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THESIS

131.

Effect of Temperature upon Gement Mortars

COWEN AND FLORREICH

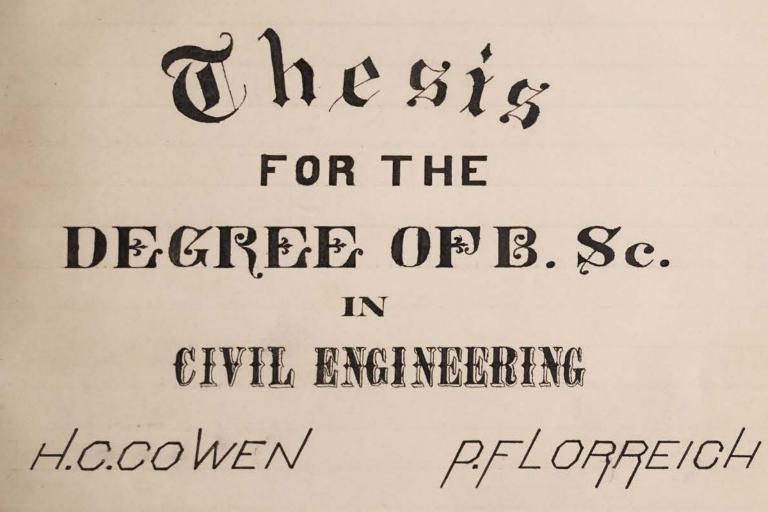
1895

THE EFFECTS of TEMPERATURE UPON CEMENT MORTAR 2649 HERMAN C' COWEN PHILIP FLORREICH

THE EFFECTS OF TEMPERATURE UPON CEMENT MORTAR

HERMAN C COWEN

PHILIP FLORREICH



H.C.COWEN

1895

Thesis

FOR THE

DEGREE OF B. Sc.

IN

CIVIL ENGINEERING

P.FLORREICH

1895

Probably no material in iner by the Enquiering projection at the present Ture has bern subjected to more careful and rigin Faste by Export Engineers Than our hydraulie enuents, both natural and artificial. While The manufacture and use of cruents in America is of comparatively recan't origin, This industry is fast accuning Enormous proportions, and the new of exacut is fast displacing many of our more common building materials. Its use in our more unportant structures has created an increasing demand for the best quality of cruciato, and this manufacturers have not beru slow to comply with This demand. Until in secret grave it has been considered impossible to manufacture a grade of auerican erment, withur Rosendale or Portland, which could compare even favorably with Europran brando, but recruit comparative trets of The

Probably no material in use by the Engineering profession at the present time has been subjected to more careful and rigid tests by expert Engineers than our hydraulic cements, both natural and artificial. While the manufacture and use of cements in America is of comparatively recent origin, this industry is fast assuming enormous proportions, and the use of cement is fast displacing many of our more common building materials. Its use in our more important structures has created an increasing demand for the best quality of cements, and the manufacturers have not been slow to comply with this demand. Until in recent years it has been considered impossible to manufacture a grade of American cement, either Rosendale or Portland, which could compare even favorably with European brands, but recent comparative tests of the

leading brands serem to show that american crucento can be made which compare favorably with the unported execution all Fisto to which they have been subjected. The Enoungacture of Rocradale crucent in America was first begun on a commercial scale, about 1820, The Fim "natural erment" has frequently bern Employed to denote This encuent, breakense it is generally made from a natural stone. The him Rosendale' has been proposed for this excuent, because it was first manufactured at Rocrudale, two york; and the term will be used with this distinction through out This article

frequently called artificial excuent, becaused The constituents and usually mited artificeally preparatory to the manufacture. The term Portland well be adhered to

Portland ennent is

leading brands seem to show that American cements can be made which compare favorably with the imported cements, in all tests to which they have been subjected.

The manufacture of Rosendale cement in America was first begun, on a commercial scale, about 1820. The term "Natural cement" has frequently been employed to denote this cement, because it is generally made from a natural stone. The term 'Rosendale' has been proposed for this cement, because it was first manufactured at Rosendale, New York; and the term will be used with this distinction throughout this article.

Portland cement is frequently called artificial cement, because the constituents are usually mixed artificially preparatory to the manufacture. The term Portland will be adhered to

Throughour this article. The manufacture of Portland excuent, in America, was first begun on a commercial scale about the year 1878, although it had been imported to a considerable extent suce 1865, Roerudal ennent is in general, a light, coarsely ground, and quick orthing exments but attaining a less ultimate strength, both in Frusion and compression, that the Portland. which is heavier and slower-certhing, and is usually harder burned, more finely ground, and attains a greater ultimate strugth. I har widely varying users for which excuents have been employed in recruit years, together with the varying quality of excuents which have been placed upon the marget has led to the adoption of a series of tests, to be applied to all cruleats offered for use in important construction. In order that seels by differents experimenters may be comparative,

throughout this article. The manufacture of Portland cement, in America, was first begun, on a commercial scale, about the year 1878, although it had been imported to a considerable extent since 1865. Rosendal cement is, in general, a light, coarsely ground, and quick-setting cement, but attaining a less ultimate strength, both in tension and compression, than the Portland, which is heavier and slower-setting, and is usually harder-burned, more finely ground, and attains a greater ultimate strength. The widely varying uses for which cements have been employed in recent years, together with the varying quality of cements which have been placed upon the market, has led to the adoption of a series of tests, to be applied to all cements offered for use in important construction. In order that tests by different experimenters may be comparative, 3

the Aurican Society of Civil Rengineers has recommended a uniform system of Festo to be applied to exments, and this system is now generally adopted throughout The United States. In Justing The strength of

crucents, The set for suice strugth is the one gunerally adopted, not that the het for compriseive strugth is of no value, but that the Insting machines for This purpose and comparatively, very costly, and parhaps in the majority of cases where it is drained to set a sample of cruceus the machines for maxing the compreserve tests and not available. There is threefore a very larger amount of data obtainable in regard to The Frueile strength of erwents, but in many all of theer Fists, wither no has bern sarra of the Funperature during the time of making Frets, or it has been stated to be that of

the American Society of Civil Engineers has recommended a uniform system of tests to be applied to cements, and this system is now generally adopted throughout the United States.

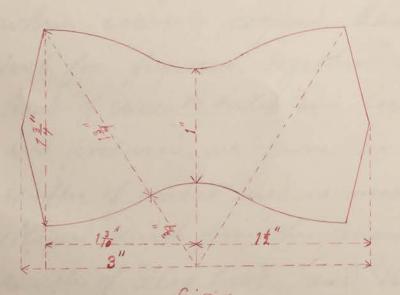
In testing the strength of cements, the test for tensile strength is the one generally adopted, not that the test for compressive strength is of no value, but that the testing machines for this purpose are, comparatively, very costly, and perhaps in the majority of cases where it is desired to test a sample of cement, the machines for making the compressive tests are not available. There is therefore a very large amount of data obtainable in regard to the tensile strength of cement, but in nearly all of these tests, either no has been taken of the temperature during the time of making tests, or it has been stated to be that of

The Justing laboratory, usually about 60° or To. The lack of data on this subject, and the belief That variations of Semperature must efast a considerable influence upon the hydraulic array and busile strugth of crucent mortars, has led the writer to carry out the series of desto which are fire in This article, There hat have been carried out in as strict accordance with The recommendations of the american Society of Cevil Eujueurs, as was possible, Decauser of the difficulty of maxing any prolonged seels at the higher Sumpratures, and in order That the Justo might be comparative the age of briquetter, when broken was uniformly limited to two days; one day in ain, and one day in water, The friguettes worr herpt on precess of slate, and protected from air by daup cloth, before innereion,

the testing laboratory, usually about 60° or 70°. The lack of data on this subject, and the belief that variations of temperature must exert a considerable influence upon the hydraulic energy and tensile strength of cement mortars, has led the writers to carry out the series of tests which are given in this article.

These tests have been carried out in as strict accordance with the recommendations of the American Society of Civil Engineers as was possible. Because of the difficulty of making any prolonged tests at the higher temperatures, and in order that the tests might be comparative, the age of briquettes, when broken, was uniformly limited to two days; one day in air, and one day in water. The briquettes were kept on pieces of slate, and protected from air by damp cloth, before immersion,

and are always broken directly from the water. The briquettes were of the standard form shown in figure 1. having a net section of one equin, The machine used was a Richle Bros, cruent weting machine, This machine has clips with a rubber bearing. surface and has given good satisfaction. but little trouble brings experienced in gatting the briquettes to break in least section. Three briquettes constitute a test, and where there has been any considerable variation in The recults the Fist has been duplicated.



and were always broken directly from the water. The briquettes were of the standard form shown in figure 1, having a net section of one sq. in. The machine used was a Riehle Bros, cement testing machine. This machine has clips with a rubber bearing surface and has given good satisfaction, but little trouble being experienced in getting the briquettes to break in least section. Three briquettes constitute a test, and where there has been any considerable variation in the results, the test has been duplicated.

fig 1

The tests which have been werd ave, (A) Just for finence: (B) Just for charming and cracking. (a) June of setting at different Jump-Eratures, (D) Jusile straugth, In maxing the first for furnes there standard seeves were used, No. 50, No, 80, 20 As, 100, having respectively 2500, 6400, and 10000 muches per sq. in, The test for furnes while it is perhaps not as unfor Faut as the others, is considered desirable. a given criment, finely pround, will bran a larger doer of eard and get develop a given Jusile strougth, than will the same crulent when coarsely ground. The results of the Jest for fairures, logether with a list of The brands of current tested and locality in which they are produced, are given in Fable I, The samples of exment used in making these sist were Atained direct from The manufacturer wheept the sample of Flag brand', and Hiltons' three two Ramples built of the crucent found in the market.

The tests which have been used are, (A) Test for fineness; (B) test for checking and cracking, (C) Time of setting at different temperatures, (D) Tensile strength.

In making the test for fineness three standard sieves were used, No. 50, No. 80, and No. 100, having respectively 2500, 6400, and 10000 meshes per sq. in. The test for fineness, while it is perhaps not as important as the others, is considered desirable. A given cement, finely ground, will bear a larger dose of sand and yet develop a given tensile strength, than will the same cement when coarsely ground. The results of the test for fineness, together with a list of the brands of cement tested, and locality in which they are produced, are given in table I. The samples of cement used in making these test were obtained direct from the manufacturer, except the sample of 'Flag brand', and 'Hiltons'; these two samples being of the cement found in the market.

7

	010	Retor	Reivin	Noloo Screen Screen Noloo Screen Screen red on No 50 Screen Betained on No 50 Screen
Black Diamond		16	9.5	Louisville Rosendale
Speed Mills		23.2		Louisville Rosendale
Flag		16.5		Louisville Rosendale
Brooklyn Bridge		13.6		New York Rosendale
Utica	27.6	23.2	11.2	Illinois Rosendale
Akron	21	16	6.5	Ohio Rosendale
Saylor	10	2.4	0	American Portland
Atlas	11	6	0.6	American Portland
Hilton	18.6	10.6	0.7	Einglish Portland.

Table I

In making the test for checking and cracking, two pats of neat cement were made, each about three inches in diameter and one half inch thick. One of these was immersed in in water, the other allowed to set in air, and their appearance closely noted from time to time. All of the brands tested apparently bore this test equally well, none of the pats showing any blotches, but remaining of a uniform color while induration was going on, and showing no cracks around the edges of the pats when fully set. This series of tests was carried out in full at a uniform temperature of about 60° to 70°. See also the results from test (C). The results of test "C" are given in Table II. In making this test the laboratory in which the pats were exposed was kept at a uniform temperature of 60°.

In making the sest for chrening and cracking, two pats of near current were made, each about three inchere in diameter and one half inch Thick. One of these was immered in in water, the other allowed to out in air, and Their appravance closely noted from have to time. All of the brando rested apparently fore This rest equally well, none of the pale showing any blotches, but remaining of a uniform ellor while inducation was going on, and showing no cracks around the redges of the pats when fully set. This price of tests was carried out in full at a uniform Aupenature of about 60° to 70°. See also The results from such (C! The results of first " and given in Sable II. In maxing this first the lab oralogy in which The pato war exposed was kapt at a miniform remporature of 60°.

In making the test for checking and cracking, two pats of neat cement were made, each about three inches in diameter and one half inch thick. One of these was immersed in in water, the other allowed to set in air, and their appearance closely noted from time to time. All of the brands tested apparently bore this test equally well, none of the pats showing any blotches, but remaining of a uniform color while induration was going on, and showing no cracks around the edges of the pats when fully set. This series of tests was carried out in full at a uniform temperature of about 60° to 70°. See also the results from test (C). The results of test "C" are given in Table II. In making this test the laboratory in which the pats were exposed was kept at a uniform temperature of 60°.

Brands	I	Beg	unt	70 S	'et'	Fully Set				-
27077000	Temperature 32° 60° 100° 150° 212° 32° 60° 100° 150° 212									
to accure	320	60°	1000	150	2120	32°	60°	1000	1500	212°
BlackDiamond										
Speed Mills	36'	30'	1.0'	3'	3	/ ^ħ /'	52'	24'	14'	22'
Flag	13'	10'	2'	2'	2'	19'	15'	4'	9'	26'
Brooklyn Bridge	13'	1 26	1 ^ħ 8'	20'	6'	2*50	2 33	1#13'	/ħ//'	47'
Utica	18'	/6'	26'	18'	17'	/*3'	59	48'	4 ³ 35	5h41'
Akron	37'	35'	/9'	5'	11'	119	172	37'	8 2/	1756
Saylor										' <i>18[‡]5</i> '
Atlas						3*40				
Hilton	50'	7'	d's		1/0'	135'	fall	2	733	17.
										· · · · ·

			Begun to	o Set		Fully Set						
Brands					Tempera	ture						
	32 ⁰	60 ⁰	100 ⁰	150°	212 ⁰	32 ⁰	60°	100°	150°	212°		
Black Diamond	59'	34'	12'	4'	3'	1h 38'	1h 22'	22'	12'	10'		
Speed Mills	36'	30'	10'	3'	3	1h 1'	52'	24'	14'	22'		
Flag	13'	10'	2'	2'	2'	19'	15'	4'	9'	26'		
Brooklyn Bridge	1h 3'	1h 26'	1h 8'	20'	6'	2h 50'	2h 53	1h 13'	1h 11'	47'		
Utica	18'	16'	26'	18'	17'	1h 3'	59'	48'	4h 35	5h 41		
Akron	37'	35'	19'	5'	11'	1h 19'	1h 17'	37'	8h 21'	1756		
Saylor		24'	19'	1h 7′	1h 50′		1h 29'	3h 20'	8h 42'	18h 5		
Atlas	36	42'	21'	8'	3'	3h 40'	3h 55'	2h 30'	44'	35'		
Hilton	50'	7'			1h 10'	1h 5'			7h 33'	17'		

Table II

Table II

The palo were about 3" in diameter and &" Thick and worn made as near ly uniform in size and dryrer of plasticity as was possible. The water and crement for each pat were exparately heated to the degree at which the fast was to be made, and were three quickly and thoroughly mixed and affeored on pieces of slate ales heated to the same Funferature as the water and creacent, For determining the time of setting. the wire test was used as recommended by . Sur, billinore, It is as follows; The pat is said to have begun to set when it just supports a wire to in diameter and loaded to wrigh our quarter found, and it is said to have fully set when it just supports a were \$4" in diametur, "in loaded & wrigh one pound. The results of this but and also shown graphically in Fig 2. where the here of setting is plotted as vertical ordinates, and Frup, and plotted as abscissar,

The pats were about 3" in diameter and 1/2" thick, and were made as nearly uniform in size and degree of plasticity as was possible. The water and cement for each pat were separately heated to the degree at which the test was to be made, and were then quickly and thoroughly mixed and exposed on pieces of slate also heated to the same temperature as the water and cement. For determining the time of setting, the wire test was used as recommended by Gen. Gillmore. It is as follows; The pat is said to have begun to set where it just supports a wire 1/12" in diameter and loaded to weigh one quarter pound; and it is said to have fully set when it just supports a wire 1/24" in diameter, and loaded to weigh one pound.

The results of this test are also shown graphically in Fig 2. where the time of setting is plotted as vertical ordinates, and temp., are plotted as abscissae.

A study of this table shows that in all the brands of Rosendale current which area hasted the turn of byginning is set rapidly decreased as the sumprature increased. The Utica excuent showed the least variation in fime, its curve in fig. I being almost a horizontal line. The Brooklyn Bridge brand series to be most radically effected by changes in Fruip. At ordinary rulp, it is comparaturly a very slow setting Prosendale, requiring one hour and Monety six minutes to begin to set at a remp, of 60°, but when the trup was finally raised to 212° it begain to set in six minutes which is perhaps about the average time for Rosrudale crement at That Imperature. The sime until fully set also decreased as The Traperature increased and with nearly all Rosendales the ceture continued to droke until the highest Inuperature was reached, There were however two noticrable exceptions to This ground rule, "The Ulica coment, at a

A study of this table shows that in all the brands of Rosendale cement which were tested the time of beginning to set rapidly decreased as the temperature increased. The Utica cement showed the least variation in time, its curve in fig. 2 being almost a horizontal line. The 'Brooklyn Bridge' brand seems to be most radically effected by changes in temp. At ordinary temp., it is comparatively a very slow setting Rosendale, requiring one hour and twenty six minutes to begin to set at a temp. of 60°, but where the temp. was finally raised to 212° it began to set in six minutes, which is perhaps about the average time for Rosendale cement at that temperature. The time until fully set also decreased as the temperature increased and with nearly all Rosendales the curve continued to drop until the highest temperature was reached. There were however two noticeable exceptions to this general rule. (1) The Utica cement, at a

Inuperature of 212° requiring five hours and forly mintertes will' fully out, and " the Ateron brand, at the same sump, requiring eighteen home I fully out, Both of This excuents were apparently much injured by the increased Junparature, The pati had but little strength. and both were easily crumbled, even after bring fully set. All the Possudale enuruto might at 212° were very badly checked and eracted while setting. The fable shows no grund rule to be applied to the Portland erments, possibly because of the limited number of brands rested. The hydraulic activity of the Atlas count steadily increased with the Jump, while with the Hilton cruce the minimum ordinate Is to curve in fig & is found at The 100° point. From This point the enve for both Hiltons and Daylors rever rapidly and has really little significance. Both crudits were apparently runed at 212°, The

temperature of 212° requiring five hours and forty minutes until fully set, and (2) the Akron brand, at the same temp., requiring eighteen hours to fully set. Both of these cements were apparently much injured by the increased temperature. The pats had but little strength, and both were easily crumbled, even after being fully set.

All the Rosendale cements mixed at 212° were very badly checked and cracked while setting.

The table shows no general rule to be applied to the Portland cements, possibly because of the limited number of brands tested. The hydraulic activity of the Atlas cement steadily increased with the temp., while with the Hilton cement the minimum ordinate to its curve in fig 2 is found at the 100° point. From this point the curve for both 'Hiltons' and 'Saylors' rises rapidly and has really little significance. Both cements were apparently ruined at 212°, the

sample of Helton "requiring seventeen hours to set completely, the sample of Saylors requiring eighteen hours. Both win soft and easily crumbled and appeared to have hardened by drying as much as by any chemical action of the cement. None of the brands of Portland cements tested shourd any signe of checking or cracking when fully set. The effect of freezing infor the strength of near cement mortar is shown in column six of Table No. III. Three of the coments Flag Akron and Atlas brands, were received too late to be used in the freezing tests, and are not given in the table. In making the tests for freezing, the briquettes, were maile of cement mixed with water at a temperature of 32° and immediately exposed to a temperature

sample of "Hilton" requiring seventeen hours to set completely, the sample of Saylors requiring eighteen hours. Both were soft and easily crumbled and appeared to have hardened by drying as much as by any chemical action of the cement. None of the brands of Portland cements tested showed any signs of checking or cracking when fully set. The effect of freezing upon the strength of neat cement mortar is shown in column six of Table. No. III. Three of the cements Flag, Akron, and Atlas brands, were received too late to be used in the freezing tests, and are not given in the table. In making the tests for freezing, the briquettes were made of cement mixed with water at a temperature of 32° and immediately exposed to a temperature

Brands		Temperature 32° 50° 75° 100° 150°									
Drands	32° .	50°	750	100°	150°	Frozen					
Black Diamond	69#	71#	89*	94#	135#	40*					
Speed Mills	/10*	105#	99 ^{**}	99#	118#	82*					
Flag											
Brooklyn Bridge	53*		44*	57*		58*					
Utica	33*	40*	6)#	76*	100#	*					
Akron			heigh			i Jas					
Saylor	131*			260#	390*	154*					
Atlas			and the	*							
Hilton	258#	324#	370*	408*	403*	203*					
* Completely ru	ined										

Table III Showing Effect of Temperature on Tensile Strength of Cements.

Brands			Т	emperature		
	32 ⁰	50°	75 ⁰	100°	150°	Frozen
Black Diamond	69*	71*	89*	94*	135*	40*
Speed Mills	110*	105*	99*	99*	118*	82*
Flag						
Brooklyn Bridge	53*		44*	57*		58*
Utica	33*	40*	69*	76*	100*	*
Akron						
Saylor	131*			260*	390*	154*
Atlas						
Hilton	258*	324*	370*	408*	403*	203*

*Completely ruined

Table III Showing Effect of Temperature On Tensile Strength of Cements.

varying from about 12° abour zero. at time of exposure, to about 15° below zero during the night. The length of time during which the briquettes wire exposed did not effect the strength of the briquetter, they showing that all chemical cection of the cement was suspended while the briquetter wor exposed to a freezing temperature. The briquetter in these test's work exposed to a freezing temperature for 24 hrsand were then immersed in water at a temperature of 60° for 24 hours, and ware then broken directly from the water. The briquetter were exposed on pieces of state. No tests wor made. in which the briquettes were frozen in water. J The temperature of 32,° for the teste shown in column one of table Nott, was maintained by Keeping the briquetter,

varying from about 12° above zero, at time of exposure, to about 15° below zero during the night. The length of time during which the briquettes were exposed did not effect the strength of the briquettes, thus showing that all chemical action of the cement was suspended while the briquettes were exposed to a freezing temperature. The briquettes in these tests were exposed to a freezing temperature for 24 hrs and were then immersed in water at a temperature of 60° for 24 hours, and were then broken directly from the water. The briquettes were exposed on pieces of slate. No tests were made in which the briquettes were frozen in water.

The temperature of 32°, for the tests shown in column one of table No III, was maintained by keeping the briquettes,

before immersion, in a vessel packed with melted snow. They were kept in This condition for 24 hours and then immensed for 24 hours in water containing melted snow and war then broken directly Soon water. The higher temperatures were maintained by the use of a water bath and store. He were constantly have pered for watert of ' proper appliances, and had considerable trouble in maintaining a constant temperature for any length of time. Although in most eases the temperature did not vary somuch as 10° from the desired temperature. The original plan of these experimento included a tech at the boiling point of Water but it was found in possible with the apparatus on hand to maintain this temperature for any length of time. Briquettes of some of the cement, were

before immersion, in a vessel packed with melted snow. They were kept in this condition for 24 hours and then immersed for 24 hours in water containing melted snow and were then broken directly from water. The higher temperatures were maintained by the use of a water bath and stove. We were constantly hampered for want of proper appliances, and had considerable

The higher temperatures were maintained by the use of a water bath and stove. We were constantly hampered for want of proper appliances, and had considerable trouble in maintaining a constant temperature for any length of time. Although in most cases the temperature did not vary so much as 10° from the desired temperature. The original plan of these experiments included a test at the boiling point of water, but it was found impossible with the apparatus on hand to maintain this temperature for any length of time Briquettes of some of the cements were

boiled for one hour The results of this test will be given in another blace The Utica cement cracked badly when exposed to freezing temperature and when intracted in water it becaue completely disintegrated and was reduced to a soft much the briquettes not bring strong enough to be handled without braking and crumbling As shown in table III, the Ustica cement gives an almost constant increase in tensile streng the for an increase in temperature The Black Diamond, Laylor & Hilton also show an increase of strong the with increase oftemperature. The Speed Mills & Brooklyn Bridge brands do not show a regular increase, although the gratestensile strength is obtained at the highest temperature in each case. None of the other cements tested shourd any signs of damage from freezing except the Brooklyn Blidge brand.

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the corners and edges of this cluent wor soft and easily crusble dalthough the briquettes which were frozen shourd higher tensile strength than the tests of higher temperatures. Saylon also shows a higher strength when forzen that at 32° Only sucoll sample of Saylon + Brooklyn bridge brands wer obtained and we were unable to make the 50° and 150° testo of Brooklyn Bridge and the 50° and 75° testo of the Sayloro. For all tests abour 32° the Perheut were mixed with water at 600 Experiments were also made with Speed Mills, Akrow and Hilton brands. to determine the effect of using motar after it had beguns to set. It is a common practice among masono when using cement mortaro in small amounto to mix enough mortar at one time to use for 10 minut

the comers and edges of this cement were soft and easily crumbled although the briquettes which were frozen showed higher tensile strength than the tests of higher temperatures. Saylor also shows a higher strength when frozen that at 32° Only small sample of Saylors & Brooklyn bridge brands were obtained and we were unable to make the 50° and 150° tests of Brooklyn Bridge and the 50° and 75° tests of the Saylors. For all tests above 32° the cements were mixed with water at 60°. Experiments were also made with Speed Mills, Akron and Hilton brands to determine the effect of using mortar after it had begun to set. It is a common practice among masons when using cement mortars in small amounts to mix enough mortar at one time to use for 15 minutes

or a half hour and often longer The results in table show that this practice should be discouraged. except in cases where a very slow setting cementsion used. Although only three brands won tested the general result is the same in all three eases, and would probably be found to be the same with other ecuents. In making these tests a pat wasmade and placed aside as soon as the centent was mixed when this par legan to set the first set of three bricks the was made when the pat was fully set the remaning cement was made into briquettes. A set of three brignetter was also made immediately after the water was added to the centent. These briquettes were kept at a temperature of 60,° for 24 hours when they were

or a half hour and often longer The results in table show that this practice should be discouraged except in cases when a very slow setting cement is used. Although only three brands were tested the general result is the same in all three cases, and would probably be found to be the same with other cements. In making these tests a pat was made and placed aside as soon as the cement was mixed when this pat began to set the first set of three bricks was made when the pat was fully set the remaining cement was made into briquettes. A set of three briquettes was also made immediately after the water was added to the cement. These briquettes were kept at a temperature of 60° for 24 hours when they were

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immersed in water of about the same temperature, for the same length of time they wenthen broken diretly from the water. From the considerable variation in the strength of the briquetter from the sauce series, it seemed evident that the final strength varied rapidly with the time after the cement had once begun to set. Our tests of cements with sand arenot as complete as we wished to make them. It was impossible at the time of our experiments, to obtain a sufficient quantity of sharp clean sand of necessary. coarseness, with which to carry ou tests of all the cements on hand, at the temperatures at which we tested the next elucato. The cements wir tested at temperature of 32? The proportions. I saud & cement worry 2 to 1 Aud 1 to 1. Briquettes of Hillon with these proportion o

immersed in water of about the same temperature, for the same length of time. they were then broken directly from the water. From the considerable variation in the strength of the briquettes from the same series, it seemed evident that the final strength varied rapidly with the time, after the cement had once begun to set. Our tests of cements with sand are not as complete as we wished to make them. It was impossible at the time of our experiments, to obtain a sufficient quantity of sharp clean sand of necessary coarseness, with which to carry on tests of all the cements on hand, at the temperatures at which we tested the neat cements. The cements were tested at temperatures of 32°. The proportions of sand & cement were 2 to 1 and 1 to 1. Briquettes of Hilton with these proportions

were not injured by freezing The results of these tests are shown in following table.

		/ Cement 2 Sana		/Cement Sand	/ <i>Cement</i> 2 Sand
Hilton	7/#	28#	Black Diamond	t 34#	14#
Speed Mills	56#	22#	Utica	26#	12#

The briquetter in these tests were kept at a temperature of 32° and then inmened in Water containing melting mow for the same length of time, and then broken.

Some tests were also made to determine

the effect day & soil on cements. The cements used in these experiments were Hilton and Akrow. The clay + soil was pularized before it was mixed with the cuesul. The clay way the ordinary yellow impervious clay. The soil

used was the ordinary black sandy loam

were not injured by freezing The results of these tests are shown in following table.

	1 Cement 1 Sand	1 Cement 2 Sand		1 Cement 1 Sand	1 Cement 2 Sand
Hilton	71 [#]	28 [#]	Black Diamond	34#	14#
Speed Mills	56 [#]	22 [#]	Utica	26#	12#

The briquettes in these tests were kept at a temperature of 32° and then immersed in water containing melting snow for the same length of time, and then broken.

Some tests were also made to determine the effect clay & soil on cements. The cements used in these experiments were Hilton and Akron. The clay & soil was pulverized before it was mixed with the cements. The clay was the ordinary yellow impervious clay. The soil used was the ordinary black sandy loam

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Sound on the banks of small creeks. These tests were made to determine to what extent the silt which is so connou in ordinary and would effect elmeith The following table shows the result of Various percentages of Clay + Soil mixed with the cements. The brighettes were made at a temperature of about 60? After 24 hours they were unnersed in water where they were allowed to remain for the same leng they time, they were then broken. deretly from the water. From the table lik will be seen that the effect on cencente when clay was used was not as injurious as when the same percentage I soil was used. When 50% of soil was used the brighter ware so soft and friable that they could not be houdled without crumbling.

found on the banks of small creeks. These tests were made to determine to what extent the silt which is so common in ordinary sands would effect cement. The following table shows the result of various percentages of Clay & Soil mixed with the cements. The briquettes were made at a temperature of about 60°. After 24 hours they were immersed in water where they were allowed to remain for the same length of time, they were then broken directly from the water. From the table it will be seen that the effect on cements when clay was used was not as injurious as when the same percentage of soil was used. When 50% of soil was used, the briquettes were so soft and friable that they could not be handled without crumbling.

	Vent		Soz	5		Clay 10% 25% 50%			
	xcui	5%	10%	25%	50%	10%	25%	50%	
Hilton	4.03*	320*	176*	11*	.00*	241*	100*	44#	
Akron	102*	76*	51#	21*	00#				
Akron	102*	26*	5/*	21*	00"				

*

	Beş	our Full	ý.	Boiled	
Hilton	403* 2	90*245	* Utica	21#	60#
Akron	103# 8.	7* 43*	Diamon	d 62*	89"
Speed Mills					403*
the result	Ta	ble IV	· · the	lente	ohu
for the ce lose in In	ment d col	had	begund	to set. brquet	thes
nade after	cem	ent -	lad beg	ain to	eet
nd those	in 3	rde	olunda	after	-
ement v	rus f.	ully	set.	•/	
the result	5 rec	orde	din co	lunn	/
lour show	s the	effe	it of ho	iling b	rique
		00	0	d	/

	Neat		Soil			Clay		
	5%	10%	25%	50%	10%	25%	50%	
Hilton	403 [#]	320#	176#	11#	00#	241#	100#	44#
Akron	102#	76#	51#	21#	00#			

		Begun	Fully		Boiled	
Hilton	403#	290#	245#	Utica	21#	60#
Akron	103#	87 [#]	43#	Diamond	62#	89#
Speed Mills	154 [#]	138 [#]	41#	Hilton	280 [#]	403#

The results recorded in the first column were obtained from briquettes made before the cement had begun to set. Those in 2nd column, from briquettes made after cement had begun to set and those in 3rd column after cement was fully set. The results recorded in column four show the effect of boiling briquettes.

Table IV

The briquettes in This First war allowed to set for 48 hours, & 4 hours in air and It hours in water at a surpristing of 60°. They were then immersed in boiling water for one how. The last column in table IV gives the strugth of the same cements when kept at a runpriature of 60° and not subjected to the boiling test, None of the cements boiled showed any craces, and to the upe were uninjured, but they all showed a considerable decrease in trusile strugth. This concludes the experiments made upon these excuents. From the results of the experiments have given, and of many That are not given in This article, the writers forly warranted in drawings the following general conclusions, Truperature eferto a considerable influence upon the hydraulic activity of cruent mortars, and in grund, the activity. increases directly with the increase of

The briquettes in this test were allowed to set for 48 hours, 24 hours in air and 24 hours in water at a temperature of 60°. They were then immersed in boiling water for one hour. The last column in table IV gives the strength of the same cements when kept at a temperature of 60° and not subjected to the boiling test. None of the cements boiled showed any cracks, and to the eye were uninjured, but they all showed a considerable decrease in tensile strength.

This concludes the experiments made upon these cements. From the results of the experiments here given, and of many that are not given in this article, the writers feel warranted in drawing the following general conclusions. Temperature exerts a considerable influence upon the hydraulic activity of cement mortars, and, in general, the activity increases directly with the increase of

Junprature. Our expriment would show That Portland erments and seriously injured if subjected to a sumperature above 150. while orthings all excress of water in mixing retardo the setting of erecent mortans, and may possibly promanently Them The addition of sand relaids The setting of excent mortano. all the brando of Portland, and with one or two exceptions, all the trando of Rosrudale Fisted, were uninjured when briquettes of neat erment were subjected to sever freizing in air. all quice ertingo cumento should be used as soon as mixed. Current work is primanently injared if sampred with after setting has begun, Current mortar must not be allowed to dry los quickly. Loamy sand it an enemy to any criment.

temperature. Our experiments would show that Portland cements are seriously injured if subjected to a temperature above 150° while setting.

An excess of water in mixing retards the setting of cement mortars, and may possibly permanently them The addition of sand retards the setting of cement mortars. All the brands of Portland, and with one or two exceptions, all the brands of Rosendale tested, were uninjured when briquettes of neat cement were subjected to severe freezing in air. All quick-setting cements should be used as soon as mixed. Cement work is permanently injured if tampered with after setting has begun. Cement mortar must not be allowed to dry too quickly. Loamy sand is an enemy to any cement.

Either loan or clay scriously injure the mortan, and the effect of loan or silt is found to be much more inquirious Than clay. The strugth of cruceus mortane is considerably reduced by inniversion in boiling water.

School of Mines, - May 1895

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Either loam or clay seriously injure the mortar, and the effect of loam or silt is found to be much more injurious than clay. The strength of cement mortar is considerably reduced by immersion in boiling water.

School of Mines. -- May 1895.

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