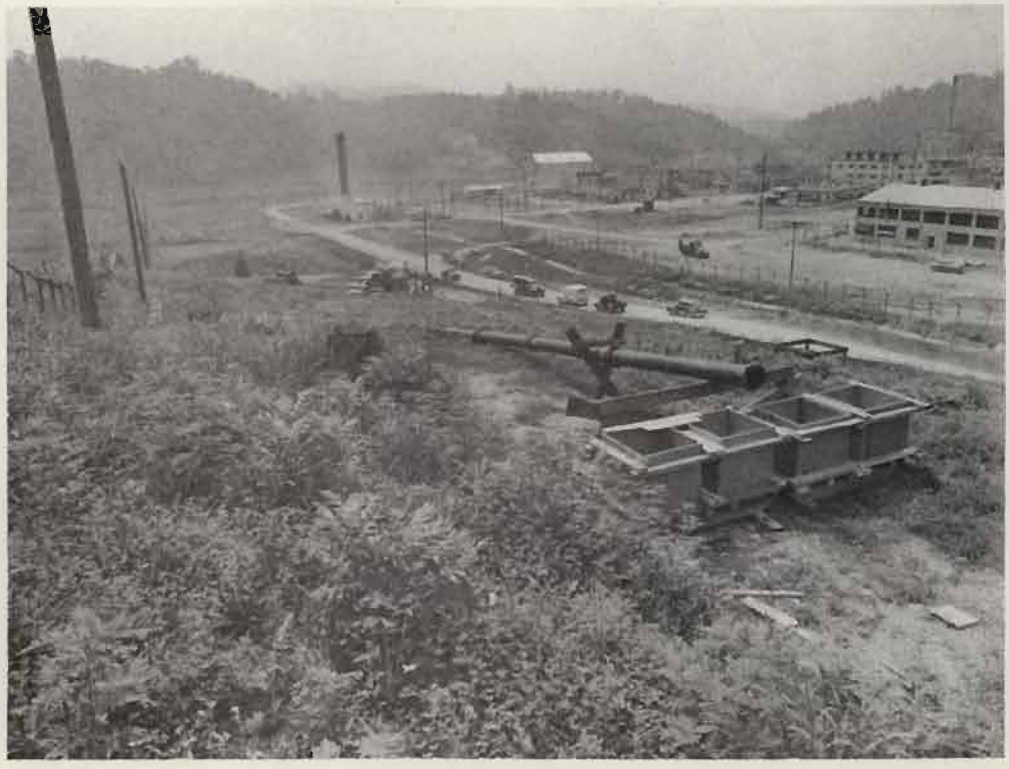
HOISTING BAGS OF MgO TO THE TOP OF THE TRUCK MIXER



PREPARING AND AGITATING $MgCl_2$ SOLUTION

ADDING $MgCl_2$ SOLUTION TO THE MIXER

THE PUMPCRETE MACHINE

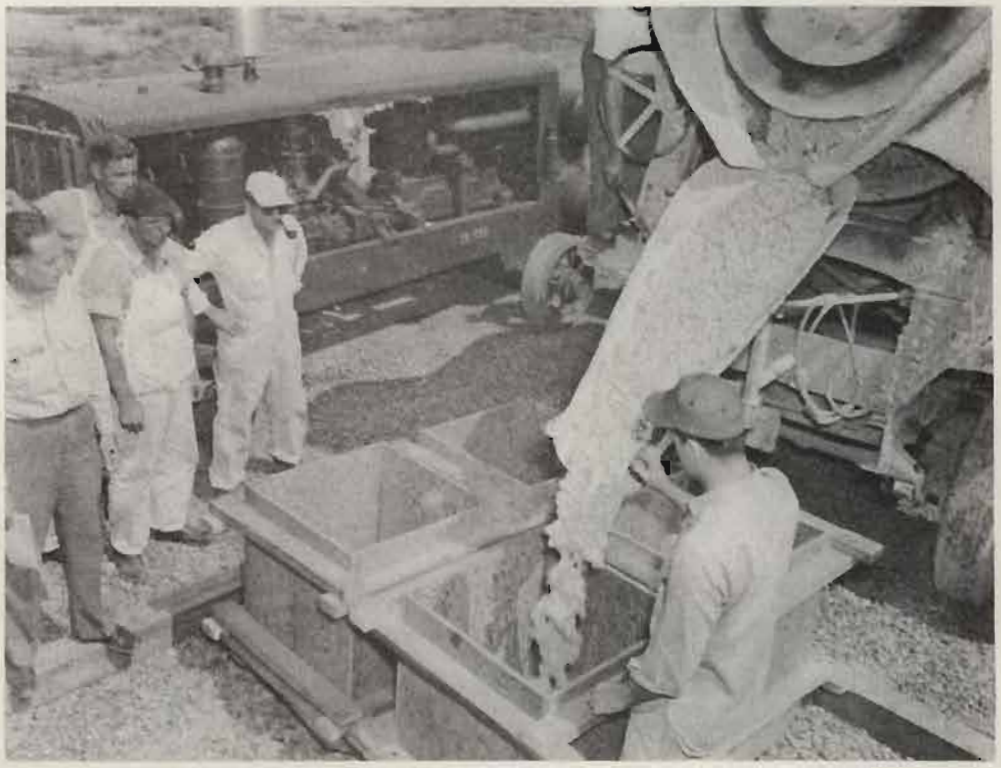


THE DISCHARGE END OF THE PUMPCRETE PIPELINE WITH THE TRUCK MIXER AND THE PUMPCRETE MACHINE IN THE BACKGROUND

TRUCK MIXER POURING MO INTO THE PUMPCRETE PUGMILL

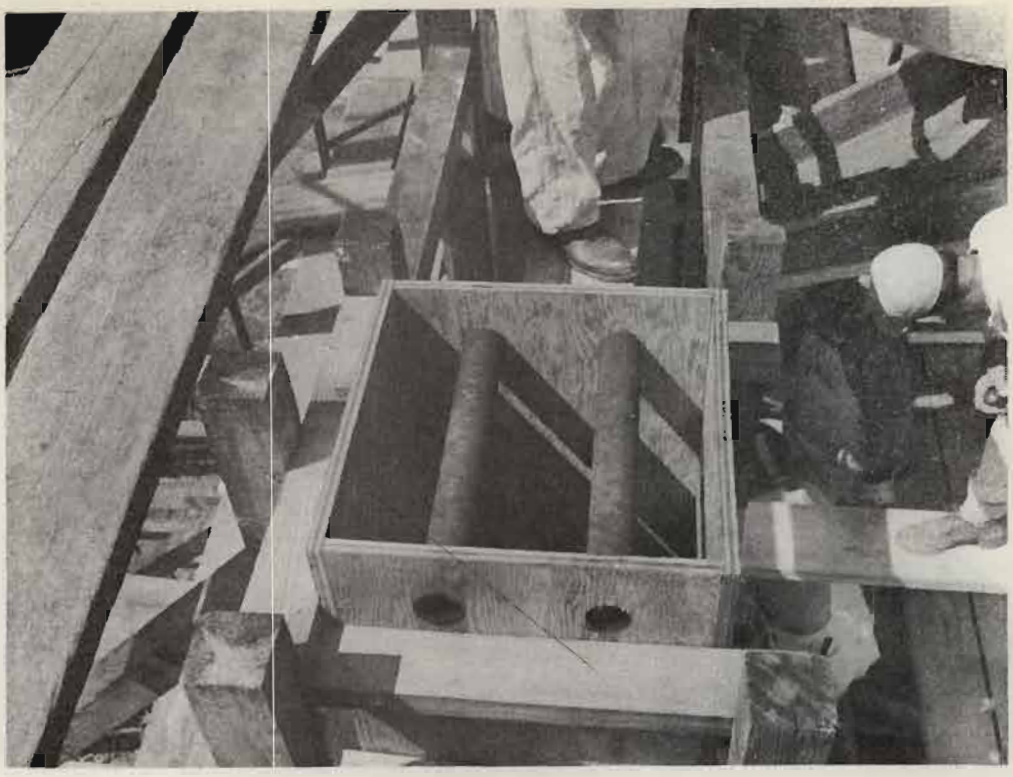
TRUCK MIXER POURING MO INTO THE PUMPCRETE PUGMILL

POURING MO INTO FORMS FOR VIBRATION TEST

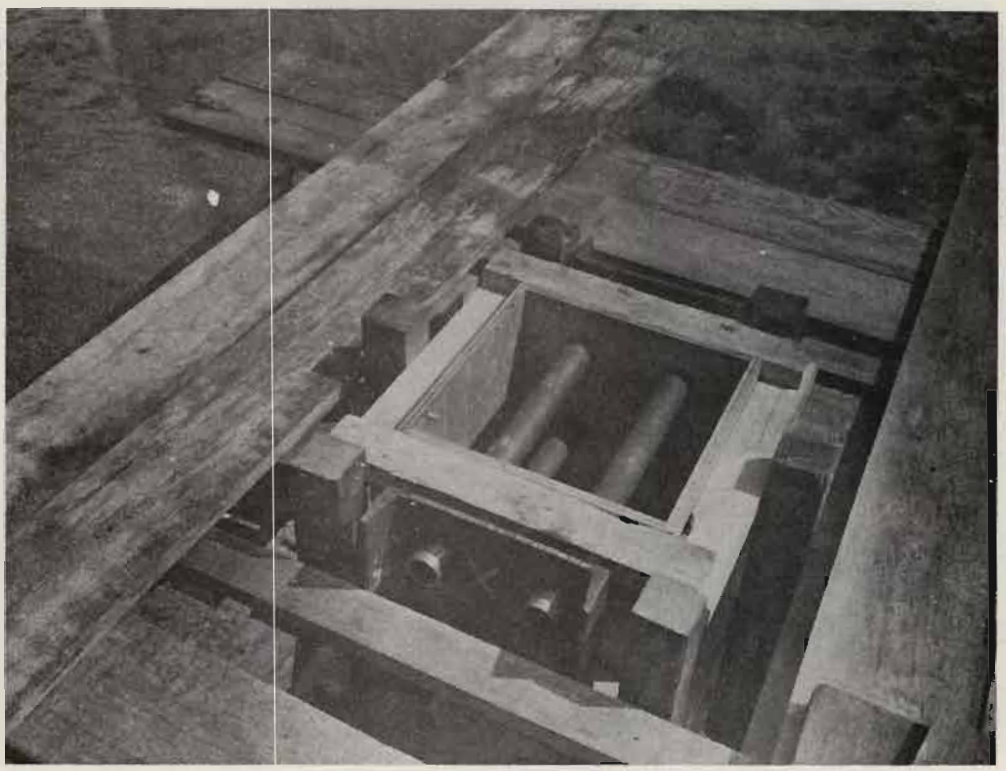


POURING MO INTO FORMS FOR VIBRATION TEST

VIBRATING MO TO STUDY SEGGREGATION CHARACTERISTICS



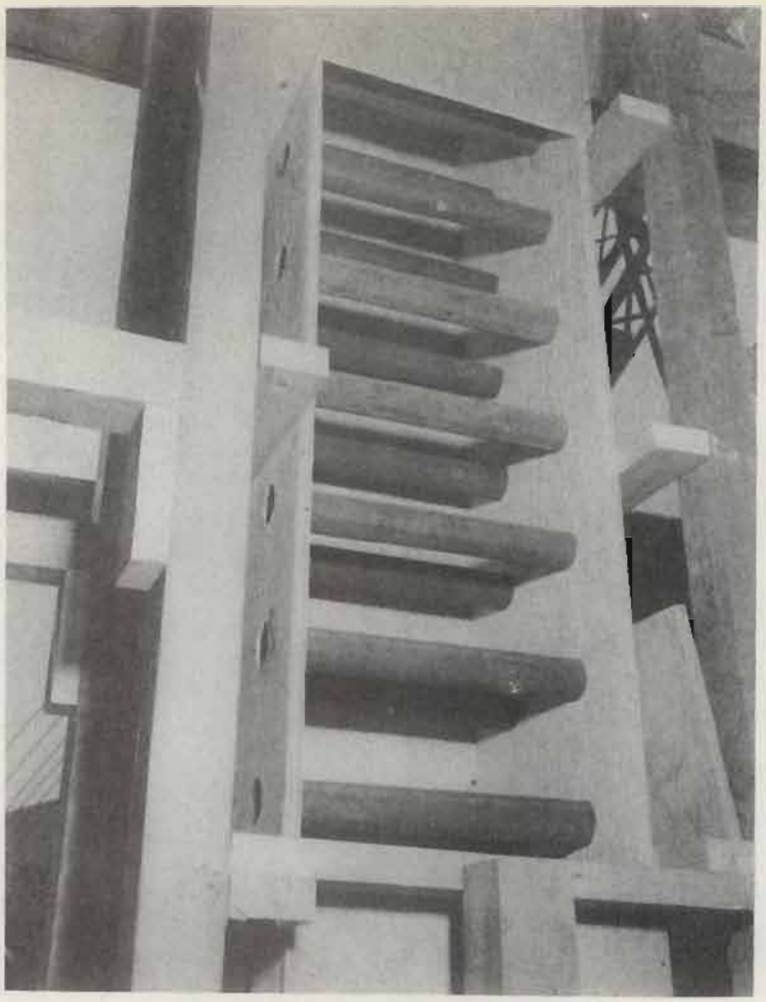
TOP VIEW OF THE P.C. TREMIE COLUMN



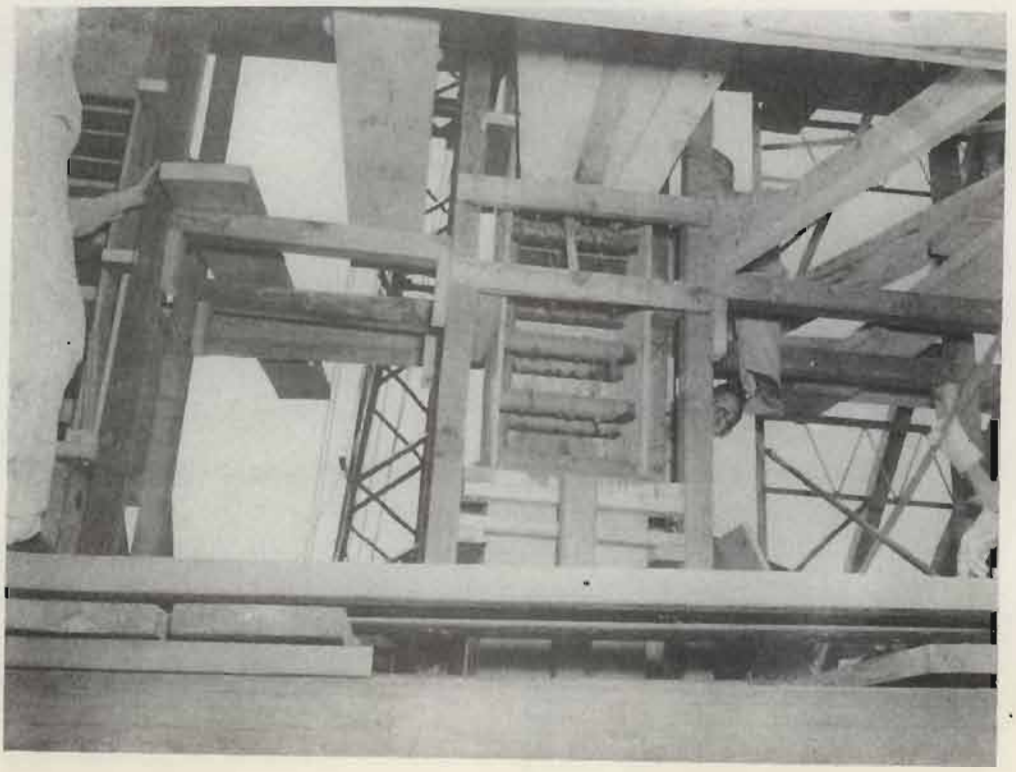
TOP VIEW OF THE MO TREMIE COLUMN SHOWING CHANNEL JIGS

SIDE VIEW OF THE MO TREMIE COLUMN
SHOWING CHANNEL JIG

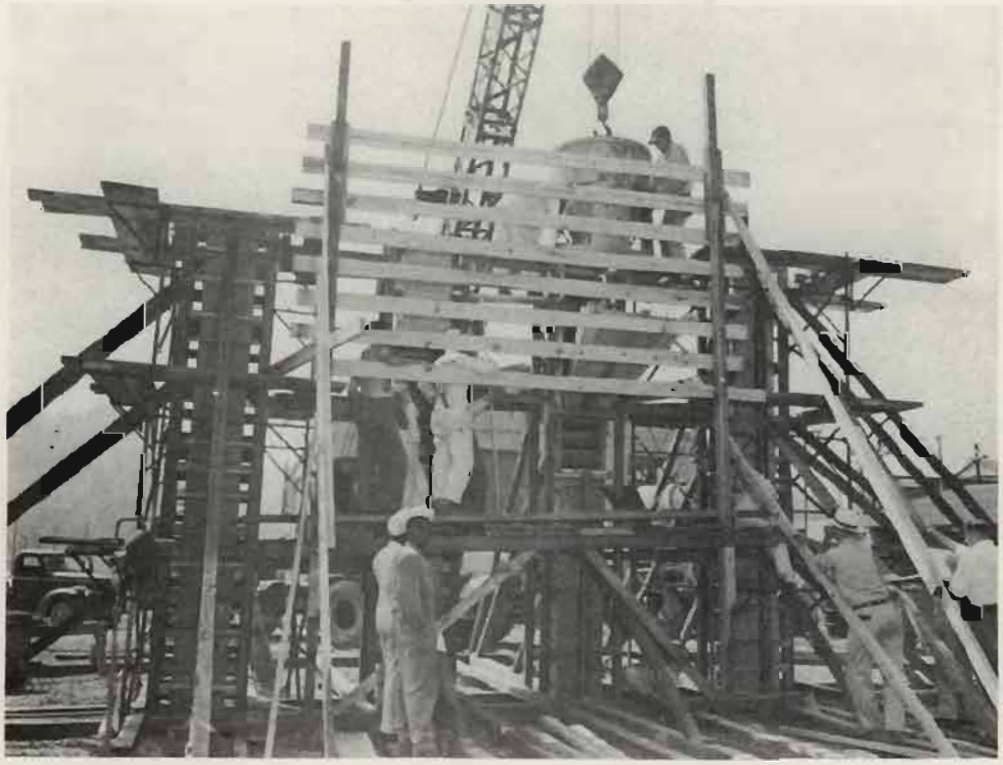
VIEW OF COLUMNS SHOWING TREMIE PIPE AND HOPPER



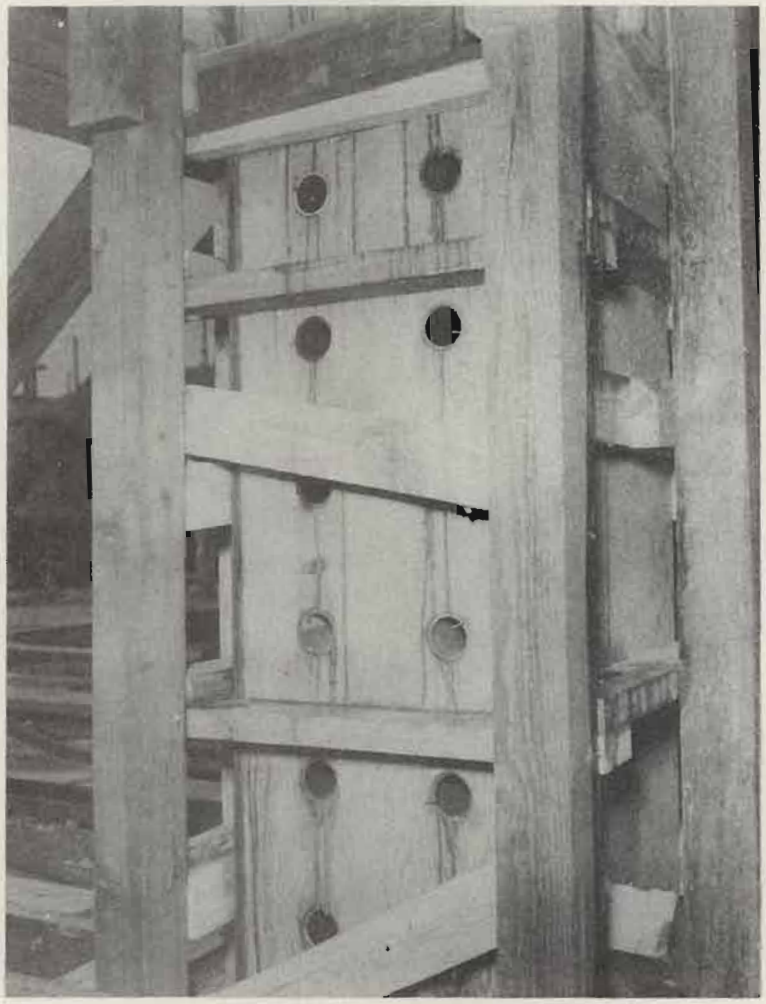
SIDE VIEW OF ONE OF THE "FREE FALL" COLUMNS



POURING A "FREE FALL" COLUMN



POURING A "FREE FALL" COLUMN



SIDE VIEW OF ONE OF THE P. C.
COLUMNS AFTER POURING

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APPENDIX C

ADDITIONAL REMARKS ON PUMPCRETE TEST

For record purposes it seems advisable to clarify the events prior to and during the experimental MO concrete pour which utilized the Pumpcrete machine rented from the Martin Machinery and Supply Company of Knoxville on August 16 - 17, 1948.

MO concrete had been experimented with in several small scale laboratory tests at ORNL. During the past year, MO concrete was batched, mixed and poured in several small scale field tests using 6 cubic foot batches. In the first of these, the materials reacted more rapidly than expected and due to inexperience in handling the material, a portion of the concrete set-up in the mixer. The mixer was cleaned out and the remaining batches presented no problem. As a result of these experiments there was every reason to believe that MO concrete could be pumped and would remain workable for pumping purposes and subject to flushing with water for 2 hours or longer. This was the information previously given to Mr. Hay and Mr. Cooper of the Martin Machinery and Supply Company.

The Pumpcrete machine appeared to be working properly and the pump was operated occasionally while the second and third batches were being mixed. As the load on the pump gradually built up it became apparent that the rated power was not being delivered to the pump. The reason for this power deficiency is not certain but it is believed to have been caused by a faulty electric motor. Significant is the fact that the motor would not shear the flywheel shear pins. This fact is important when considered with the time factor, for if the motor's failure, or if a jam in the pump valve had been readily evident, there would have been time to clean out the pug mill and the pump while the concrete was still subject to handling and water flushing. As it was, the lack of power only gradually became evident with the increase in the load and even then much time was lost while Mr. Cooper endeavored to get the motor to operate properly. After the power failure was evident, Mr. Cooper repeatedly stated that if the pump were jammed or over-loaded and if the machine were developing its rated power, the machine would buck and vibrate and would certainly shear the flywheel shear pins. The line voltage was checked and found adequate by an electrician foreman of the C&CCC.

During the time that efforts were being made to get the motor to function, Mr. Cooper was repeatedly requested to dismantle the pipe and dispose of the concrete. Apparently his years of experience in pumping Portland cement concrete led him to underestimate our concern. By the time that efforts to make the motor function were dropped, it was too late to flush the MO concrete out of the pugmill with water, partly because of inaccessibility and partly because after a relatively short time (compared to Portland cement) water has little effect on oxychloride cement.

[redacted]

[redacted]

Following this, about an hour was spent in a futile effort to remove the pug mill from the machine. A truck crane available on the project was unable to lift the pug mill. By then the concrete had begun to set up sufficiently to make it evident that its removal would have to be accomplished by hand. It would cost the ORNL as much or more to clean out the concrete with its own forces as it would if the work were done by the Martin Machinery and Supply Company. In order to terminate the daily rental, it was decided to return the Pumpcrete machine to Knoxville.

Mr. Hay of Martin Machinery and Supply Company reports that during cleaning operations some pieces of steel too large to pass through the pump valves were found in the pug mill. Although these pieces of steel had evidently been in the coarse aggregate, this fact was not known by anyone on the project. Considerable observation and use of the coarse aggregate prior to and during the experimental pour had not revealed any steel pieces of excessive size among the punchings. Even though a pump valve may have been jammed by a large piece of steel, there should have been time to remove the concrete from the machine, if this condition had been evident by the failure of the flywheel shear pins under normal power.

[redacted]