STUDY OF ARMOUR STONE SHAPE CHARECTERESTICS AND PACKING EFFICIECY OF SEAWALL STRUCTURE

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1. INTRODUCTION

A seawall is a structure made of stones, concrete, masonry or sheet piles, built parallel to the shore at the transition between the beach and the mainland or dune. Seawalls are generally made of armourstone. The stones are readily available and are not considered as a manufactured product just because they come directly from quarry. Since they are naturally formed, they are not a threat to marine life in any way. The stones generally have a longer life compared to the rest of the safety measures. The only threat is that they may be washed away due to the high tide strength.

Armour stone packaging is important for preparing goods for containment, protection, transport, handling, distribution, delivery and presentation. During the construction of seawalls, it is necessary to have proper packing of armour stone. It's impossible to arrange the stones one by one manually for the construction of the seawall because of the following reasons-

- Working on the shores is both difficult and dangerous at the same time
- A very large number of labours are required
- Its impossible to handle very stones using manual labours
- It'll literally take years for the construction if it's done manually.
- As a lot of labours are required the cost is increase drastically.

Therefore one way of achieving packing efficiency is to arrange armour stone using heavy machineries like a crane or a JCB.

While packing stones it is essential to have voids of a certain percentage. This is because a structure packed in 0% void can be easily broken by wave action. When a void is given, a certain amount of seawater passes through it and the impact of the wave on the sea wall decreases.

Packing affects the shape of the structure so it is important to have proper packing. Usually while construction of a seawall the only gradation of armour stones are considered, but if only gradation is considered the quality and overall bill are affected. For example if the design condition is to have stones of grade 350-700 and we used any stones within this grade irrespective of their shape and quality there is a chance of huge void formation within the structure which can adversely affect the bill and overall stability of the structure. Thus shape is an important factor that has to be considered.

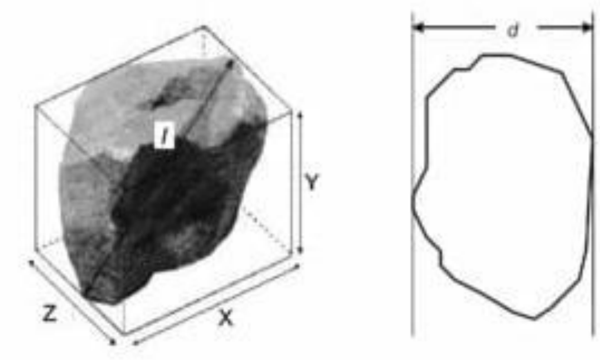
The Armourstone for the construction of the seawalls are obtained from the quarry's. The stones obtained from the quarry are blasted to become the product we want. Stones blasted in this way are available in various shapes and sizes. In the old days, we used split stones for the construction of sea wall. It was made of exactly the same cubical shape. The void ratio between them was less than 5% as it is not available for construction now, blasted stones are used instead.

The blasted stones come in various shapes and size like flaky, cubical, elongated etc. Therefore it is very important to select the appropriately shaped stones during construction. In this project we have used two parameters to determine which shaped stones are suitable and which is not one is aspect ratio and the other is blockiness.

1.1 PARAMETERS

ASPECT RATIO

Aspect Ratio (Length-to-thickness ratio) is defined as the maximum length(m) divided by the minimum distance, d (m), between parallel lines through which the particle would just pass. This form description is the industry standard now embodied in EN 13383 for both armourstone and aggregates.

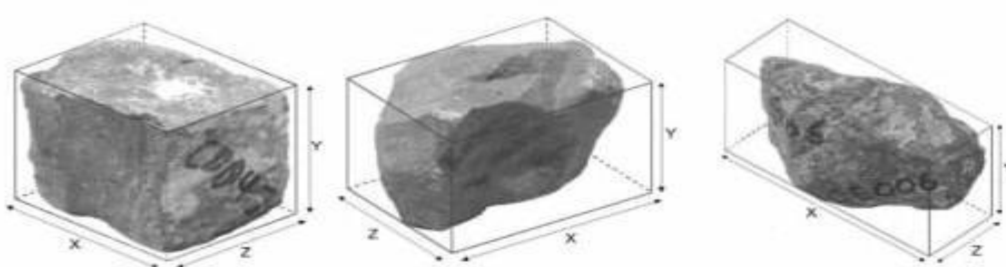


$$\text{Aspect Ratio}=(L/D)$$

FIG 4.2 ASPECT RATIO OF STONE

BLOCKINESS

- Blockiness (BL) is defined as the volume of a stone divided by the volume of the enclosing XYZ orthogonal box with a minimum volume.
- Higher blockiness can lead to higher density, more numbers of contact points and finally it will result into greater interlock.



(a) (b) (c)

FIG 4.3 BLOCKINESS OF STONE

(a) CUBICAL (b) FLAKEY STONE (c) ELONGATED STONE

$$BL=[V_{stone}/V_{cubical}]\ x100$$

Armour stone with an aspect ratio greater than 3 is considered as an elongated or Flaky stone so such stones should not be used and it should be rejected .Stones with an aspect ratio between 1 to 2 are most preferred as they provide better packing.

Blockness of a perfectly cubic stone is 100% so as the number goes down the shape of the stone becomes lesser cubic and more of an elongated or flakey shaped stone, but 100% blocky stones is nearly impossible to obtain because these are obtained from blasting there for the cubic stones that we get usually have a blockness of 60 to 70% sometimes up to 80 percentage.

2. EXPERIMENT 1- CONSTRUCTION OF SEAWALL EMBANKMENT USING MIXED STONES

We collected 70 samples of armour stone for this experiment. 70 stones were randomly taken and had different shapes and sizes. Using these stones we constructed a frustum embankment by dropping each stones.

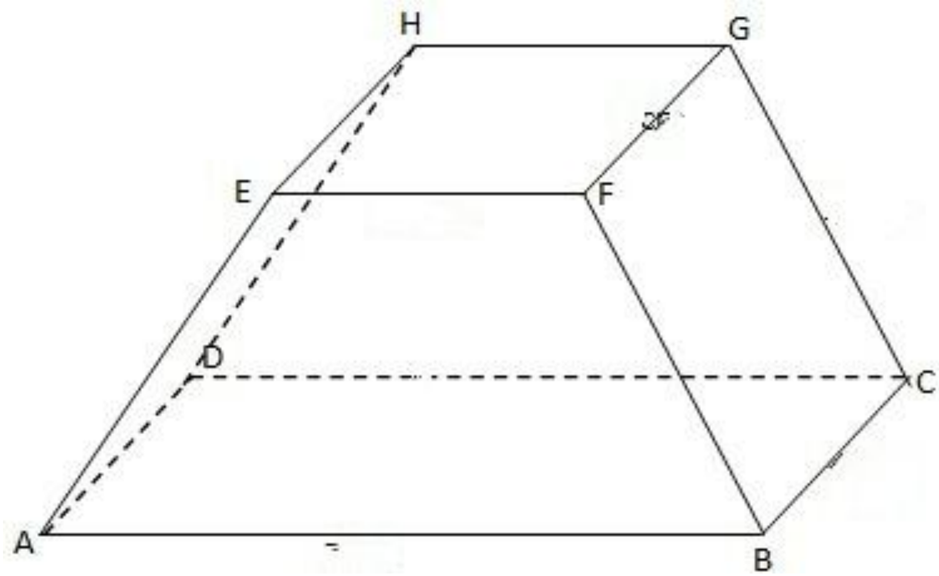


FIG 1 EMBANKMENT USING MIXED STONE

The dimensions of the so formed embankment were measured and noted down,

The resultant embankment has the following dimensions.

Base length=170cm

Base width=90cm

Top length=110cm

Top width=50cm

Height=75cm

Using the obtained data's we were able to calculate the volume of the frustum section. Each stone from the embankment were taken out to measure it's weight and dimensions(length,breadth,depth).These readings were noted down. Using these readings, we calculated the aspect ratio(Aspect Ratio=(L/D) and blockiness (BL=[Vstone/Vcubical] x100) of each stone.

Now to find Volume of voids we need to subtract the total volume of stones from the volume of the embankment. Next step is to find the value Void Ratio & Porosity.

Void Ratio=(Volume of Voids/Total volume of stones)

Porosity = (Volume of Void / Total volume of embankment)

3. EXPERIMENT 2- CONSTRUCTION OF SEAWALL EMBANKMENT USING CUBIC STONES

We collected 84 samples of cubical armourstone for this experiment. Although these are cubical stones they are not exactly cubical but resembles cubical stones .Using these stones we constructed another frustum embankment by dropping each stones .

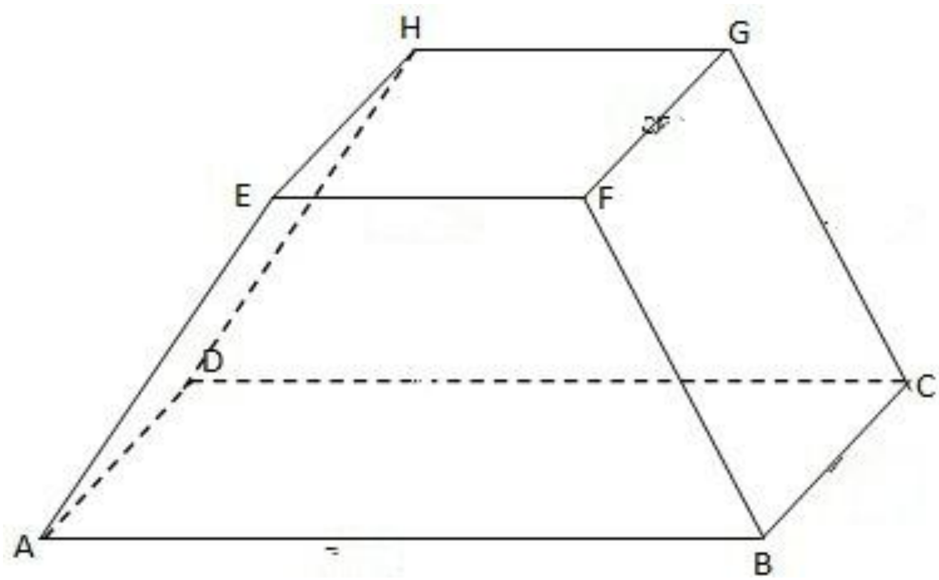


FIG2 EMBAKMENT USING CUBICAL STONE

The dimensions of the so formed embankment were measured and noted down,

The resultant embankment has the following dimensions

Base length=160cm

Base width=90cm

Top length=100cm

Top width=30cm

Height=70cm

FIG3 MINIATURE EMBAKMENT USING CUBICAL STONES

Using the obtained data's we were able to calculate the volume of the frustum section. One by one each stone from the embankment were taken out to measure it's weight and dimensions(length,bredth,depth).These readings were noted down. Using these readings we calculated the aspect ratio(Aspect Ratio=(L/D) and blockiness (BL=[Vstone/Vcubical] x100) of each stone

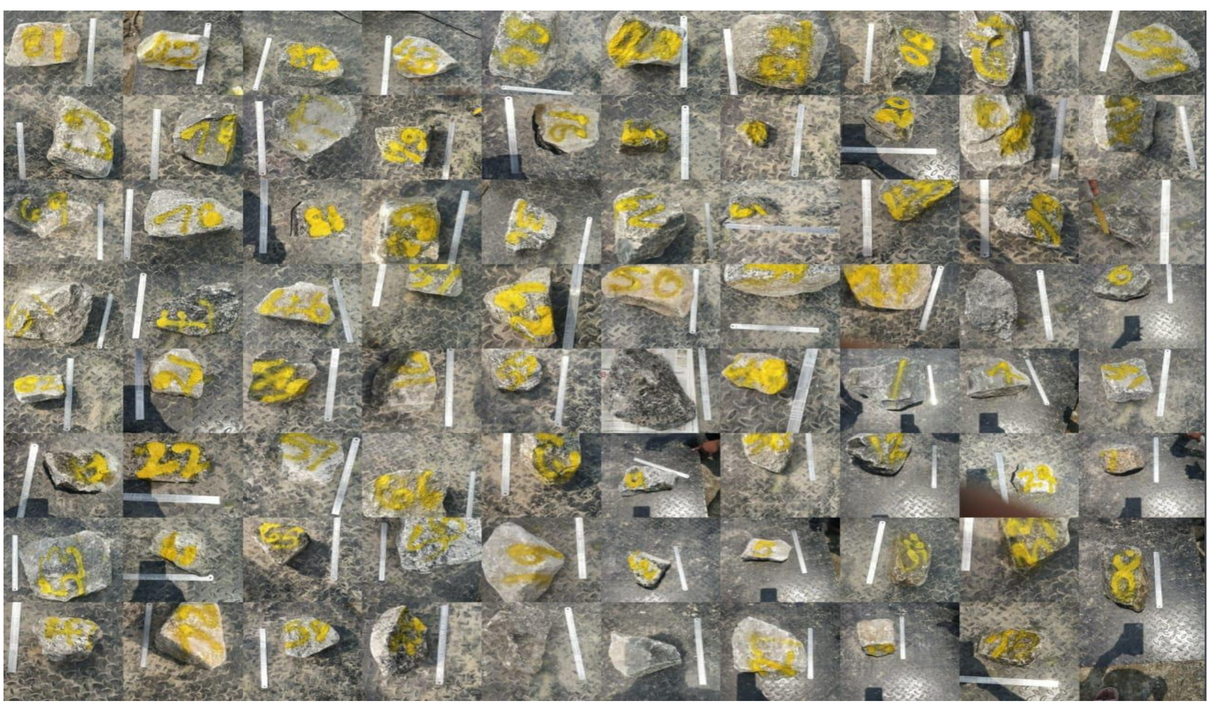


Fig 4 CUBICAL STONES

Now to find Volume of voids we need to subtract the total volume of stones from the volume of the embankment. Next step is to find the value Void Ratio & Porosity.

Sl no.	Weight	Length	Width	Depth	Aspec ratio	Vol of stone	Vol of stone in cubical	Blockiness
1	61	41.8	36.2	28.2	1.482269504	0.022592593	4523131.872	**4.9949E-07**
2	8.2	25.4	17.4	13.9	1.827338129	0.003037037	651177.864	**4.66391E-07**
3	7.8	25.2	19.6	14.8	1.702702703	0.002888889	774855.696	**3.72829E-07**
4	11.4	27.5	20.6	16.9	1.627218935	0.004222222	1014822.1	**4.16055E-07**
5	5.8	20.6	14.6	13.7	1.503649635	0.002148148	436757.672	**4.9184E-07**
6	16.6	28	23	18.5	1.513513514	0.006148148	1262878	**4.86836E-07**
7	10.6	23.6	19.3	17.5	1.348571429	0.003925926	844909.4	**4.64656E-07**
8	20.8	31.3	24.1	18.3	1.710382514	0.007703704	1463243.334	**5.26481E-07**
9	9	26.3	15.2	15.7	1.675159236	0.003333333	665274.592	**5.01046E-07**
10	7.6	21.4	17.7	13.8	1.550724638	0.002814815	554073.384	**5.08022E-07**
11	18.2	31.2	21.8	17.9	1.74301676	0.006740741	1290529.584	**5.22324E-07**
12	25.4	35.5	28.1	26.6	1.334586466	0.009407407	2812685.98	**3.34463E-07**
13	20.8	32.3	25.4	18.2	1.774725275	0.007703704	1582748.264	**4.8673E-07**
14	30.8	41.2	24.4	21.3	1.9342723	0.011407407	2269715.184	**5.02592E-07**
15	12.3	28.4	14.1	15.6	1.820512821	0.004555556	662161.584	**6.87982E-07**
16	6.8	20	18.1	10.8	1.851851852	0.002518519	414411.6	**6.07734E-07**
17	6.8	22.4	20.4	12.5	1.792	0.002518519	605466	**4.15964E-07**
18	3.2	17.8	16.7	9.7	1.835051546	0.001185185	305636.732	**3.87776E-07**
19	3.6	20.4	11.4	12.6	1.619047619	0.001333333	310601.136	**4.29275E-07**
20	4.6	18.1	12.4	14.2	1.274647887	0.001703704	337821.088	**5.04321E-07**
21	4	20.1	14.4	8	2.5125	0.001481481	245439.12	**6.03604E-07**
22	4.6	17.2	14.7	10.3	1.669902913	0.001703704	276044.712	**6.17184E-07**
23	6.2	22.6	16.8	15.4	1.467532468	0.002296296	619783.632	**3.705E-07**
24	3.4	17.6	17.5	5.6	3.142857143	0.001259259	182822.8	**6.88787E-07**
25	2.6	15.92	14	7	2.274285714	0.000962963	165370.96	**5.82305E-07**
26	7.2	13.8	14.2	13.5	1.022222222	0.002666667	280412.76	**9.50979E-07**
27	2.4	15.9	11.5	7.8	2.038461538	0.000888889	151174.38	**5.87989E-07**
28	13.8	33	24.5	12.6	2.619047619	0.005111111	1079826.6	**4.73327E-07**
29	4	19.5	13	9.9	1.96969697	0.001481481	266016.9	**5.56913E-07**
30	15	32.6	28.21	18	1.811111111	0.005555556	1754678.568	**3.16614E-07**
31	5.2	19.8	18.5	12.5	1.584	0.001925926	485341.5	**3.96819E-07**
32	8.6	25	18.2	10.8	2.314814815	0.003185185	520878	**6.11503E-07**
33	7.8	25.5	17	13	1.961538462	0.002888889	597357	**4.83612E-07**
34	7.2	26.5	24	9	2.944444444	0.002666667	606738	**4.39509E-07**
35	7.2	33.5	12	10.9	3.073394495	0.002666667	464464.8	**5.74138E-07**
36	11.8	39.4	19.5	12	3.283333333	0.00437037	977271.6	**4.47201E-07**
37	6.6	16.9	15.3	16	1.05625	0.002444444	438528.72	**5.57419E-07**
38	7.6	22.5	16.5	14	1.607142857	0.002814815	550929	**5.10922E-07**
39	19	31	20.6	13.9	2.230215827	0.007037037	940907.24	**7.47899E-07**
40	9.8	22.8	19	17	1.341176471	0.00362963	780620.4	**4.64967E-07**
41	14.8	29	21.8	14	2.071428571	0.005481481	938178.8	**5.84268E-07**
42	9.2	23.5	16.9	29.2	0.804794521	0.003407407	1229252.68	**2.77193E-07**
43	8.2	23	22.5	11.2	2.053571429	0.003037037	614370	**4.94334E-07**
44	2	12.4	11	9.5	1.305263158	0.000740741	137348.8	**5.39314E-07**
45	4.8	19.8	18.5	12.8	1.546875	0.001777778	496989.84	**3.57709E-07**
46	6.8	25.6	16.8	10	2.56	0.002518519	455878.8	**5.52454E-07**
47	4.6	18.6	17.4	13.5	1.377777778	0.001703704	463122.84	**3.67873E-07**
48	1	12.3	9	5.8	2.120689655	0.00037037	68052.36	**5.44243E-07**
49	5.8	23.5	15.6	11.5	2.043478261	0.002148148	446879.4	**4.807E-07**
50	14.4	28.2	15	16.5	1.709090909	0.005333333	739821	**7.20895E-07**
51	31.4	38.2	32.8	19.6	1.948979592	0.01162963	2603143.696	**4.46753E-07**
52	2.2	15.1	10.6	6	2.516666667	0.000814815	101792.16	**8.00469E-07**
53	42.8	40	37.1	24	1.666666667	0.015851852	3775290	**4.19884E-07**
54	21.6	37	21	18.8	1.968085106	0.008	1548399.6	**5.16662E-07**
55	4.8	20.6	20.2	11	1.872727273	0.001777778	485189.92	**3.66409E-07**
56	9.6	24	16.2	19.2	1.25	0.003555556	791279.76	**4.49342E-07**
57	8.4	23	22.1	15.6	1.474358974	0.003111111	840518.88	**3.70142E-07**
58	36.8	37	33.4	18.3	2.021857923	0.01362963	2397198.84	**5.68565E-07**
59	8.4	20.9	20.9	12.9	1.620155039	0.003111111	597287.994	**5.20873E-07**
60	1.2	12.5	9.6	7.2	1.736111111	0.000444444	91578	**4.85318E-07**

61	1.4	13.7	9.6	10.8	1.268518519	0.000518519	150558.096	**3.44398E-07**
62	2.6	19.7	13.8	7.9	2.493670886	0.000962963	227649.564	**4.23002E-07**
63	8.8	26.6	16.3	12.9	2.062015504	0.003259259	592871.292	**5.49741E-07**
64	6.8	22.9	21.9	9.5	2.410526316	0.002518519	505014.57	**4.98702E-07**
65	4.4	18.3	15	13.9	1.316546763	0.00162963	404442.3	**4.02933E-07**
66	21.8	35.5	31.3	12.6	2.817460317	0.008074074	1484045.94	**5.44058E-07**
67	17	36.2	23.5	16	2.2625	0.006296296	1442781.2	**4.364E-07**
68	12.8	28.2	22.6	15	1.88	0.004740741	1013332.8	**4.67837E-07**
69	20.6	24.2	28.4	13.3	1.819548872	0.00762963	968921.344	**7.87435E-07**
70	30.8	29	21.5	12	2.416666667	0.011407407	793086	**1.43836E-06**
71	6.6	24	19.9	10.8	2.222222222	0.002444444	546750.48	**4.47086E-07**
72	17	35.4	26.2	18.2	1.945054945	0.006296296	1789288.416	**3.51888E-07**
73	4.6	20.5	19.2	14.4	1.423611111	0.001703704	600785.04	**2.8358E-07**
74	21.2	31	28.6	20.3	1.527093596	0.007851852	1907779.88	**4.1157E-07**
75	25.2	32.3	31.6	20.1	1.606965174	0.009333333	2174654.808	**4.29187E-07**
76	12.4	31.7	22.3	13.2	2.401515152	0.004592593	989102.472	**4.64319E-07**
77	15.8	30.9	29.5	13.9	2.223021583	0.005851852	1343071.77	**4.35707E-07**
78	10.8	22.4	23.1	17.1	1.30994152	0.004	937905.744	**4.26482E-07**
79	25.8	41.5	27.1	23.3	1.78111588	0.009555556	2777654.57	**3.44015E-07**
80	30.2	46.7	23	23.2	2.012931034	0.011185185	2641420.72	**4.23453E-07**
81	9.2	26	23	14.5	1.793103448	0.003407407	919120	**3.70725E-07**
82	5.6	28	27.5	16.3	1.717791411	0.002074074	1330400	**1.55899E-07**
83	7.8	30	23.5	29.2	1.02739726	0.002888889	2182110	**1.3239E-07**
84	17.2	39	13.5	21.9	1.780821918	0.00637037	1222211.1	**5.21217E-07**
					Total	0.39337		

TABLE 1MEASUREMENT AND CALCULATION USING CUBICAL STONE

CALCULATION

Total volume of stones = 0.39337m^3

Volume of embankment = 0.0.55936m^3

Volume of voids =Volume of embankment – Total volume of stones

=0.16599m^3

Void Ratio (e) = (Volume of Voids / Total volume of stones)

0.16599 / 0.39337= 0.42196

Porosity (n) = (Volume of Void / Total volume of embankment)

0.16599 / 0.55936 =**<u>0.2967</u>**

<u>=29%</u>

4. EXPERIMENT 3- CONSTRUCTION OF SEAWALL EMBANKMENT USING FLAKEY & ELONGATED STONES

We collected 46 samples of flaky and elongated armourstone for this experiment. Now it's clearly visible that the no of stones decreased drastically this shows the presence of voids & decrease in stone volume. Using these stones we again constructed a frustum embankment by dropping each stones .

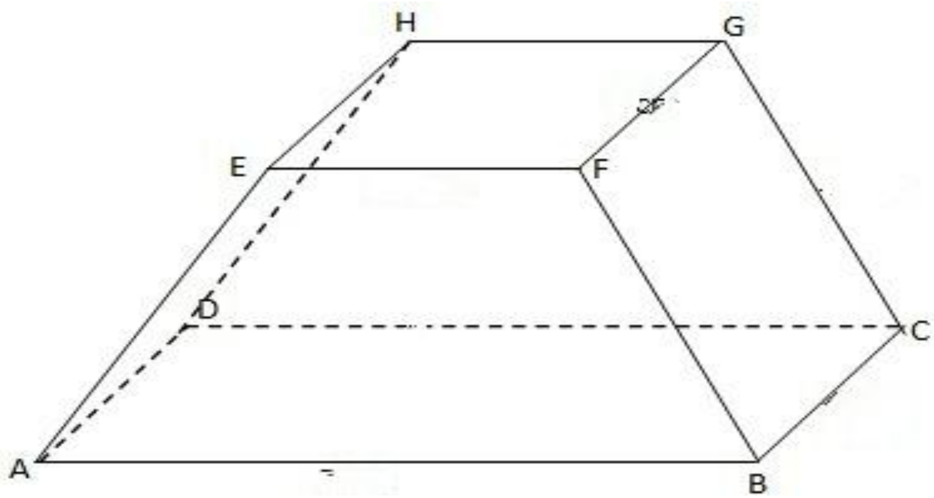


FIG5 EMBAKMENT USING FLAKEY STONES

The dimensions of the so formed embankment were measured and noted down,

The resultant embankment has the following dimensions

Base length=160cm

Base width=90cm

Top length=95cm

Top width=50cm

Height=70cm

FIG 6 MINIATURE EMBAKMENT USING FLAKEY STONE

Using the obtained data's we were able to calculate the volume of the frustum section. One by one each stone from the embankment were taken out to measure it's weight and dimensions (length,bredth,depth). These readings were noted down. Using these readings we calculated the aspect ratio(Aspect Ratio=(L/D) and blockiness (BL=[Vstone/Vcubical] x100) of each stone

FIG 7 FLAKEY STONES

Now to find Volume of voids we need to subtract the total volume of stones from the volume of the embankment. Next step is to find the value Void Ratio & Porosity.

Sl no.	Weight	Length	Width	Depth	Aspec ratio	Vol of stone	Vol of stone in cubical	Blockiness
1	5.6	41.6	22	10.6	3.924528302	0.002113208	0.00970112	**21.78312965**
2	21.2	43.6	26.6	13.6	3.205882353	0.008	0.015772736	**50.72043303**
3	29.8	50	33.5	19.5	2.564102564	0.011245283	0.0326625	**34.42872719**
4	21	40	31	13	3.076923077	0.007924528	0.01612	**49.15960485**
5	15.4	47	19.8	11.4	4.122807018	0.005811321	0.01060884	**54.77809784**
6	16.8	43.2	31.5	9.3	4.64516129	0.006339623	0.01265544	**50.09405158**
7	37.8	66.5	32.3	15.4	4.318181818	0.014264151	0.03307843	**43.1222127**
8	23.2	42.3	23.2	12.2	3.467213115	0.008754717	0.011972592	**73.12298775**
9	36	46.6	37.3	11.3	4.123893805	0.013584906	0.019641434	**69.16453076**
10	43.8	62.3	41.2	17.1	3.643274854	0.016528302	0.043891596	**37.65709929**
11	28.6	48.5	44.5	20.7	2.342995169	0.010792453	0.044675775	**24.15728173**
12	12.4	32.3	26.5	12.2	2.647540984	0.004679245	0.01044259	**44.80924065**
13	7.8	26	21	14.2	1.830985915	0.002943396	0.0077532	**37.96363084**
14	12	41.2	32	9.2	4.47826087	0.004528302	0.01212928	**37.33364129**
15	7	23.6	17.5	9.5	2.484210526	0.002641509	0.0039235	**67.32533284**
16	16.8	42	32	15	2.8	0.006339623	0.02016	**31.44654088**
17	16.8	49.7	23.2	16.5	3.012121212	0.006339623	0.01902516	**33.3223092**
18	15.6	41.3	23.2	11.5	3.591304348	0.005886792	0.01101884	**53.42479293**
19	20	36.2	29.5	9.5	3.810526316	0.00754717	0.01014505	**74.39263297**
20	12.8	36.2	18.9	14.8	2.445945946	0.004830189	0.010125864	**47.70149667**
21	15	41.2	21.3	11.2	3.678571429	0.005660377	0.009828672	**57.59045941**
22	22.8	39.9	26.2	14.1	2.829787234	0.008603774	0.014739858	**58.37080374**
23	26.4	51.2	23	17.2	2.976744186	0.009962264	0.02025472	**49.18490184**
24	32.4	65.5	26	10.9	6.009174312	0.012226415	0.0185627	**65.8654996**
25	23.2	51.2	31.2	12.2	4.196721311	0.008754717	0.019488768	**44.92185951**
26	30.4	51.4	18.3	25.2	2.03968254	0.011471698	0.023703624	**48.39638915**
27	7.6	25	19.2	12.3	2.032520325	0.002867925	0.005904	**48.57595746**
28	6.6	36.2	22	7.6	4.763157895	0.002490566	0.00605264	**41.14842511**
29	13.2	45.2	28.6	8.5	5.317647059	0.004981132	0.01098812	**45.3319774**
30	8.6	36.5	26.7	8.5	4.294117647	0.003245283	0.008283675	**39.17685108**
31	7.6	31.2	21	8.3	3.759036145	0.002867925	0.00543816	**52.73703842**
32	11	41	24	10.2	4.019607843	0.004150943	0.0100368	**41.35723932**
33	7	35	17.2	9.2	3.804347826	0.002641509	0.0055384	**47.69445027**
34	5.6	32.5	23.4	10.5	3.095238095	0.002113208	0.00798525	**26.46388713**
35	7.8	35.2	19.2	11.2	3.142857143	0.002943396	0.007569408	**38.88542177**
36	4.2	24.3	19.2	9.5	2.557894737	0.001584906	0.00443232	**35.75792498**
37	8	34.2	21.3	13.2	2.590909091	0.003018868	0.009615672	**31.39528807**
38	7.6	39.2	15.5	10.3	3.805825243	0.002867925	0.00625828	**45.82608206**
39	7.4	37.4	17.5	7.6	4.921052632	0.002792453	0.0049742	**56.13873246**
40	8.4	31	22	9	3.444444444	0.003169811	0.006138	**51.64241318**
41	7.2	31.2	12.3	11.4	2.736842105	0.002716981	0.004374864	**62.10435643**
42	6.8	31	18.2	9.5	3.263157895	0.002566038	0.0053599	**47.87473154**
43	4	32	16.5	4.3	7.441860465	0.001509434	0.0022704	**66.48317311**
44	5.3	26.3	25	10	2.63	0.002	0.006575	**30.41825095**
45	6.2	25	16.2	8.6	2.906976744	0.002339623	0.003483	**67.17262824**
46	4.4	19.2	14.3	7.8	2.461538462	0.001660377	0.002141568	**77.53091933**
					Total=	0.262301887		

TABLE2 MEASUREMENT AND CALCULATION USING FLAKEY STONE

CALCULATION

Total volume of stones =0.2623m^3

Volume of embankment = 0.6398m^3

Volume of voids =Volume of embankment – Total volume of stones

=0.3775m^3

Void Ratio (e) = (Volume of Voids / Total volume of stones)

0.3775 / 0.2623=1.43

Porosity (n) = (Volume of Void / Total volume of embankment)

=0.3775 /0.6398 =**0.590**

=**59%**

Sl no.	Weight	Length	Width	Depth	Aspec ratio	Vol of stone	Vol of stone in cubical	Blockiness
1	16.9	30.75	22	20.1	1.529850746	0.006259259	0.01359765	**46.03191919**
2	3.4	21.3	19.8	12.6	1.69047619	0.001259259	0.005313924	**23.6973517**
3	6.8	22	16.8	13.3	1.654135338	0.002518519	0.00491568	**51.23438707**
4	9.6	32.5	22	17.8	1.825842697	0.003555556	0.012727	**27.93710659**
5	5.6	24.2	16.1	12.2	1.983606557	0.002074074	0.004753364	**43.63381542**
6	13.4	30.1	20.9	19.4	1.551546392	0.004962963	0.012204346	**40.66553802**
7	8	25.6	19.4	13.8	1.855072464	0.002962963	0.006853632	**43.23201133**
8	6.6	27.6	13.7	11.6	2.379310345	0.002444444	0.004386192	**55.73044783**
9	6.6	13.7	19	10.2	1.343137255	0.002444444	0.00265506	**92.06738998**
10	7.2	30.7	14.9	14.3	2.146853147	0.002666667	0.006541249	**40.76693406**
11	7	21.9	19.5	15.3	1.431372549	0.002592593	0.006533865	**39.67931068**
12	4.6	16.6	15.1	13.4	1.23880597	0.001703704	0.003358844	**50.72291847**
13	25.2	30.6	30.1	21.9	1.397260274	0.009333333	0.020171214	**46.2705583**
14	26.2	36.4	20.9	23.5	1.54893617	0.009703704	0.01787786	**54.27776984**
15	4.8	15.6	12	11.1	1.405405405	0.001777778	0.00207792	**85.55564111**
16	9.2	23.9	17.9	14.5	1.648275862	0.003407407	0.006203245	**54.92943463**
17	26.6	34.5	26.5	19.4	1.778350515	0.009851852	0.01773645	**55.54579328**
18	3.8	20.4	13.4	12.8	1.59375	0.001407407	0.003499008	**40.22304057**
19	3.2	20.9	11.1	10.9	1.917431193	0.001185185	0.002528691	**46.86951412**
20	3.2	23.5	12.1	10.2	2.303921569	0.001185185	0.00290037	**40.86324108**
21	32.6	34.2	29.6	21.6	1.583333333	0.012074074	0.021866112	**55.21820282**
22	36.08	45.2	34.9	23.1	1.956709957	0.013362963	0.036439788	**36.6713521**
23	18.3	37	20.1	19	1.947368421	0.006777778	0.0141303	**47.96626949**
24	32.2	39	33.5	20.2	1.930693069	0.011925926	0.0263913	**45.18885362**
25	30.8	40.5	29.4	22.9	1.768558952	0.011407407	0.02726703	**41.83590001**
26	21.6	40.2	23	26	1.546153846	0.008	0.0240396	**33.27842393**
27	23	31.1	29.5	25.2	1.234126984	0.008518519	0.02311974	**36.84521763**
28	18	29.3	20.1	21	1.395238095	0.006666667	0.01236753	**53.90459264**
29	35.6	34.9	26.1	30	1.163333333	0.013185185	0.0273267	**48.25019188**
30	16.8	29.2	21.4	18.6	1.569892473	0.006222222	0.011622768	**53.53477091**
31	21.4	31.1	22.1	17.6	1.767045455	0.007925926	0.012096656	**65.52162784**
32	19	37.7	30.1	18.6	2.02688172	0.007037037	0.021106722	**33.34026495**
33	23	37.7	26.6	20.7	1.821256039	0.008518519	0.020758374	**41.03654033**
34	13.2	29	22.2	30.8	0.941558442	0.004888889	0.01982904	**24.65519707**
35	22.8	14.4	24.5	14.4	1	0.008444444	0.00508032	**166.2187509**
36	4.4	17	14.8	14.2	1.197183099	0.00162963	0.00357272	**45.61313592**
37	17.6	32	26.6	16.8	1.904761905	0.006518519	0.01430016	**45.58353556**
38	25	37.6	27	24	1.566666667	0.009259259	0.0243648	**38.00260728**
39	15.8	27.6	25.5	21.9	1.260273973	0.005851852	0.01541322	**37.96644602**
40	14.6	34.6	26.2	17	2.035294118	0.005407407	0.01541084	**35.08833657**
41	25.8	35	29.5	21.4	1.635514019	0.009555556	0.0220955	**43.24661382**
42	13	27.7	26.4	16.6	1.668674699	0.004814815	0.012139248	**39.66320496**
43	10	29.6	21.4	18.9	1.566137566	0.003703704	0.011972016	**30.93634108**
44	6.4	24	21.5	11.6	2.068965517	0.00237037	0.0059856	**39.60121576**
45	9.2	24.1	21.3	20.9	1.153110048	0.003407407	0.010728597	**31.76004661**
46	10.6	36.5	18.1	15	2.433333333	0.003925926	0.00990975	**39.61680089**
47	19.4	38.6	33.5	17.6	2.193181818	0.007185185	0.02275856	**31.57135243**
48	17.5	28.9	16.2	20	1.445	0.006481481	0.0093636	**69.21997396**
49	18.6	37	27.5	16.6	2.228915663	0.006888889	0.0168905	**40.78558295**
50	14.2	31.6	30.3	18.1	1.745856354	0.005259259	0.017330388	**30.347037**
51	11.6	26.5	24	8.6	3.081395349	0.004296296	0.0054696	**78.54863786**
52	7.4	38	29	17.5	2.171428571	0.002740741	0.019285	**14.21177465**
53	15.2	30.6	26.5	17.8	1.719101124	0.00562963	0.01443402	**39.00250678**
54	15	34.4	20.1	15.7	2.191082803	0.005555556	0.010855608	**51.17682543**
55	15.2	32.2	30.3	15	2.146666667	0.00562963	0.0146349	**38.46715474**
56	6.6	25.5	22.2	14.2	1.795774648	0.002444444	0.00803862	**30.40875728**
57	19	33.9	21.5	14.5	2.337931034	0.007037037	0.010568325	**66.58611499**
58	15.6	33.9	25.8	18.5	1.832432432	0.005777778	0.01618047	**35.70834332**
59	10	32.4	25.7	13	2.492307692	0.003703704	0.01082484	**34.21485864**
60	13.2	30.2	25.4	16.6	1.819277108	0.004888889	0.012733528	**38.39382839**

61	11.6	36.5	21.4	11.2	3.258928571	0.004296296	0.00874832	**49.10995821**
62	11.8	29.4	20.2	12.4	2.370967742	0.00437037	0.007364112	**59.34687536**
63	10.2	20.9	21.2	14.1	1.482269504	0.003777778	0.006247428	**60.46932878**
64	8.4	22.6	21.6	14.5	1.55862069	0.003111111	0.00707832	**43.95267678**
65	8.8	30.6	19.1	12.2	2.508196721	0.003259259	0.007130412	**45.7092698**
66	8.8	33.8	19.8	11.3	2.991150442	0.003259259	0.007562412	**43.0981446**
67	7.2	24.6	15.4	15.4	1.597402597	0.002666667	0.005834136	**45.70799629**
68	6.8	21.4	14.6	15.9	1.34591195	0.002518519	0.004967796	**50.69689896**
69	7.6	23.6	16.4	16	1.475	0.002814815	0.00619264	**45.45419748**
70	6.6	23.3	20.2	9.2	2.532608696	0.002444444	0.004330072	**56.45274361**
					Total	0.37533		

TABLE 3 MEASURMENT AND CALCULATION OF MIXED STONES

CALCULATION

Total volume of stones = 0.375m^3

Volume of embankment = 0.749m^3

Volume of voids =Volume of embankment – Total volume of stones

= 0.37367m^3

Void Ratio (e) = (Volume of Voids / Total volume of stones)

0.37367 / 0.37533=**0.995**

Porosity (n) = (Volume of Void / Total volume of embankment)

0.37367 / 0.749 =**0.5**

=50%

FIG 8 MIXED STONES

5.PAYMENT ISSUES

There are two bulk volumes to consider. Before construction the design bulk volume, Vd, is required. This volume equals the area A times the orthogonal thickness Td,which is a theoretically predicted average thickness that the engineer has introduced for the design drawings, using recommended layer thickness coefficients. Clearly, for a given range of armourstone weights or sizes, the best design guidance on the expected single or double layer thickness is required. These volume calculations are necessary for ordering the quantities prior to construction. After construction, in addition to profile tolerance conformance checks, it may be necessary to determine volumes for payment purposes. Having surveyed the under layer surface and the armour layer surface, the average cross-sectional area, D, times the chainage length L gives the surveyed bulk volume, Vs. From D and the down-slope length, an actual average orthogonal thickness can be deduced and this often makes an interesting comparison with the orthogonal thickness shown on the design drawings. Large differences generally lead to contractual problems.

6. **HOW VOIDS AFFECT THE OVERALL COST OF THE PROJECT**

Consider building a seawall with dimensions 2m, 3m & 5m.

Let this seawall extend to a length up to 5 km.

Volume of the entire embankment = ([3+5] / 2)*2*5000 =40000m^3

- For 30% voids

40000*0.7= 28000m^3 volume of stones are needed

ie 40000*0.3=12000m^3 volume is just voids

Weight of the stones in ton =volume of stones in embankment * specific gravity of stone

Weight=28000*2.65=**74200 ton stones are needed** (Ideal)

- For 10% voids

40000*0.9= 36000m^3 volume of stones are needed

Example 40000*0.1=4000m^3 volume is just voids

Weight of the stones in ton =Volume of stones in embankment * specific gravity of stone

Weight=36000*2.65=**95400 ton stones are needed**

- For 40% of voids

40000*0.6= 24000m^3 volume of stones are needed

ie 40000*0.4=16000m^3 volume is just voids

Weight of the stones in ton =volume of stones in embankment * specific gravity of stone

Weight=24000*2.65=**63600 ton stones are needed**

- For 20% decrease in voids with respect to 30% voids -Increase in stones volume =95400-74200=21200 ton(for the contractor)

Considering the cost 1 ton of stone costs 710rs

Example if 10% volume of voids are considered total cost would be

95400*710= 6.77 CR

Cost of stones for 30% voids= 74200*710=5.26 CR

Example 6.77-5.26=**1.51CR extra cost for 20% decrease in voids with respect to 30% voids**

- For 10% increase in voids with respect to 30% volume -decrease in stones volume =74200-63600=10600 ton(for the company)

Considering the cost,1 ton of stone costs 710rs

Example if 40% volume of voids are considered total cost would be

63600*710= 4.51 CR

Cost of stones for 30% voids= 74200*710=5.26 CR

Example 5.26-4.51=**0.75 CR decrease in cost for 10% increase in voids with respect to 30% voids**

7. CONCLUSION

Among the three experiments conducted cubical stones gave better packing with a porosity 30% .The 30% void gives favourable cost for buyers and sellers in Sea wall construction.

Good interlocking property was provided for the sea wall when using cubicle stone. Secondly, we used flaky stones for the experiment in which the structure was not stable with this stone. With flaky stones R valuable to lateral forces. These kinds of stones tend to break when dropped from a certain height since it's porosity value is more.

Finally, mixed stones like flaky, elongated and cubical were used for the structure the porosity value that we got for the structure is 50% so it's better to use cubicle stones which is better for the construction of seawall than mixed stone structure.

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