

(Paper No. 2802.)

(Abridged.)

“Experiments on the Strength of Cement Concrete.”

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IN this Paper the Author gives the results of experiments carried out to ascertain the modulus of rupture of concrete bars and the resistance to thrust of concrete arch ribs. The experiments are a continuation of those detailed by the Author in a previous Paper.¹ The Table (Appendix I) contains a summary of the

Fig. 1.

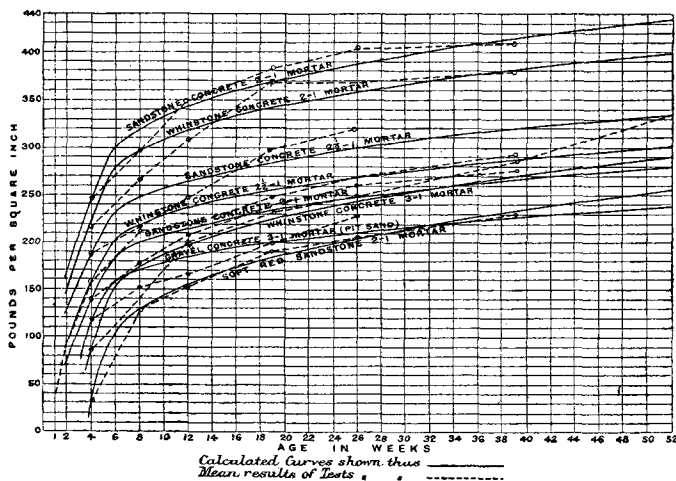


DIAGRAM SHOWING INCREASE OF STRENGTH OF CONCRETE BARS.

comparative results obtained by calculation and experiment, and these are graphically represented in the accompanying diagram. In Appendix II the figures are recorded which were arrived at from a series of experiments with concrete arches of different composition and varying ages. The Author concludes from his experiments that, up to four weeks, concrete increases more rapidly in tensile than in crushing strength, and that, subsequent to that age, the reverse is the case.

The Paper is accompanied by a diagram from which the Fig. has been prepared.

¹ Minutes of Proceedings Inst. C.E., vol. cxiii. p. 219.

APPENDIXES.

APPENDIX I.

MODULUS OF RUPTURE OF CONCRETE BARS.—COMPARATIVE RESULTS OBTAINED BY CALCULATION AND BY EXPERIMENT.

Age in Weeks.	Sandstone Concrete.						Whinstone Concrete.					
	Proportion of Sand to 1 of Cement.						Proportion of Sand to 1 of Cement.					
	2 to 1		2½ to 1		3 to 1		2 to 1		2½ to 1		3 to 1	
	Calculated.	Mean of Tests.	Calculated.	Mean of Tests.	Calculated.	Mean of Tests.	Calculated.	Mean of Tests.	Calculated.	Mean of Tests.	Calculated.	Mean of Tests.
1	..	..	..	71	..	..	..	..	..	29	..	..
2	164	..	123	107	85	..	145	..	96	94	..	..
4	233	233	182	182	134	134	217	217	154	154	82	82
8	320	297	249	214	199	174	296	267	218	212	172	141
12	343	348	266	248	216	206	317	307	234	218	196	201
19	369	382	286	297	236	238	341	368	253	248	223	231
26	387	402	300	320	249	259	357	380	266	269	242	249
39	413	409	319	..	268	291	381	379	285	311	268	285
52	433	..	335	..	283	..	398	..	299	357	289	335
Average between Ages of 4 and 39 weeks.	344	345	257	252	217	217	318	319	233	235	197	198
Difference per cent.	0.3	..	+1.9 ¹	..	..	..	-0.3	..	-0.8	..	-0.5	..
Mean error in calculation 0.6 per cent.												
Characteristic formula	$233 + 55$		$f = 182 +$		$f = 134 +$		$f = 217 +$		$f = 154 +$		$f = 82 + 57$	
	$3\sqrt{x-4}$		$42\sqrt{x-4}$		$41\sqrt{x-4}$		$50\sqrt{x-4}$		$40\sqrt{x-4}$		$(2)^3\sqrt{x-4}$	

f denotes modulus of rupture in lbs., and x denotes age of concrete in weeks.

¹ The greater divergence between calculation and experiment in this case is due to "b," the constant for increase of strength, being fixed at 42 instead of at 41; but a greater number of tests with freshly-crushed sand would probably have given results nearly corresponding to bars Nos. 30 and 50, raising its value to at least 45.

² The high value of "b," obtained for whinstone concrete with 3 to 1 mortar, is no doubt owing to the weaker mortar requiring a longer time to harden sufficiently to grip the smooth faces of the broken whinstone, hence the low mean test at four weeks, which it after makes up for as the age increases.

APPEN

RESISTANCE OF ARCHES TO

No. of Corresponding Test-Bars.	Parts to 1 of Cement.	Composition.	Age in Weeks.					
			1		2		4	
			S	$\frac{S}{f}$	S	$\frac{S}{f}$	S	$\frac{S}{f}$
2 to 1 Mortar.								
48	3	Sandstone . . . .	..	..	552	2.0 ¹		
	2	Crushed sandstone .						
43	3	Whinstone	{405 ¹	2.0	..	..	1,846	4.3
62	1 $\frac{1}{2}$	Crushed Whinstone .			633	13.5		
	1 $\frac{1}{2}$	„ sandstone						
49	3	Gravel . . . . .	..	..	834	3.8	2,022	6.7
	2	Crushed sandstone .						
2 $\frac{1}{2}$ to 1 Mortar.								
42	5	Sandstone . . . .	..	..	..	..	..	..
50	2 $\frac{1}{2}$	Crushed sandstone .	..	..	866	8.0	..	..
52	5	Whinstone . . . .	..	..	679	7.3	1,294	7.7
63 ⁵	1	Crushed Whinstone .	..	..	520	8.3	..	..
65 ⁵	1 $\frac{1}{2}$	„ sandstone			363	6.4	..	..
56	5	Whinstone . . . .	..	..	..	..	931	5.2
57 ⁴	2 $\frac{1}{2}$	Crushed sandstone .	..	..	..	..
59	6	Whinstone . . . .	..	..	1,315	25.8 ²	856 ⁴	7.5
	2 $\frac{1}{2}$	Crushed sandstone .						
38	6	Gravel . . . . .	..	..	..	..	435	5.1
	2 $\frac{1}{2}$	Pit sand						
51	5	Gravel . . . . .	..	..	866	12.4	{	..
60 ⁵	2 $\frac{1}{2}$	Crushed sandstone .	..	..	260	4.5 ⁴		
3 to 1 Mortar.								
53	5	Sandstone . . . .	..	..	455	3.2	544 ³	3.3
	3	Crushed sandstone .						
18	7	Sandstone	190	5.2	..	..	426 ¹	3.9
	3	Crushed sandstone .						
	5	Whinstone . . . .	..	..	..	..	..	..
65	1	Crushed Whinstone .	..	..	..	..	670	3.3
	2	„ sandstone						
	6	Whinstone . . . .	..	..	674	3.1	..	..
54	3	Crushed sandstone .						
	5	Gravel . . . . .	..	..	..	..	663	5.8
34	3	Pit sand						
	7	Gravel						
39	3	Pit sand of inferior quality . . . .	..	..	245	5.8	421	6.7

¹ Abutment yielded prematurely owing to insufficient loading.² Tested during hard frost, which may have increased the compressive strength while it diminished the tensile strength.³ Defect in one haunch.

DIX II.

THRUST IN LBS. PER SQUARE INCH.

Age in Weeks.							
8		12		19		26	
S	$\frac{S}{f}$	S	$\frac{S}{f}$	S	$\frac{S}{f}$	S	$\frac{S}{f}$
908	4.5						
..	..	1,330	6.3				
..	..	895	4.6	1,144	5.5		
1,284	5.2	..	..	3,406	12.3		
..	..	2,188	14.9				
..	..	1,160	7.4				
1,112	6.0						
..	..	2,447	11.9	..	..	5,243	17.8
925	5.4						
912	8.7	1,058	6.0				
806	3.3						
..	..	990	6.1				

⁴ Tested after hard frost.⁵ Sandstone from which sand was crushed for Nos. 57 to 65 was of a softer quality than that previously used.