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REPORT ON DUNAGAN'S BUOYANCY APPARATUS

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By: J. M. Holme

REPORT ON DUNAGAN'S BUOYANCY APPARATUS

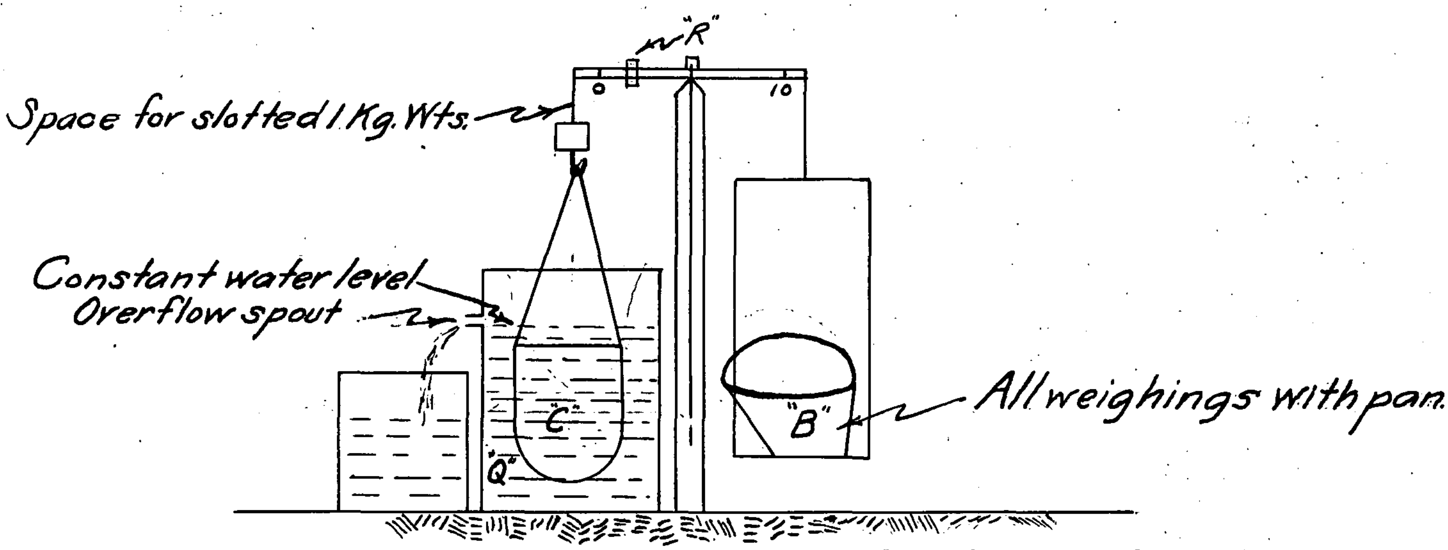
I - GENERAL PURPOSE OF APPARATUS AND SHORT DISCUSSION OF OTHER METHODS

The Dunagan Buoyancy Apparatus is designed for the purpose of determining the constituents of fresh concrete. The industry has long felt the need of an efficient apparatus for making this determination as it would un- meaning?
edly
doubtably reduce the time element in our present cylinder strength tests. Several engineers have advanced methods but without exception they lack practicability.

R. L. Bertin of the White Construction Company has described a method for segregating fresh concrete in the April issue of the A.C.I. Journal, as have W. I. Freel, G. J. Griesenauer, H. C. Ross and C. A. Huges. While I have not attempted to apply any of these methods, I am of the opinion they all fall short of their purpose. Bertin's method is the one most worthy of note, but should be placed all in the april issue?
Bertin or Dunagan's?
2nd to Dunagan's. His fundamental suggestion is to eliminate the use of previously established apparent specific gravities thruout a series of tests. He states that different samples of aggregate will give great variations in specific gravities determinations. This point he stresses but passes over the subjects of silt content and the cement retained on the

#100 sieve by saying that the final results should be corrected for these items. From my experience this past semester, I would say that he has stressed too highly the point which involves least error and slighted the sources of greatest error.

II - DESCRIPTION OF DUNAGAN APPARATUS AND DISCUSSION OF ITS USE



Cross section of apparatus - Balanced without load as shown when Q is filled to overflow container "C" is immersed and pan B is in position.

Weighing of samples.

(a) In air.

Sample is weighed in pan B to an even kilogram by placing slotted Kg wgs on left-hand side of balance.

(b) Weighing sample immersed.

Container C is removed and partly filled with water.

The sample is poured into C and stirred to remove entrained air. C is then filled with water, the sample allowed to settle for 1 minute and then replaced on beam and Q filled to overflowing. The weight immersed is then obtained by placing wgs in pan B and sliding the rider "R". The beam is graduated from zero to ten grams and the weight is accurate to the nearest one half gram.

III - NECESSARY PRELIMINARY TESTS

Before beginning any series of tests certain preliminary tests must be made. A - Apparent Specific Gravities. The first of these is for the apparent specific gravities of the aggregates and of cement. Representative samples of the aggregates should be secured, soaked in water for 24 hours and allowed to surface dry. Using either surface dried coarse aggregate, surface dried fine aggregate, or cement the sample is weighed in air and its weight recorded as W_1.

W_1 for
- Coarse aggregate = 2000 gms.
- Fine aggregate = 1000 gms.
- Cement = 1000 gms.

The sample is then weighed immersed and its weight recorded as W_2.

$$\text{Then app. Sp. Gr.} = \frac{W_1}{(W_1 - W_2)}$$

A - Consistency of Results

In our work we made a series of determinations for the specific gravities of the aggregates and of the cement. For the cement we obtained a consistent result of 3.1. For the aggregates results were averaged in both cases and variations from the mean noted noticed. The largest variation from the mean was in no case greater than 2 parts in 260. This is certainly a striking contrast to figures Bertin cities wherein he notes variations from the mean as large as 9 parts in 260. I am inclined to believe with Dunagan that samples taken from the same stock pile will give a resulting apparent specific gravity that will not cause any appreciable error in the results. At any time results are in doubt the aggregates can be checked for the specific gravity by weighing immersed, surface drying and weighing in air.

B - Moisture Determination

The determination for free moisture or absorption is based on the previously determined apparent specific gravity.

The sample is first weighed in air - W_1 and then ? $W_1 - (W_1 - W_2) g$

weighed immersed W_2. Then the ?

Free Moisture = $(W_1 - W_2)\dfrac{\text{sp. gr.}}{\text{sp.gr.} - 1}$ if the result is positive. If the result is a negative value it indicates the amount of moisture the aggregate is capable of absorbing. These tests should be made before actual working tests and should be checked from time to time during the work. Corrections can readily be made and resulting errors are negligible.

C - Silt Determination

The remaining preliminary tests are for the purpose of determining the percentage of silt in the aggregates and the percentage of cement retained on the #100 sieve. Silt is considered to be any of the aggregate passing the #100 sieve. I shall outline the method Dunagan suggests for these determinations.

A representative sample of aggregate is secured and is weighed immersed. Recorded W_1. The sample is then transferred to the nested sieves (#4 on #100) and washed until free of silt. It is then weighed immersed again - Recorded W_2.

$$\text{The percentage of silt} = \frac{W_1 - W_2}{W_1}$$

C - Determination of Cement Correction

In his manual Dunagan makes mention of the cement retained on #100 sieve but fails to state a method for determining its percentage. It may be obtained in two ways.

1 - Weigh a sample immersed - record W_1. Transfer to #100 and wash. Weigh immersed the cement that does not pass the sieve and record W_2.

$$\text{percent retained} = \frac{W_2}{W_1}$$

2 - Use a mix of fine aggregate (with silt previously removed by washing) and cement in the proportions they occur in the working mix.

Weigh the washed sand immersed; record W_1.

Add cement and record total weight immersed or W_2.

Transfer to #100 sieve and wash until all cement has passed that will pass and then weigh immersed; record W_3

cement % retained = $\dfrac{W_3 - W_1}{W_2 - W1}$ ✓

These last determinations (% silt passing the #100 and % cement retained on the #100) are the sources of error that make determinations of the constituents of concrete obtained by this method of doubtful value. I shall discuss them after giving an example of an actual test run.

IV - PROCEDURE FOR ACTUAL TEST

The preliminary tests described above are assumed to have been run. A sample of concrete is secured.

Wg in air = W_1

Wg immersed = W_2

It is washed on the nested sieves #3 and #100 until free of cement and silt. The aggregate retained on #4 (coarse aggregate) is weighed immersed; record as W_3. The aggregate on #100 (fine aggregate) is added and total wg weight W_4 obtained.

W_3 = wg of C.A. immersed - $W_3 \left(\frac{\text{sp gr}}{\text{Sp gr-1}}\right)_{C.A.}$ = wg of C A in air.

W_4 - W_3 = wg of FA immersed $(W_4 - W_3)\left(\frac{\text{sp gr}}{\text{sp gr-1}}\right)_{FA}$ = wg of FA in air.

W_2 - W_4 = wg of cement immersed $(W_2 - W_4)\left(\frac{\text{sp gr}}{\text{sp gr-1}}\right)_{Cement}$ = ~~cement~~ = wg of cement in air.

V - DISCUSSION OF RESULTS AND PROBABLE ERRORS

The wg of the original sample in air minus the sum of these last 3 wgs in air = the wg of the water. If no corrections be made any silt that was present in the aggregates in recorded as cement. Secondly any cement retained on the #100 is recorded as aggregate. These two factors do not cancel each other and the result is the W/C is incorrect. Corrections can be made for both of these factors but the corrections are of uncertain value.

In one series of tests which we made to determine the percentage of silt in fine aggregate the mean equaled 0.8% silt. The greatest variation from the mean was 1.0%. This variation would cause an error in the W/C ratio of 0.2 gals. per sack. For 2000# concrete this error (if it were the only error) might not be serious. In another series of tests on different sand we found a mean of 4.83% silt with the greatest variations from the mean = 2.1%. This variation would cause an error in the W/C ratios of 0.4 gals/ sack. An error of this magnitude would probably render the or the determination

concrete questionable. Errors of this nature fall on the wrong side of safety since they give a W/C ratio of a lower value than the actual W/C. Consequently a strength determination based on this method would indicate too high strength concrete.

The question of cement retained on the #100 sieve is dependent on several factors. More cement is retained when washed mixed with sand than when washed alone. The time and thoroughness of washing also have a decided effect.

In tests we made (when washed alone) the % amount of cement retained = 0.8%. When washed with sand in proportions of the mix the % ret = 1.6%. These second washings were done as nearly as possible to the way they would be done in actual test. However, Mr. Nettles determined that by continued washing he could greatly reduce the percentage retained. Washing a sample without the addition of sand he obtained 0.9% ret. Washing a second sample together with sand and continuing washing long after the last trace of cement passing could be detected he obtained a figure of 0.93% retained which is in close aggreement with his first figure. I am of the firm opinion and our tests bear witness that with ordinary washing the percentage of cement retained on the #100 sieve is a function of the sand (both quantity and kind).

working a

VI - EXAMPLES AND DISCUSSION OF RESEARCH AND FIELD TEST RESULTS

In handling the apparatus during the course of a test (that is weighing and washing) considerable care must spell out?

meaning

be exercised. Any loss of aggregate will cause an increase in the cement determination. An error in weighing again effects the W/C but this may be in either direction.

On the accompanying sheets, 1,2,3 are the results of five tests we made on one batch of concrete. It may be seen in each case the water cement ratio is somewhat less than the actual water cement ratio used in preparing the mix. The largest variation amounts to 0.31 gals. per sack, while the average variation is 0.17 gals/sack.

On sheet 4, I have listed several of the results taken from actual test done for the Clinton Conveyor by Mr. Dunagan. These samples were in each case taken from a mixer and in each run the samples received approximately the same amount of mixing. The results show great inconsistencies. In two cases the W/C is approximately 1 gal. low. In another case it is 1.72 gal./sack too high. A third value is 0.28 gals/sack low and two additional values 0.08 gals. per sack high.

From the comparision of these few figures, which are symbolic of both sets of tests in general, I feel that our results are by far the more consistent and show that they are the result of extreme laboratory care. The second set of figures (sheet 4) are such as might be expected from field tests made with the apparatus. It is decidedly im-

Sheet #1

Sample No.	***Item	Weight Submerged	Corrections Weight Submerged: Per Cent	Silt -No. 100	Cement +No. 100	Total	Corrected Weight Submerged	Multiplier ** sp.gr. / **sp.gr.-1	Weight in air	w/c Ratio by Weight	w/c Ratio by wt.x1.5x7.5 = gal./sack	Proportions by Weight	Abs. Vol. (wt. displ.)	Proportions by Abs. Vol.	Proportion of orig. Mix: by wt.	by A.V.	Notes:Ref.No.	
1	1	*1893.0							*3278.0				1385.0				H	
	2								3039.0									
	3								239.0				239.0	17.26		17.28		
	4	*1610.5										6.080			6.490			.72202
	5	*966.3	**0.3	+4.7		+4.7	971.0	**1.633	1583.0			3.660	612.0	44.19	3.905	44.61		
	6	644.2	**1.2	+6.8	-4.6	+2.2	646.4	**1.625	1050.0			2.420	403.6	29.14	2.585	28.78		
	7	282.5	**1.6	-4.7-6.8	+4.6	-6.9	275.6	**1.476	406.0			1.000	130.4	9.42	1.000	9.23		
	8									0.588	6.63				6.74			
2	1	*1791.7							*3113.0				1321.3				N	
	2								2879.1									
	3								233.9				233.9	17.70		17.28		
	4	*1520.5										6.356						75683
	5	*882.7	**0.3	+2.6		+2.6	885.3	**1.633	1445.7			3.694	560.4	42.41	3.905	44.61		
	C	637.8	**1.2	+7.7	-4.3	+3.4	641.2	**1.625	1042.0			2.662	400.8	30.33	2.585	28.78		
	7	271.2	**1.6	-2.6-7.7	+4.3	-6.0	265.2	**1.476	391.4			1.000	126.2	9.55	1.000	9.23		
	8									0.598	6.73				6.74			

* Test Data

** Preliminary Test Data

*** Key: - 1. Total Sample
2. Cement + Sand + Stone
3. Water
4. Stone and Sand
5. Stone
6. Sand
7. Cement
8. Water-Cement

Operator

Sample) (1
Taken) (2

Sheet #1

Sheet #2

Sample No.	***Item	Weight Submerged	Corrections Weight Submerged: Per Cent	Silt -No. 100	Cement +No. 100	Total	Corrected Weight Submerged	Multiplier ** sp.gr. / ** sp.gr.-1	Weight in air	w/c Ratio by Weight	w/c Ratio by wt.x1.5x7.5 = gal./sack	Proportions by Weight	Abs. Vol. (wt. displ.)	Proportions by Abs.Vol.	Proportion of orig. Mix by wt.	Proportion of orig. Mix by A.V.	Notes:Ref.No.	
3	1	*1697.5							*2938				1240.5					
	2								2728.2									
	3								209.8				209.8	16.91		17.28	N	
	4	*1442.8																
	5	*853.5	**0.3	+2.6		+2.6	856.1	**1.633	1398.0			3.802	541.9	43.68	3.905	44.61		,80613
	6	589.3	**1.2	+7.1	-4.1	+3.0	592.3	**1.625	962.5			2.617	370.2	29.84	2.585	28.78		
	7	254.7	**1.6	-2.6-7.1	+4.1	-5.6	249.1	**1.476	367.7			1.000	118.6	9.56	1.000	9.23		
	8									0.571	6.42							
4	1	*1847.3							*3206.0				1358.7				H	
	2								2967.9									
	3								238.1				238.1	17.52		17.28		
	4	*1564.2																,7360e
	5	*912.5	**0.3	+2.7		+2.7	915.2	**1.633	1494.5			3.654	579.3	42.64	3.905	44.61		
	6	651.7	**1.2	+7.8	-4.5	+3.3	655.0	**1.625	1064.4			2.602	409.4	30.13	2.585	28.78		
	7	283.1	**1.6	-2.7-7.8	+4.5	-6.0	277.1	**1.476	409.0			1.000	131.9	9.71	1.000	9.23		
	8									0.582	6.55							

* Test Data

** Preliminary Test Data

*** Key: - 1. Total Sample
2. Cement + Sand + Stone
3. Water
4. Stone and Sand
5. Stone
6. Sand
7. Cement
8. Water-Cement

Operator
Sample)(1
Taken)(2

Sheet #2

Sheet #3

Sample No.	***Item	Weight Submerged	Corrections Weight Submerged: Per Cent	Silt -No. 100	Cement +No. 100	Total	Corrected Weight Submerged	Multiplier ** sp.gr. / **sp.gr.-1	Weight in air	w/c Ratio by Weight	w/c Ratio by wt.x1.5x7.5 = gal./sack	Proportions by Weight	Abs. Vol. (wt. displ.)	Proportions by Abs.Vol.	Proportion of orig. Mix by wt.	Proportion of orig. Mix by A.V.	Notes:Ref.No.
5	1	*1789.0							*3106.0				13170				H
	2								2873.4								
	3								232.6				232.6	17.66		17.28	
	4	*1510.5															
	5	*866.5	**0.3	+2.6		+2.6	869.1	**1.633	1419.2			3.526	550.1	41.77	3.905	44.61	
	6	644.0	**1.2	+7.7	-4.5	+3.2	647.2	**1.625	1051.7			2.613	404.5	30.71	2.585	28.78	
	7	278.5	**1.6	-2.6-7.7	+4.5	-5.8	272.7	**1.476	402.5			1.000	129.8	9.86	1.000	9.23	
	8									0.578	6.50						
	1	*							*								
	2																
	3																
	4	*															
	5	*	**					**									
	6		**					**									
	7		**					**									
	8																

75930

* Test Data ** Preliminary Test Data

*** Key: - 1. Total Sample
2. Cement + Sand + Stone
3. Water
4. Stone and Sand
5. Stone
6. Sand
7. Cement
8. Water-Cement

Operator

Sample)(1
Taken)(2

13170

Sheet #3

	Per Cent Absolute Volume				Mix by Weight				
	Water	Cement	Sand	Rock	Cement	Sand	Rock	S + R	W/C = gals/sack
Standard	18.34	9.52	25.64	46.50	1	2.33	4.16	6.49	7.00
Run 1	15.58	9.16	20.96	54.30	1	1.98	5.05	7.03	6.12
	17.40	9.39	24.05	49.15	1	2.21	4.46	5.67	6.72
Run 2	19.27	9.78	26.83	44.02	1	2.35	3.79	6.14	7.08
	18.24	10.89	24.42	46.18	1	1.97	3.61	5.58	6.08
Run 3	21.22	8.83	22.89	47.06	1	2.24	4.54	6.78	8.72
	18.08	9.26	24.76	47.90	1	2.31	4.40	6.71	7.08

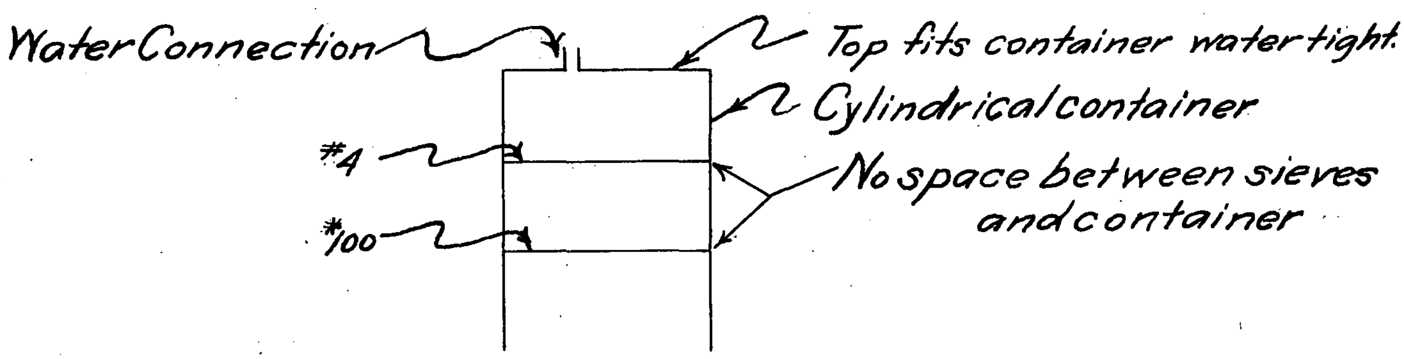
Sheet 4.

possible to use the care and take the time necessary in field tests that can be used in laboratory research work.

Therefore operating the apparatus under the present suggested method results such as those on sheet 4 are to be expected.

VII - TECHNIQUE AND ADEQUATE SIEVES

I feel that some errors may be eliminated if a more rigid code for operation is set forth. It is my suggestion that the sieves used be changed and a time element be introduced into the washing. The accompanying figure shows the screens as I think they might be arranged.



Both sieves fit tightly against sides of container

If an arrangement of sieve of this type could be devised "clean" water could be used in washing; the sieves could be shaken violently and no losses could occur with reasonable cars being exercised. If the preliminary tests were made using these sieves the percentage of cement retained on #100 could, I believe be somewhat controlled by using the 2nd method I have suggested for its determination and by washing and shaking the sieves in as a consistent manner for a certain established length of time.

VIII - CONCLUSION

I do not feel that the apparatus is without possibilities. It's greatest fault comes from the lack of check on the two most important i~~d~~tems cement and water. As it stands therefore I do not think the apparatus serves its purpose to an appreciable extent. However since the sources of error are well known a study devoted to their elimination should certainly bring about results that will tend to increase the efficiency of the apparatus to a considerable extent.

Renders a little service.