THESIS
ON CEMENTS
THEIR STRENGTH AND VALUE

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Of all the subjects now occupying the important places in the minds of our mechanical engineers probably none deserve more attention than the subject of hydraulic cements, and, indeed, one of the leading engineers of this country, in a recent article read before the American Society of Mechanical Engineers, placed cements and allumi-num at the top of the list in importance.

Ever since the time when man first came to recognize this need of protections from surrounding influances and evils, the uses of cements in some form or another, have played an important part in his general welfare.

Perhaps the simplest form of cement, (if we may call it such) of which we have any record, was the plastic mud of the Nile, which when mixed with straw and dried in the heat of an Egyptian sun, formed all the necessary qualities of the ordinary building brick. That was a time when ten, twelve, fifteen and twenty-six story buildings were un-dreamed of. Brooklyn Bridges would have been miracles, while many of the more common problems of engineering of our day would have been beyond the range of possibility and usefulness. Mud and straw were therefore all that were generally necessary for the building purposes of those ancient times. Later on when the arts of war became more horrible and land became valuable, in just that proportion did the need of a stronger and more durable cement present itself. In the many excavations which have been lately made in Rome, samples of masonry are unearthed in which the cement is often as firm and strong as the stones it joins.

To give a detailed account of the history , the manufacture, the geological classification and distribution, and the relative value of all the thousand and one brands and kinds of cement found and made is not the purpose of this thesis. What I intend more is to give the results of a series of experiments I have just completed, the comparison with similar experiments by other experimentors, and if possible arrive at some satisfactory conclusions regarding the same.

I have not done as exact work as might be expected in a line of experiments like this, perhaps, and the results obtained are not to be relied on as absolutely correct. There are many reasons for this: first, this is practically the first thesis, along this line, ever written at this college and I have profited by the experience of but few others than myself. The first reason coming into account, it was quite natural that I should waste a considerable amount of time in trial experiments. Insufficient quantities of cement of any one kind also prevented making very many experiments for averages. The very few accurate molds I had, prevented much work at any one time being done.

Without going farther into the accountof my dilemas and misfortunes I will proceed to describe in a brief manner the nature of the tests I made and the machines and tools used in making them. There are many tests that are of great importance in connection with every cement. Some of them are as follows: the detremination of tensil, flexure, crushing and cohesive and adhesive strengths, hardness, time of setting, (both in water and out) the influance of heat and cold, adulterants and many other things which are not quite so universslly important. The first three classes of experiments I endeavored to perform on each of the different cements I had. On some of the samples I performed other experiments. The tests for adhesive strength would have been very important but owing to innumerable varity of surfaces to adhere to it did not become conveniently possible to perform these tests. The time of "setting" I found rather roughly in some cases.

For tensil strength briquettes are made "symmetriacl in form) with an inch square cross-section at the middle point. A full sized plan and elevation drawing of the molds used will be seen in figure . These were made some years ago by " the Olsen Manufacturing concern of Philadelphia. The more modern form of mold allows for more surface each side of the one inch cross-section, thus reducing the liability of breaking the brick except at the proper place. With a well molded briquette this difficulty is easily met, providing the clips for holding the briquette are properly shaped and adjusted.

The patterns I used for molding my flexure (and crushing) pieces were for the most part like the scheme shown in figure . The patterns are made after the following descriptions: Triangular cross-section pieces of wood eight inches long with each of the two sides of the right angle two inches long. A number of these pieces are firmly nailed at right angles to one edge of a ten inch board, the right angles projecting upwards, each piece touching the adjacent piece. Another combination like the one just described, turned bottom side up and placed on the first, forms a row of opening 2 x 2 x 8 inches in dimension. Dowell pins hold the two pieces in place with each other and one or two coats of asphaltum paint well dried on and afterwards a good coal black engine oil renders the mold ready for use. This was made more satisfactory than either iron molds or wooden ones- made separately for each casting. In the former case the greatest objections were, weight, clumsiness and cost. In the second case warping due to a certain amount of moisture necessarily absorbed from the contained mortar.

Of all the contrivances used in cem nt testing, perhaps none play a more important part and none have to be prepared with more care than the "clips" for breaking the tensil pieces. The "clips" accompanying the Olson machine which was the machine used in testing were of the form shown in figure . These as will be seen fitted the sides of the briquette quite closely and any slight jar or the least irregularity in the briquette due to working in seasoning or otherwise, caused the briquette to become cracked and broken without, in many cases, any appreciable tensil strength. In order to overcome this difficulty I made a pattern described in the Engineering News for December . A drawing from the pattern I made will be seen in figure . It differs somewaht,(and for the better I think) from the "clip" recommended in the News in which a roller of rubber tubing stretched over a steel rod, which is immovable and troublesome to remove when a new rubber comes necessary from squeezing and wear. The "clip" shown in the drawing provides no place for rubber roller, and no such thing is used in it. Simply a piece of rubber packing of about one-sixteenth inch in thickness by one-half or three-quarter inches by one and one-quarter inches in dimensions slipped in at each of the four pressure places each time the new briquette is used. At first this would seem to be rather tedious work but one soon becomes accustomed to it and the results obtained are most satisfactory. In this scheme of the rubber being loose there is a chance for the briquette more easily adjusting itself without liability to cramping.

For breaking the flexure and crushing pieces I used a large Olson machine whose range was from 0 to 50,000 pounds pressure. On account of the pondrousness of the machine I did not have much faith in the results I obtained for the weaker specimens of cement, as no doubt a considerable of the indicated pressure went to moving the parts of the machine rather than wholly to breaking the cements

themselves. However, the results were more satisfactory than I had anticipated. Should ever any other experiments along this line be made I would suggest an arrangement for crushing and flexure be got and attached to the "little Olson" machine where finer gradations can be got and far less pressure goes to overcoming the friction and inertia of the parts of the machine. I have thought of a scheme which I think would be practical for such purpose and have briefly indicated it in figure . For cements and specimen which are liable to resist a pressure of 2500 pounds probably the large Olson would have to be resorted to on account of liability of straining the little one.

Now regarding the cements themselves. I performed experiments upon the following kinds of cement:

For brevity each cement will be designated by letter, thus:

Akron, - - -	"A."
German Portland, -	"G."
A New York brand now at college, - -	"P."
Louisville, - -	"L."
Common Lime. - -	"C."

"A" is the kind of cement used in the construction of the new post office building at Lansing. It is highly recommended as a strong cement and has great durability. It is of light color and on setting assumes a sort of cross between a pinkish yellow and a straw color, on the outside, and a fresh fracture shows a tendency to pale heliotrope.

"G" is rather heavier than "A" and of a dull gray color on the exposed surface with light traces of yellow. Fractures (fresh) reveal a color closely resembling blue clay. Resists disfiguring much more than does "A".

"L" is darker than "A" and lighter than "G". In the powder it rather of a pinkish gray; but on "setting" and seasoning the pink pretty much dies out, or fades away. Its weight per unit volume is nearly equal to that of "G".

"C" is too familiar to all to need description white when of good quality and darker with yellowish brown tinges when impure. It is hard to find two samples of "C" that has the same qualities owing to the great changes brought about by burning; a little too much or a little too little burning of the lime stone makes great changes in the strength of the lime. The least exposure to the air or dampness lessens the strength of the lime quite materially.

Beginning with "A":

Several tensil and flexure pieces were made by mixing "A" and water of the temperture of the air (80") together and pressin into the molds so as to remove all possible traces of air bubbles. All were allowed to stand in the molds until stiff enough to allow taking out. When barely set all were carefully laid on a smooth shelf. At the end of twenty-four hours part were placed in water and kept covered by it until the time for breaking had arrived. At the end of twelve days part of both lots were broken. The results were as follows:

Tensil breaking force one sq. inch cross section.

In air 162# and 170# average - 166#

" Water 84# " 64# " - 74#

Flexure, 2 x 2 inches cross section 4 inches between supports.

In air 221# 185#- 240# Average - 223#

" Water 180# 190# " - 185#

None of the pieces were crushed at the time, but the best pieces two inch long were sawed off and faced up perfectly square by putting on a thin layer of Portland thus preventing any irregularities in pressure forces and allowing all up and down lines in the pieces to receive an equal amount of force applied. At the end of twenty-eight days the remainder of the pieces were broken and the two inch cubes crushed.

Tensil	in	air	one	sq.	inch,	- 106-148	equals	127#.
"	"	water	"	"	"	- 164-136	"	150#
Flexure	"	air	4	"	"	- 210-216	"	213#
"	"	water	"	"	"	- 350-360	"	355#
Crushing	"	air	2	inch	cube	- 2000-2100	"	2050#
"	"	water	"	"	"	- 2550.		

"G" was treated in the same manner as "A"

Tensil	strength,	12	days	in air	- 209- 307	epuals	206#
"	"	"	"	" water	- 306	"	306#
Flexural	"	"	"	" air	- No test.		
"	"	"	"	" water	- " "		
Tensil	"	28	"	" air	- " "		
"	"	"	"	" water	- " "		
Flexure	"	"	"	" air	- 520-490	equals	505#
"	"	"	"	" water	- 780-770	"	775#

Crushing in air, only one test only " 3580#

"P"'12 day test. - By oversight no specimens of clear cement blocks were made. But for "P" one part and fine gravel two parts, sifted through meshes one-fourth inch square and not capable of passing meshes one tenth inch square, washed perfectly clean.

Tensil strength in air (only) one test, 190 lbs.

28 day test air, (only) 148-145 equals 146 1/2 #

Flexure -----

Crushing (one specimen.) 3200 #.

"P" and sharp sand (washed) - "P" one part to sand 2 parts

12 day test.

Tensil, one specimen- 183#

Flexure, None Made.

Crushing " "

28 day test.

Tensil, 180- 165 equals 172 1/2#

Flexure, 380- 300 (200) equals 340#

Crushing, None Made.

"L" 12 day test,-

None Made.

28 day rest in air,-

Tensil 35 - 32 - 38 equals 35 (nearly)

Flexure, None Made.

Crushing, " "

"L" and gravel according to gauge used in "P" and gravel

12 day test in air,

Tensil, one specimen only 20#

28 day test,

Tensil 15 - 16 - 701 equals 665#

"L" 28 day test in water,-

Tensil, one specimen equals 36#

Flexure 629 - 701 " 665#

Crushing 1200

"C" and sand, "C" 1 part, sand 2 parts.

28 day test,-

Tensil 21 - 26 - 28 equals 25#

Flexure 110- 106- 110 " 109#

Crushing, None Made.

"P" and Soap.

The soap was mixed in by first dissolving in soft water about all the hard soap it could hold in solution. This was perhaps not a very practical experiment, but it might come into practice around sewers where the pipes were joined by cements.

The detrimental effect was quite marked, as the average tensil strain above which the samples broke in twenty-eight days was only 55#, while "P" and clear water and sand was 146 1/2#.

"P" and Sugar.

Sugar is used in the mortars in India and is probably all right in such countries where there is not much dampness to dissolve the sugar out.

Made a solution of sugar and water in about the proportion of about one teaspoon ful to one ordinary drinking glass of water. The effect was quite marked on the strength of the cement, as the average tensil strength was increased from 146 1/2 to 175,or rather from 55 with soap to 175 with sugar. One striking peculiarity of the compound is the immense quantity of heat developed in "setting", especially in the flexure pieces when not much surface is exposed to the air.

The hard surface and hardness throughout was very noticeable, while the increase of quickness of setting was very great. The fact of the matter is that the cement "set so very quick that the outer surface commenced to contract and crack before the moisture within had time to let the inner moist part of the mass contract accordingly. The results was many of the specimens were cracked up so as to be quite unreliable for testing.

Flexure stood an average of 190# (nearly)

"P" and broken granite.

Broke a piece of granite rock into pieces of gauge perscribed for gravel in experiments above

The object of this experiment was to see if the shape of the pieces to which the cement clung had anything to do with the strength of the mass. "Poor brick" in making the briquettes prevented satisfactory results. Right here it may be well to state that as the stone contained in the cement does not of itself add to the strength of the cement, the strength of an inch square cross-section of the mass would depend a good deal on the amount of cement and the fewness of the stones at this section. I therefore do not feel safe in giving the results of experiments in which the ingredients had grains much larger than ordinary sand.

Besides the experiments on cements of twelve and twenty-eight days setting, I made several tests on cements eight and eight and one-half months old. Some of the more important of these I will give below:

Water lime and sand 1 to 1 gave an average of 113# tensil strain in air.

Portland	cement	and sand 1 to 1 in air		312#
"	"	" " " " 2 " "		285#
"	"	Alone	- - - - -	580#
"	"	and sand 1 to 3		155#

Ordinary lime and sand (1 to 2) gave a tensil strength of 38#

Pure water lime gave for air (or water one month and air the remainder) 478#

Same air all the time. 346#

Owing to disturbances of pieces during the winter vacation it was hard to decide which set of briquettes was which.

Ordinary lime and sand, (1 to 1) gave an average breaking tensil stress of 95#

Portland (1) Sand (1) and Adamant plaster (1) gave an average of 104#

An experiment for the rise of temperature in lime while "slacking" showed in a sample of lime fresh from a new barrel an increase of from 81 degrees Farh. to 209 degrees Farh. equals 128 degrees Farh. The volume of the lime increased from 1 to 4.

This practically ends the list of experiments. As I said in the beginning I consumed a large per.cent of the amount of time available for experiments in making patterns, getting things into shape and finding out the best way of performing experiments.

It would be useless to put a mess of figures relating to other experiments made by eminent authorities, but I will give a number of references to books articles in the college library.

For geological classification and distribution of hydraulic lime stone etc. probably no better authority can be got than 2 A. Gillmore. A. M. in his work on "Limes Hydraulic Cements and Mortars." In the same book valuable points of information regarding tests and manufacture of cements of all description abound.

The relative costs of cements and the most approved methods of testing and analyzing cements, their use etc. will be found fully stated and described in "A Tretise on Masonry Construction" by Ira O. Baker C. E., professor of civil engineering, University of Illinois. Both of the bookd just mentioned furnish almost every variety of information necessary; but there are several important allusions to the Engineering News which I deem quite interesting and important. Among them are:

Manufacture of Portland Cement from slag"- July 19-90 Also Dec. 7'89.

Adhesive strength of sulphur, lead and Portland Cement for anchoring bolts, July 20,'90.

Soda in Portland Cement, " Oct. 11, '90.

An improvement in"clips" for cement testing, Dec. 20, '90.

Does Salt Water increase the strength of cement mortar Dec. 20, '90.

"The effect of heat on Cement Mortars." July 14,'92.

"Cement Joints for water pipes." July 14,'92.

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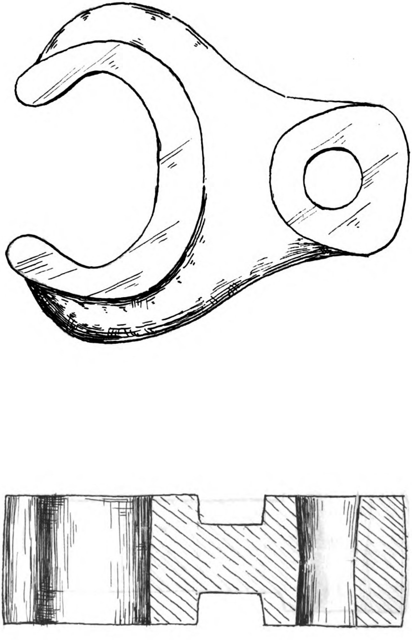
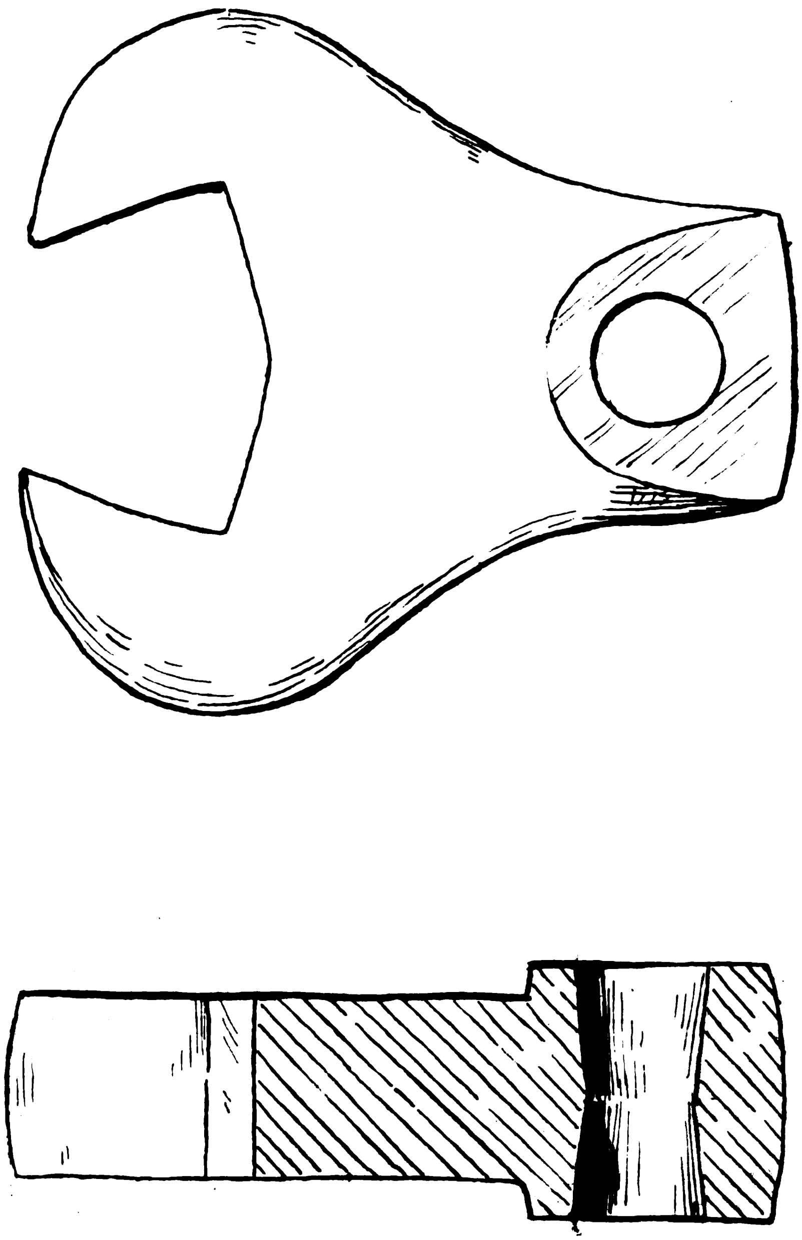


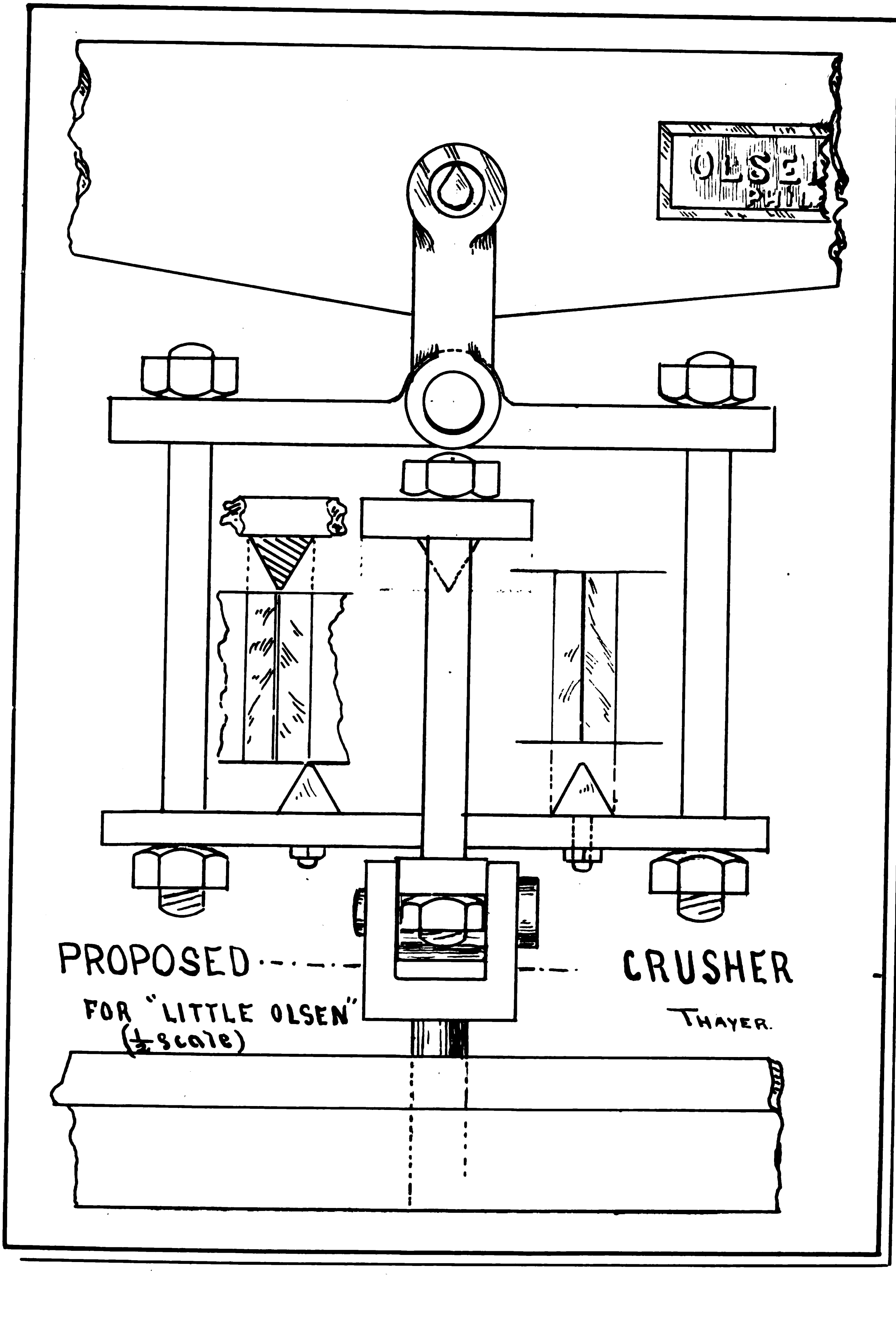
NEW CLIP
(Actual Size)

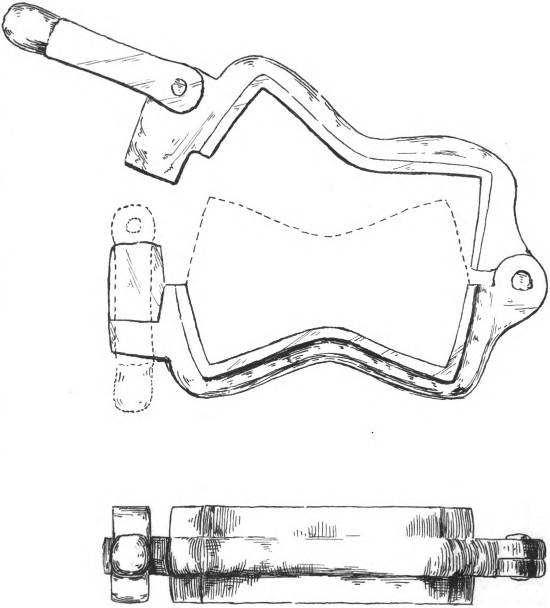
THAYER.



THE OLSEN CLIP
(Actual size)

THAYER


PROPOSED
CRUSHER
FOR "LITTLE OLSEN"
(½ scale)
THAYER.



BRIQUETTE MOULD
(Actual Size)

THAYER