L-4/T-2/WRE **Date : 01/04/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2017-2018

Sub : **WRE 421** (Professional Practice and Communications)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) "Engineers make our life better" – Illustrate the statement. **(10)**

   (b) List the scopes of professional practices of a "Water Professional". **(10)**

   (c) With the help of a flow diagram, describe the sequential steps of project development. Why feasibility study is necessary? **(15)**

2. (a) Write down a typical list of items against which costs are placed for a cement manufacturing plant project. **(10)**

   (b) List the more usual and important items to be included in the "Instructions to Tenderers". **(10)**

   (c) Write down the typical items of clauses in the conditions of a contract. **(15)**

3. (a) Write the steps to be followed to arrange a specification. What are the items to be included in a typical specification of earth works? **(10)**

   (b) Why Pre-qualification (PQ) document is necessary and what are the requirements of PQ document? **(10)**

   (c) Write down the typical preamble required for the preparation of a Bill of Quantity (BOQ). Give an example of a typical BOQ for dredging works. **(15)**

4. (a) Why Standard Tender Document (STD) is necessary? Write the contents of Section-7 and Section-8 of STD of your desired project. **(10)**

   (b) What are the matters to be examined in Post Tendering stage? **(10)**

   (c) List the functions and powers of "Engineer's Representative" and a "Resident Engineer" of a project. **(15)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Define Engineering. Write down the importance of professional registration. **(6)**

   (b) Write down the typical format of an undergraduate thesis. **(6)**

   (c) Define profession. Briefly describe how professionalism can be encouraged. **(10)**

   (d) Discuss the considerations of professionals under the guideline for professional practice. **(13)**

Contd P/2

WRE 421

6. (a) Why is 'strategic planning' important in effective management of professional practice? **(6)**

   (b) Write the importance of human resources management in professional practice. **(6)**

   (c) Briefly describe the elements that should be addressed in professional practice management plan. **(10)**

   (d) "*Professional engineers shall, in their areas of practice, hold paramount the health, safety and welfare of the public, and have regard for the environment*" – Discuss this statement. **(13)**

7. (a) List the guidelines for effective speaking for Engineers. **(6)**

   (b) Write down the different functions of Engineering. **(6)**

   (c) State the guidelines in maintaining confidentiality under the ethical practice. **(6)**

   (d) "*Professional engineers shall undertake only work that they are competent to perform by virtue of their training and experience*" – Discuss this statement. **(17)**

8. (a) Write a short note on 'Sub-Contract'. **(6)**

   (b) List the guideline of conducting an official meeting. **(6)**

   (c) Briefly describe different ways to settle contractual problems. **(10)**

   (d) "*Engineers of Phoresis Engineering Ltd. prepared plans and specifications for machinery to be used in a manufacturing process. Phoresis Engineering turned them over to Nugae Manufacturing Inc. for production. In reviewing the plans and specifications, Nugae Manufacturing's engineers came to the conclusion that the plans included certain miscalculations and technical deficiencies of a nature that likely would make the final product unsuitable for the purpose of the users. In addition, they concluded that the equipment, if built according to the original plans and specifications, might endanger the lives of persons closes to it.*

   Nugae's engineers called the matter to the attention of appropriate officers of their employer who, in turn, advised Phoresis Engineering Ltd. of the concern expected by Nugae's engineers. Phoresis replied that its engineers felt that the design and specifications for the equipment were adequate and safe and that Nugae Manufacturing should proceed to build the equipment as designed and specified. The officers of Nugae Manufacturing instructed its engineers to proceed with the work".

   Under these circumstances what should the engineers of Nugae Manufacturing Inc. do now? **(13)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2017-2018

Sub : **WRE 423** (River Engineering and Flood Mitigation)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Assume reasonable data if not given. Sketch whereever necessary.

1. (a) Define the following terms **(20)**

   (i) River Management

   (ii) Dominant discharge

   (iii) Critical velocity

   (iv) Schematization of channel section.

   (b) What is helical flow? Discuss the effect of helical flow in an alluvial river. **(10)**

   (c) A river channel of has a bankful flow area of 1000 m^2 and longitudinal slope is 1 m in 3 km. Calculate the channel forming discharge. **(5)**

2. (a) Show, in a sketch, the various of erosion in a river section. **(10)**

   (b) Sketch a typical Shield's diagram and write down its various practical uses. For a wide river, calculate boundary shear stress and the depth at which the bed particle (size=0.20 mm) starts to move. The river longitudinal slope is 5 cm in 1 km. **(15)**

   (c) Write down the at-a-station hydraulic geometry relationships. Bankfull discharge of the river Jamuna is 50000 m^3/s. Calculate the required hydraulic geometry and average velocity of the river. Assume any reasonable values of the exponents and coefficient. **(10)**

3. (a) Name the different types sediment load in river. How sediment flow rate Q_s can be estimated? **(10)**

   (b) The following hydraulic data are available for construction of a circular bridge pier of diameter 2.0 m: **(15)**

   Discharge = 1500 m^3/s

   Average width = 350 m

   Approaching flow depth = 3.0 m

   Dimensionless critical shear stress = 0.035

   Calculate the local scour depth using Jain and Fischer formula. Assume reasonable data if not given.

Contd P/2

WRE 423

Contd. Q. No. 3

(c) Name the various types river training and bank protection techniques. What types of protection techniques are commonly practiced in major rivers of Bangladesh? Answer with sketches. **(10)**

4. (a) For a river Ganges, following data are given. **(15)**

Design discharge = 77,000 m^3/s
Highest Flood level = 18.5 m PWD
Bank full Water Level = 14.5 m PWD
Low water level = 2.5 m PWD
Bed material size = 0.10 mm

Design and sketch the bank revetment works for erosion protection under current attack. Use Pilarczyk equation. Assume reasonable design value, if not given.

(b) What are the causes of deterioration of waterways in Bangladesh? How the waterways can be improved? **(10)**

(c) How you will estimate the dimension (depth and width) of navigational channel? Answer with sketches for typical example of a cargo vessel. **(10)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) What are the major challenges of using levee as a flood mitigation measure? Explain how these challenges can be rectified. **(11)**

(b) Discuss different environmental impacts of a reservoir. Elaborate various design considerations in choosing a reservoir location and dam type. **(12)**

(c) Discuss how channel improvement and watershed management can reduce flood damages. **(12)**

6. (a) What are the challenges in developing an accurate flood forecasting model? Describe different components of a flood forecasting model. **(11)**

(b) Elaborate different types of flood diversion and flood proofing methods to reduces flood damages. **(12)**

(c) What are the different flood zones? How flood zoning can be effective in reducing flood damages. **(12)**

7. (a) What is flood risk assessment? How does flood risk is estimated? **(11)**

(b) What are the direct and indirect damages of flood? What are the different ways to assess flood damages? **(12)**

Contd .. P/3

WRE 423

Contd ... Q. No. 7

(c) Construction of a levee is under consideration for a river reach vulnerable to flood damages. The estimated damages from various river stages and cost of levee protection below the given stages are given below. The return periods of the flood at mid-height of the interval are 10, 15, 25, 75, 150 and 300 years, respectively. Select the most satisfactory river stage for the design of the levee. **(12)**

Peak Stage (m)	Total damage below indicated stage (Million TK)	Project cost (Million TK)
5.9	0	40
6.5	400	60
7.3	900	90
8.1	1500	110
8.5	3000	130
9.1	4500	150
9.7	6500	180
10.3	8500	200

8. (a) List various Flood Action Plans that have been implemented in Bangladesh. **(11)**

(b)Distinguish between *flood water* and *storm water*. What are the main causes and impacts of urban flood? **(12)**

(c) What do you mean by flood resilience? What are the major concepts to estimate flood resilience of a community? **(12)**

L-4/T-2/WRE **Date : 27/03/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2017-2018

Sub : **WRE 435** (Hydraulic Structures)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Differentiate between weir and barrage. **(7)**

   (b) Why is it necessary to provide the 'fish ladder' and how does it help in achieving the required objectives? **(8)**

   (c) What are the main causes of failures of weirs on permeable foundations, and what remedies would your suggest to prevent them? **(10)**

   (d) What are the various types of Aqueduct and Syphon Aqueduct? Explain with figures. **(10)**

2. (a) What is the purpose served by the 'scouring sluices' at weirs? **(5)**

   (b) Determine the percentage uplift pressure at various key points in Figure 1 using Khosla's theory and apply necessary corrections. The correction factor for 1: 3 slopes is 4.5. Necessary equations are attached. **(30)**

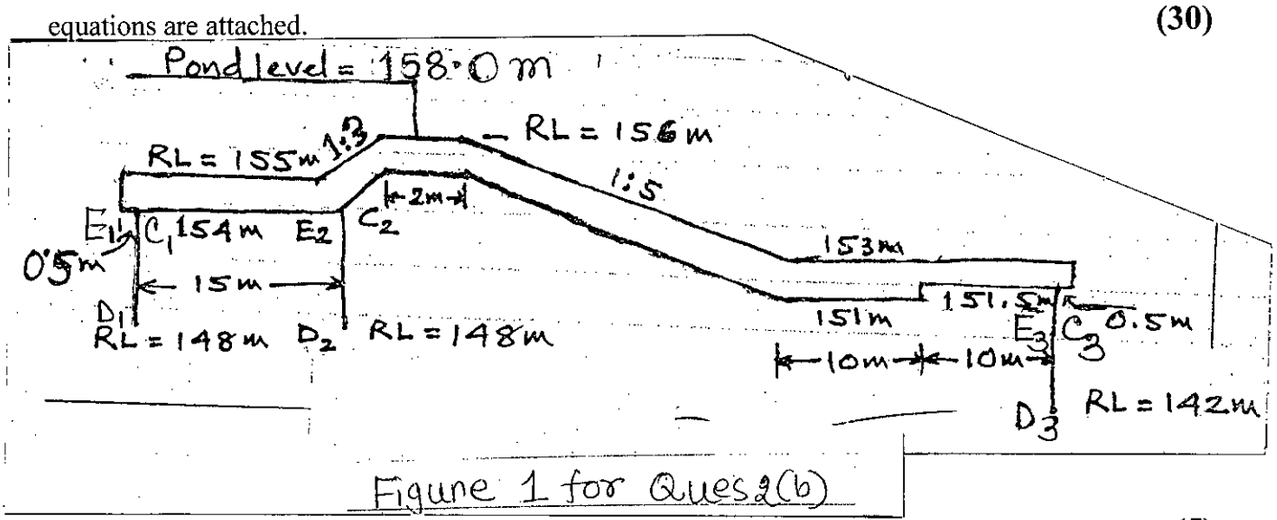


Figure 1 for Ques 2(b)

3. (a) Write short notes on (i) Afflux and (ii) Retrogression. **(5)**

   (b) A barrage is to be constructed on an alluvial river having a flood discharge of 8500 m^3/s. The relevant data are as follows: **(30)**

   Average river bed level = 202.0 m

   HFL (before construction of barrage) =207.3 m

   Permissible affix = 1.0 m

   Pond level = 205.0 m

   Lacey's silt factor = 1.0

Contd P/2

WRE 435

Contd ... Q. No.3(b)

Determine (i) the crest levels of under sluices and barrage bays,

(ii) the waterways to pass the flood discharge,

(iii) Downstream floor level for under sluices portion considering pond level and high flood condition for a retrogression of 0.5 m and 20% discharge concentration.

4. (a) Write short notes on (i) Undersluices of Barrage and (ii) Super passage **(5)**

(b) Design a suitable cross drainage works if the following data at the crossing of a canal and a drainage are given: **(30)**

(i) discharge of canal = 40 cumec
(ii) bed width of canal = 30 m
(iii) full supply depth of canal = 1.6 m
(iv) bed level of canal = 206.4 m
(v) side slopes of canal = 1.5 H: 1 V
(vi) High flood discharge of drainage = 450 cumec
(vii) High flood level of drainage = 207.0 m
(viii) Bed level of drainage = 204.5 m
(ix) General ground level = 206.5 m

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Define hydraulic structure. State the characteristics of hydraulic structures. **(5)**

(b) Describe the design concepts of hydraulic structures. **(10)**

(c) Draw typical inflow and outflow hydrographs of storage reservoir and multipurpose reservoir and explain the differences. **(10)**

(d) The inflow hydrograph of a flood control reservoir is given below. Estimate the constant outflow rate that can be maintained throughout the year. **(10)**

Month	1	2	3	4	5	6	7	8	9	10	11	12
Inflow Rate (m^3/s)	40	30	20	30	50	120	170	200	160	90	50	40

6. (a) Classify dams based on different criteria. **(10)**

(b) Describe with sketch, different ways for the diversion of river flow during dam construction. **(10)**

(c) What are earthen dams? Under what circumstances are they preferred? **(5)**

(d) What is meant by the elementary profile of a gravity dam and how it is deduced? What should be the maximum depth of elementary profile of a dam if the safe limit of stress on masonry should not exceed 1500 kN/m^2? (unit weight of masonry = 24 kN/m^3) **(10)**

Contd .. P/3

WRE 435

7. (a) Enumerate the different types of earthen dams and draw neat sketches of them. **(10)**

   (b) Figure 2 shows the section of a gravity dam built of concrete. Examine the stability of this section for reservoir empty. Consider earthquake force. **(20)**

   Also compute the hydrodynamic pressure for the reservoir full case. **(5)**

8. (a) "A spillway is a safety valve in a dam". Discuss this statement. **(5)**

   (b) Write short notes on:

   (i) Siphon Spillway

   (ii) Ski jump bucket energy dissipater

   (iii) SAF stilling basin. **(15)**

   (c) Design a suitable section for the overflow portion of a concrete gravity dam having the downstream face slopping at a slope of 0.7H:1V. The design discharge for the spillway is 9000 cumecs. The height of the spillway crest is kept at RL 205.0 m. The average river bed level at the site is 101.0 m. The spillway length consists of 7 spans having a clear width of 10 m each. Thickness of each pier may be taken to be 2.5 m. **(15)**

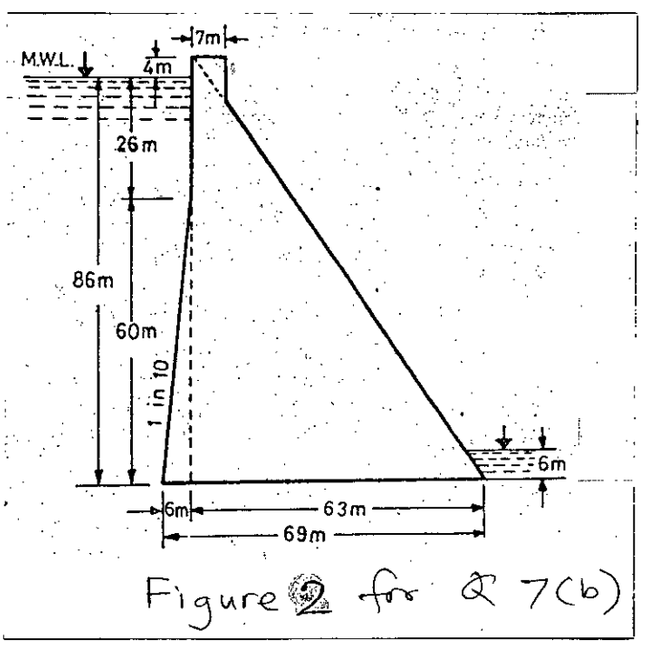
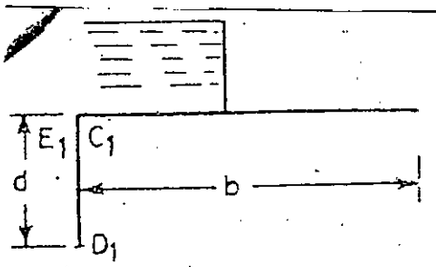


Figure 2 for Q 7(b)

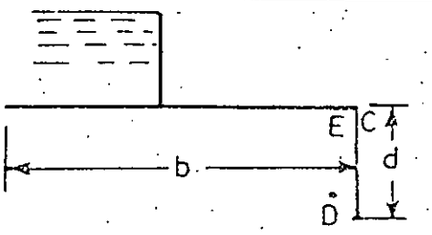
WRE 435



$$\phi_{C_1} = 100 - \phi_E$$

$$\phi_{D_1} = 100 - \phi_D$$

(a)



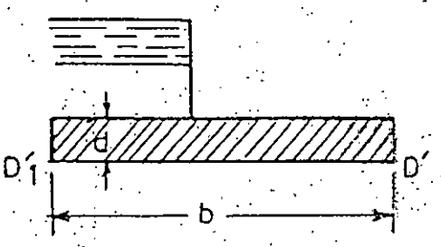
$$\phi_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

$$\phi_D = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda - 1}{\lambda}\right)$$

where $\lambda = \dfrac{1 + \sqrt{1 + \alpha^2}}{2}$

$\alpha = \dfrac{b}{d}$ (respective)

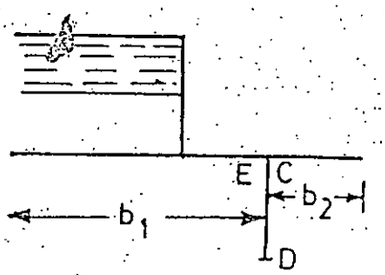
(b)



$$\phi_{D'} = \frac{2}{3}(\phi_E - \phi_D) + \frac{3}{\alpha^2}$$

$$\phi'_{D_1} = 100 - \phi_{D'}$$

(c)



$$\phi_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_1 - 1}{\lambda}\right)$$

$$\phi_D = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_1}{\lambda}\right)$$

$$\phi_C = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_1 + 1}{\lambda}\right)$$

where $\lambda = \dfrac{\sqrt{1 + \alpha_1^2} + \sqrt{1 + \alpha_2^2}}{2}$

$\lambda_1 = \dfrac{\sqrt{1 + \alpha_1^2} - \sqrt{1 + \alpha_2^2}}{2}$

$\alpha_1 = b_1/d$

$\alpha_2 = b_2/d$

(d)

Necessary equations for Ques. No. 2(b)

L-4/T-2/WRE **Date : 16/03/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2017-2018

Sub : **WRE 437** (Coastal Engineering)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Assume any reasonable data, if missing.

1. (a) Draw a neat sketch for local fluid velocities and accelerations in the direction of wave propagation for a single wave. **(5)**

   (b) Define pressure response factor K_z. Show the extra effect of dynamic pressure in the total pressure equation along with the static pressure. **(6)**

   (c) Draw a neat sketch of 'Tidal Datum' and define HAT, MHWS and MLWN. When and where a 'seiche' is likely to occur? **(5+3)**

   (d) What happens when a wave moves from deeper water to shallow water. Also what happens when a wave breaks in the surf zone. **(4+4)**

   (e) Given a wave with a period T = 6 sec in water depth d = 15.5 m and wave height 2.0 m. Find the local horizontal and vertical velocities at a depth of 5.5 m below SWL when $\theta = 2\pi x/L - 2\pi t/T = \pi/6$. **(8)**

2. (a) "Coastal Engineering" is an important subject not only for the development of coastal area of Bangladesh but also for the whole country– explain. **(6)**

   (b) The study of any topic generally involves a scientific base and an engineering component of scientific knowledge– discuss on the basis of coastal engineering. **(6)**

   (c) Discuss the present overlap and future expansion among different disciplines involves in the ocean. **(5)**

   (d) Primary coasts are shaped primarily by marine agents– explain. List up different types of 'sub-aerial deposition coasts' under primary coasts configuration. **(5+5)**

   (e) Draw a typical 'beach profile' for the coastal area and identify all the zones. **(8)**

3. (a) What are the significance of 'drag coefficient' C_D and 'inertia coefficient' C_M in the design of vertical piles for non breaking waves? **(5)**

   (b) Draw the Miche-Rundgreen wave condition at a structure and seaward of a structure when no reflection occurs for non-breaking wave condition on a vertical wall. **(6)**

   (c) What is an estuary according to Pritchard? Define estuary based on 'tidal range' and 'water circulation'. **(3+6)**

Contd P/2

WRE 437

Contd ... Q. No. 3

(d) What are the differences in total force F_t and net force F_{net} in the design of vertical wall for non-breaking waves? Write down the equation for non-breaking wave with an approach angle on a non-vertical wall. **(4+2)**

(e) Find the non-breaking wave force and moments against a completely reflecting vertical wall ($\chi = 1.0$) resulting from the wave condition given below: **(9)**

(i) wave height at the structure if the structure were not there $H_i = 1.75$ m.

(ii) depth at structure d = 3.50 m

(iii) the wave period considered in the design is T = 8.0 sec. Figure 1, Figure 2 and Figure 3 is attached for relevant uses.

4. (a) Define : (i) Wave height, H, (ii) Wave number, k, (iii) Relative depth criteria, and (iv) Shallow water wave. **(10)**

(b) What are the assumption to derive "small amplitude surface wave" theory? How can you prioritize the assumptions based on their importance? **(8)**

(c) A wave with a period of 6 seconds is propagated shoreward over a uniformly sloping shelf from a depth of 325.0 m to a depth of 3.25 m. Find the wave celerity and wave length at depths of (a) 325.0 m, and (b) 3.25 m. **(8)**

(d) What is the significance of the 'dispersion relation' equation in water wave theory? **(4)**

(e) Illustrate the significance of the changes in value of (kd) and tanh(kd) when a wave travels from deep water through transitional water to the shallow water. **(5)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Define the following terms: Mean Lower Low Water, Equinoctial tide, Tidal constituents, Locked basin, Storm surge. **(5)**

(b) Briefly explain the dynamic theory of tide generation. **(5)**

(c) Why does the tidal bore occur? Write down the principal characteristics of tidal bore. **(5)**

(d) There is an approach channel to enter the ship to a harbour. At mean tide level, the water depth at the approach channel is 10 m. The spring and neap tidal range at the approach channel is 4.5 m and 2.8 m respectively. The maximum wave height is 2.7 m. Find out the maximum draught of a ship which can pass the channel. **(5)**

(e) Explain the measures to take care the littoral drift during laying out the breakwaters constructed to protect harbour. **(5)**

(f) Explain how the adverse natural challenges have been taken care in laying out the Madras harbor in India. With neat sketches show the layout of Madras harbor with outer dock. **(10)**

Contd P/3

WRE 437

6. (a) Explain how the upwind and downwind storm surge level can be calculated in a lake of uniform depth and equivalent rectangular plan. **(5)**

(b) With neat sketch show the typical surface wind structure inside a tropical cyclone. **(5)**

(c) Write short notes on (i) Ring of fire, (ii) DART. **(5)**

(d) Write down the main features and effects of Indian Ocean Tsunami 2004. **(5)**

(e) The fetch in a tropical cyclone has a maximum wind velocity 30 m/s and the triangular wind distribution can be considered to have a 1000 km fetch. The cyclone approaches normally across a continental shelf whose width is 10 NM, edge depth 135 m and inshore depth 15 m. If its average speed of approach is 5 m/s, compute the maximum surge height and determine what length of coast will be affected by large surge. (Necessary figures are attached: Fig. 4 and Fig. 5) **(15)**

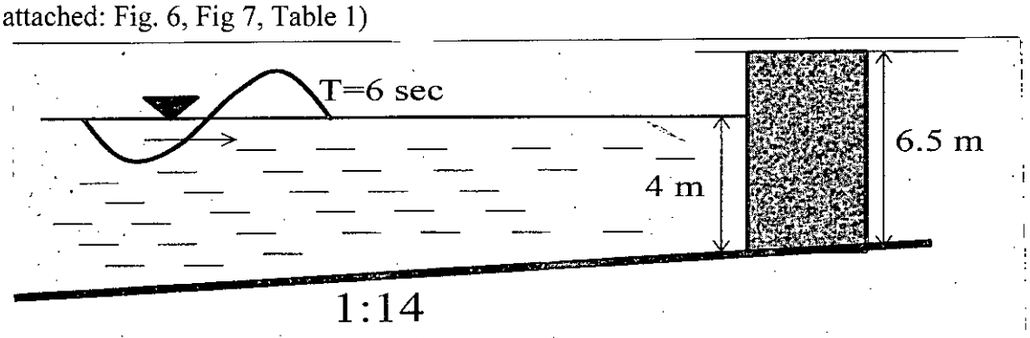
7. (a) State the features of different layers of conventional rubble mound breakwater. Also show its cross section with neat sketch. **(5)**

(b) What design factor governs the formation of Tombolo and Salient in detached breakwater? Show the typical beach configurations with detached nearshore breakwater with neat sketches. **(5)**

(c) State the reasons and also show with neat sketch the modes of rear side erosion of a sloping front breakwater with capping due to wave overtopping. **(5)**

(d) State the criteria/considerations for designing coastal groins in terms of its length, cross section, height, orientation and layout. **(5)**

(e) A seawall under wave action is shown in the figure below. Calculate the magnitude of the breaking wave force acting on the wall using Goda's formula. (Necessary Figures and Table are attached: Fig. 6, Fig 7, Table 1) **(15)**



$$P_1 = (\alpha_1 + \alpha_2)\gamma_w H_b$$

$$P_3 = \alpha_3 P_1$$

$$P_4 = \left(1 - \frac{h_c}{1.5\,H_b}\right) P_1$$

$$\alpha_1 = 0.6 + \frac{1}{2}\left[\frac{4\pi h/L}{\sinh(4\pi h/L)}\right]^2$$

$$\alpha_2 = \min\left[\left(\frac{h_b - d}{3h_b}\right)\left(\frac{H_b}{d}\right)^2, \frac{2d}{H_b}\right]$$

$$\alpha_3 = 1 - \frac{d_s}{h}\left[1 - \frac{1}{\cosh\left(\frac{2\pi h}{L}\right)}\right]$$

Contd ... P/4

WRE 437

8. (a) Write down the names of 10 (ten) different types of concrete armour units used in coastal protection structures. **(5)**

(b) With neat sketches, show the protection of coastal revetment for (i) concrete blocks with toe wall, (ii) concrete block with embedded toe and (iii) concrete block with rubble toe. **(5)**

(c) Explain the criteria for designing filter of coastal revetment for (i) graded rock filter, (ii) plastic filter fabric. **(5)**

(d) Sandfilled caisson breakwaters are sometimes constructed as (i) vertical composite, (ii) horizontal composite, (iii) sloping top and (iv) perforated front wall caisson breakwater. Why? State one reason for each of these types along with neat sketches. **(5)**

(e) The site and wave conditions along a coastal shore line are as below: **(15)**

Road level = 115 ft MLLW

Storm surge height = 8 ft

50 year high water level = 112 ft MLLW

MHHW = 110 ft MLLW

Bed level at the end of bank slope = 105 ft MLLW

R.L. of MLLW = 100 ft

Bottom slope of sea bed = 1:50

Design wave height = 8 ft

Design wave period 6 sec.

Design a revetment type shore protection structure with quarry stone armor unit including the filter and toe protection. Also show the design section with neat sketch. Use the attached tables (Table 2, 3, 4) and graph (Fig. 7). Assume the reasonable value of any data if not given.

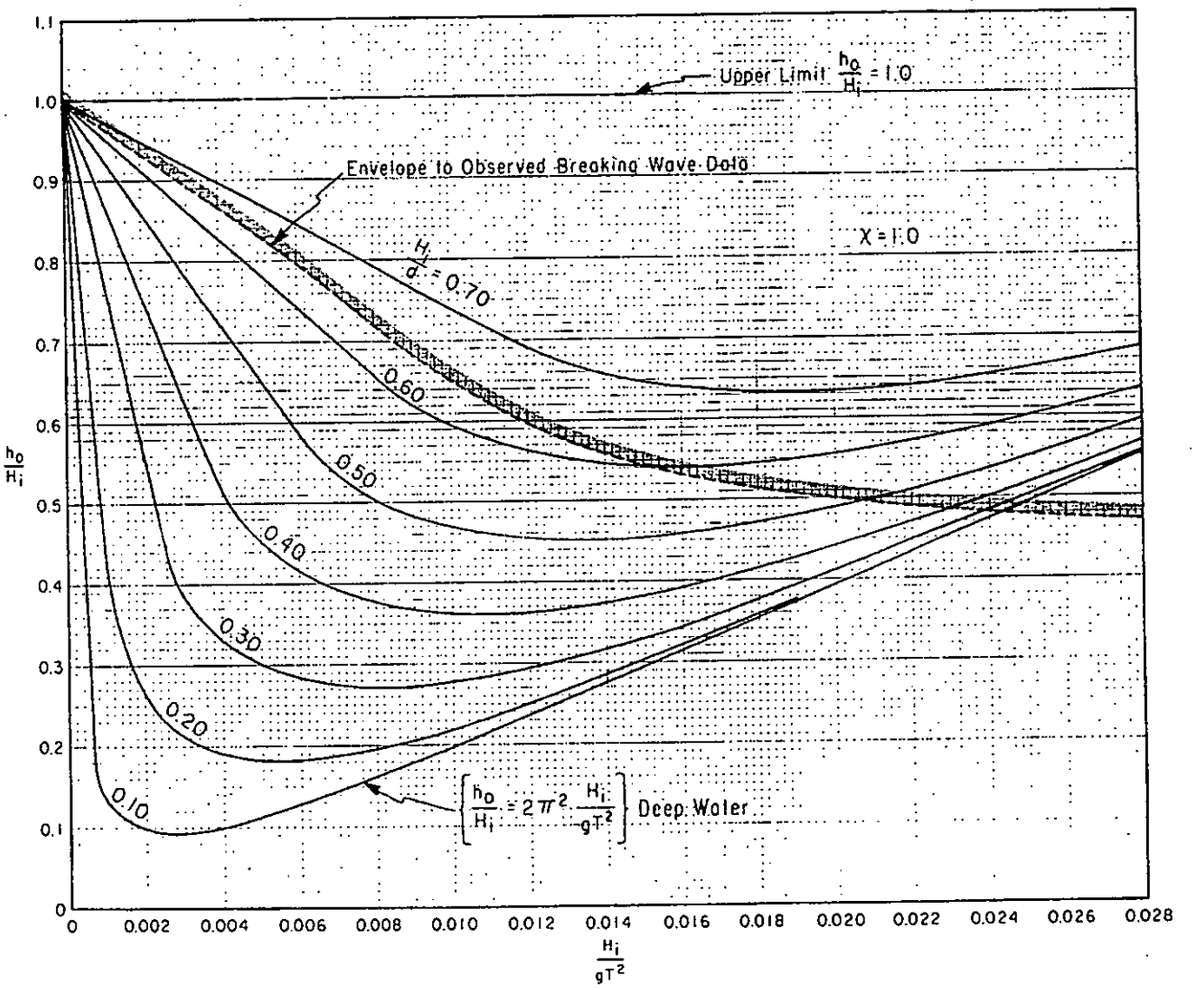


Figure 1 Nonbreaking waves; $\chi = 1.0$.

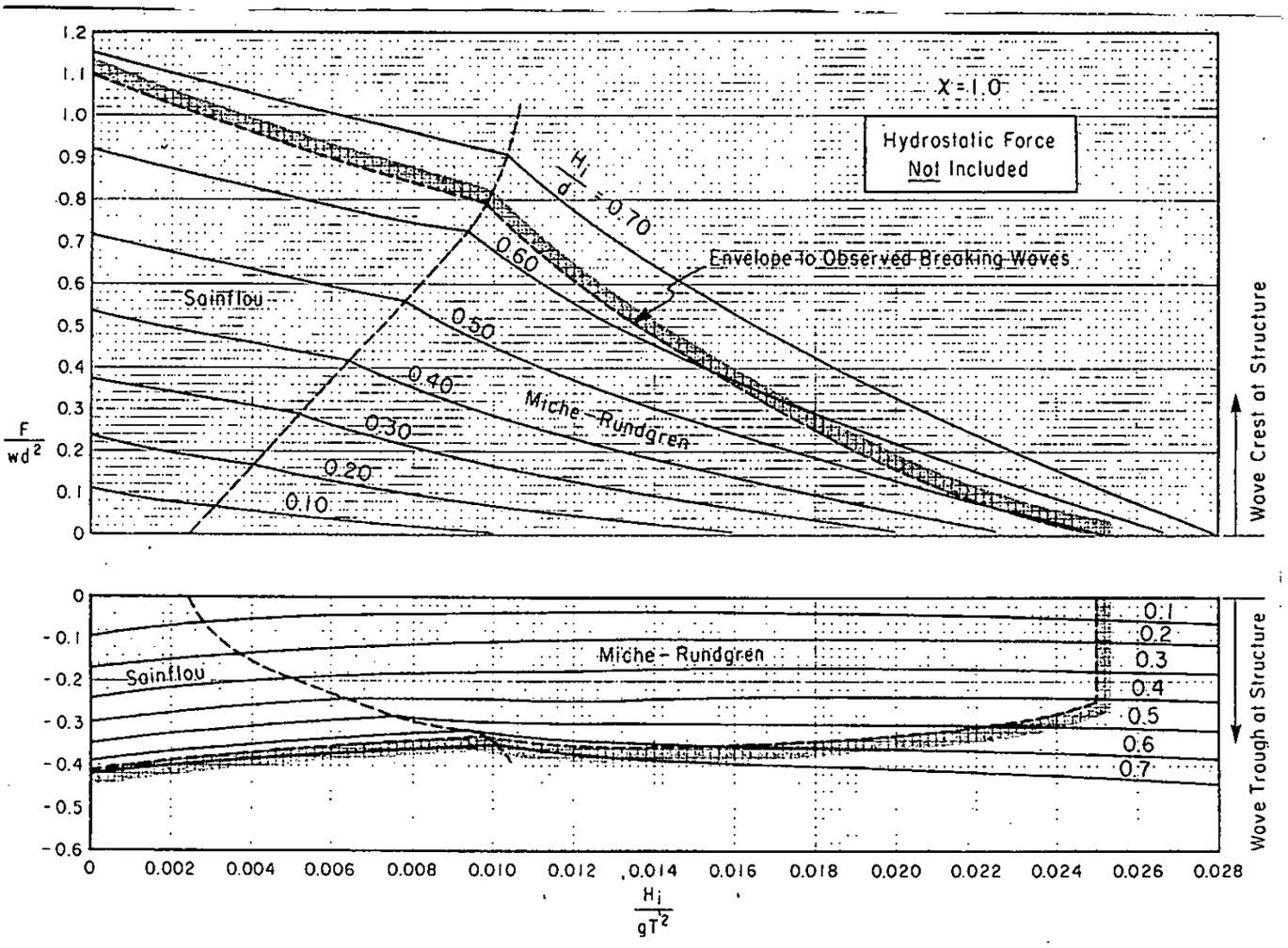


Figure 2 Nonbreaking wave forces; $\chi = 1.0$.

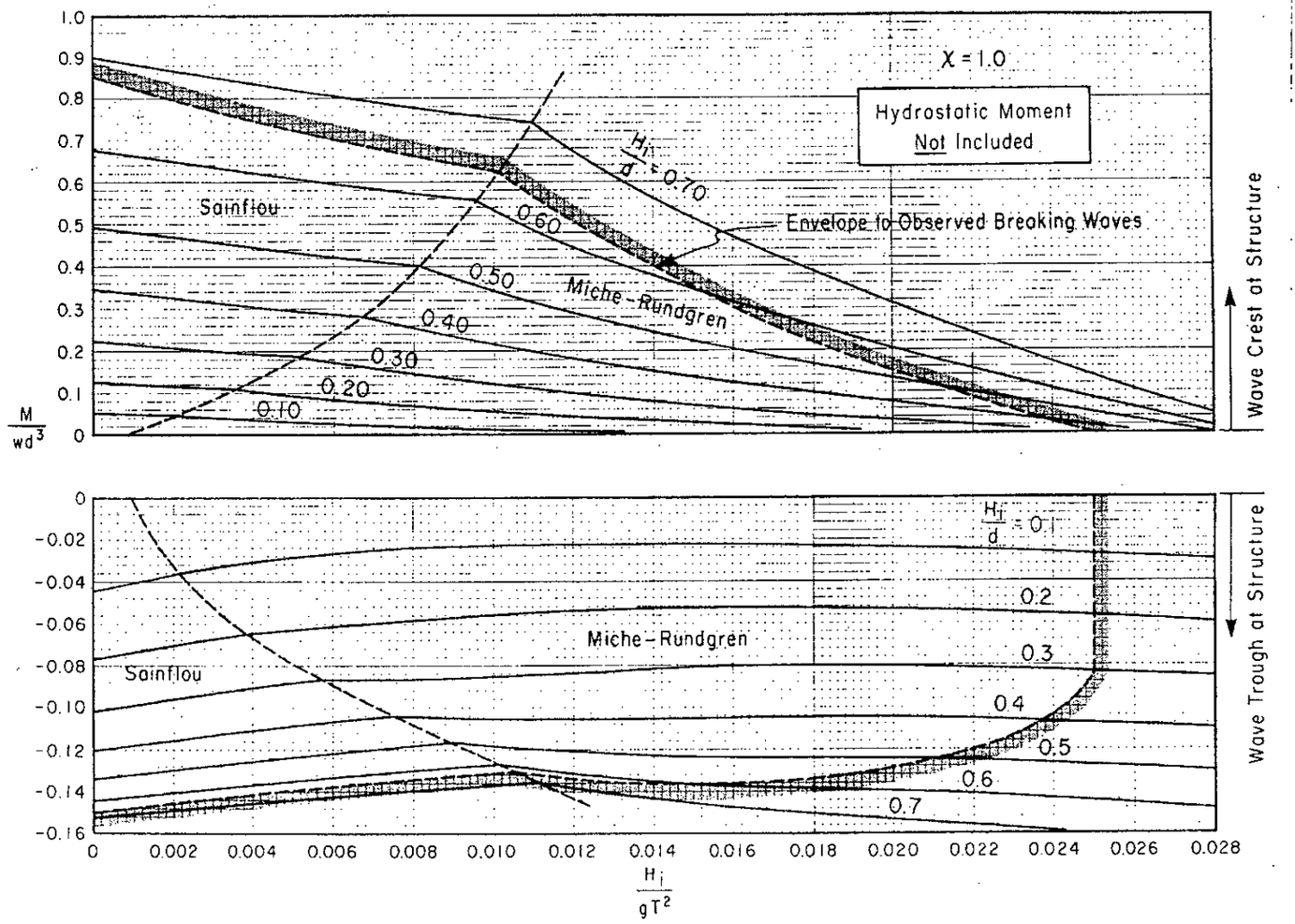


Figure 3 Nonbreaking wave moment; $\chi = 1.0$.

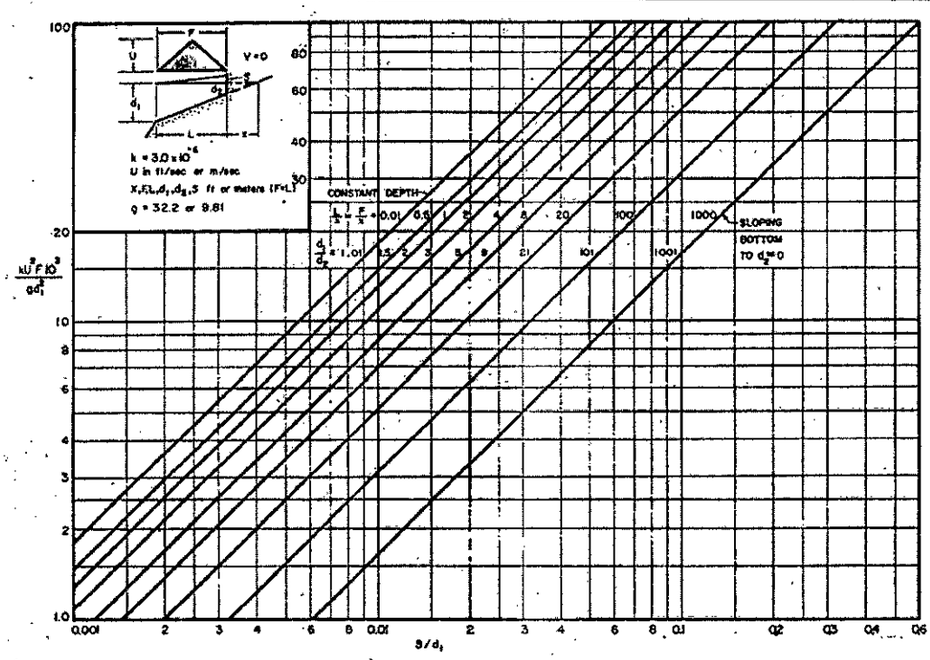


Fig. 4 Surge produced by a static triangular wind field extending across the continental shelf.

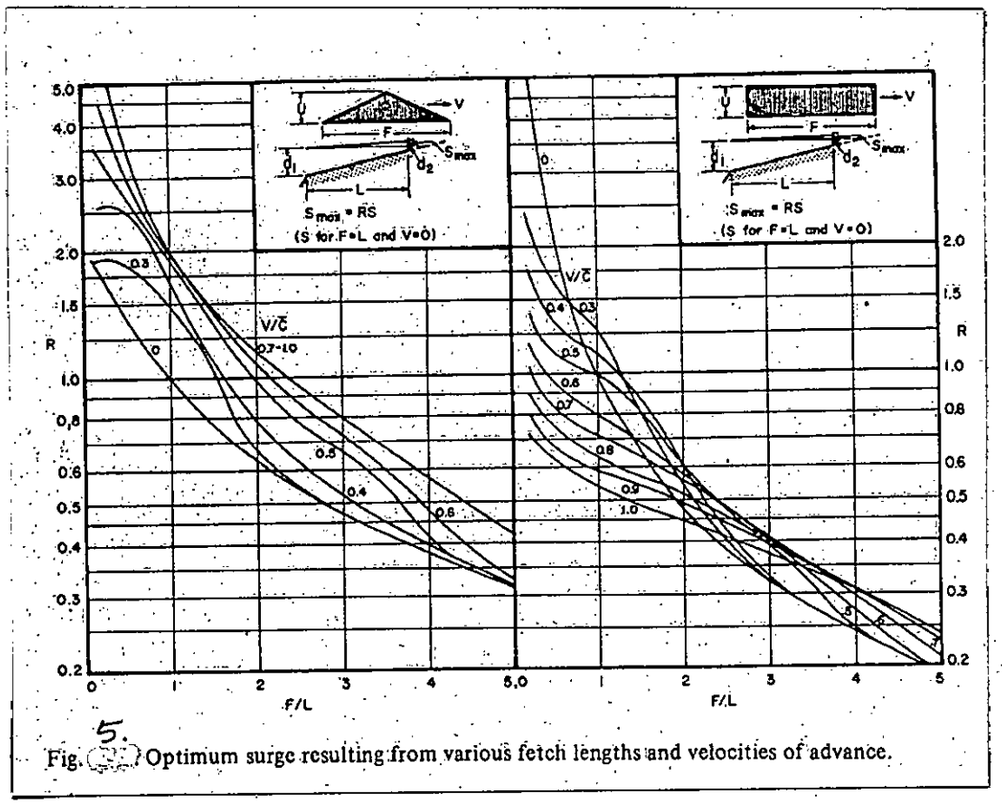


Fig. 5. Optimum surge resulting from various fetch lengths and velocities of advance.

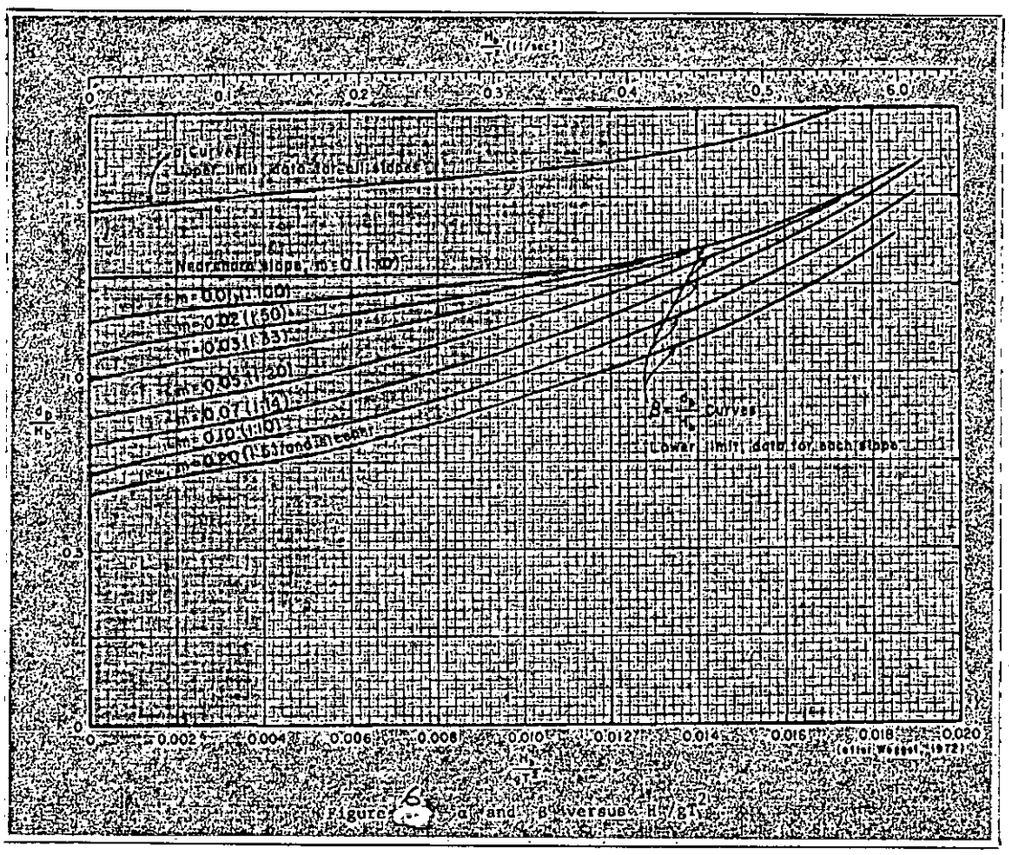
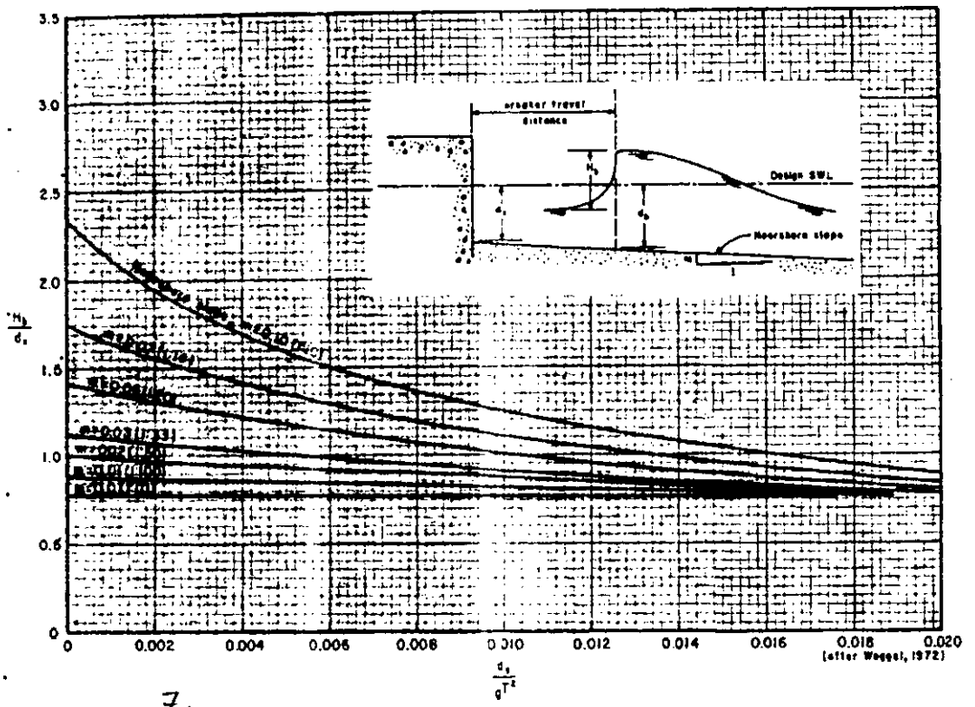


Figure 6. α_1 and β versus H_b/gT^2



7.

Figure Dimensionless design breaker height versus relative depth at structure.

Table 1. Continued.

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_g/C_o	H
.03000	.07135	.4483	.4205	.4634	1.1021	1.125	.9973	.8966	1.022	1.430	.9388	.3947	21.0
.03100	.07260	.4562	.4269	.4721	1.1059	1.118	.9942	.9124	1.044	1.446	.9369	.4000	21.1
.03200	.07385	.4640	.4333	.4808	1.1096	1.111	.9912	.9280	1.067	1.462	.9349	.4051	21.3
.03300	.07507	.4717	.4395	.4894	1.1133	1.104	.9882	.9434	1.090	1.479	.9329	.4100	21.6
.03400	.07630	.4794	.4457	.4980	1.1171	1.098	.9852	.9588	1.113	1.496	.9309	.4149	21.8
.03500	.07748	.4868	.4517	.5064	1.1209	1.092	.9821	.9737	1.135	1.513	.9289	.4196	21.19
.03600	.07867	.4943	.4577	.5147	1.1247	1.086	.9791	.9886	1.158	1.530	.9270	.4242	21.56
.03700	.07984	.5017	.4635	.5230	1.1285	1.080	.9761	1.003	1.180	1.547	.9250	.4287	21.97
.03800	.08100	.5090	.4691	.5312	1.1324	1.075	.9731	1.018	1.203	1.564	.9230	.4330	22.42
.03900	.08215	.5162	.4747	.5394	1.1362	1.069	.9701	1.032	1.226	1.582	.9211	.4372	21.90
.04000	.08329	.5233	.4802	.5475	1.1401	1.064	.9671	1.047	1.248	1.600	.9192	.4414	21.46
.04100	.08442	.5304	.4857	.5556	1.1440	1.059	.9641	1.061	1.271	1.617	.9172	.4455	20.92
.04200	.08553	.5374	.4911	.5637	1.1479	1.055	.9711	1.075	1.294	1.636	.9153	.4495	20.16
.04300	.08664	.5444	.4964	.5717	1.1518	1.050	.9688	1.089	1.317	1.654	.9133	.4534	20.03
.04400	.08774	.5513	.5015	.5796	1.1558	1.046	.9652	1.103	1.340	1.672	.9114	.4571	19.62
.04500	.08883	.5581	.5066	.5876	1.1599	1.042	.9621	1.116	1.363	1.691	.9095	.4607	19.23
.04600	.08991	.5649	.5116	.5954	1.1639	1.038	.9592	1.130	1.386	1.709	.9076	.4643	18.85
.04700	.09098	.5717	.5166	.6033	1.1679	1.034	.9562	1.143	1.409	1.728	.9057	.4679	18.49
.04800	.09205	.5784	.5215	.6111	1.1720	1.030	.9532	1.157	1.433	1.747	.9037	.4713	18.15
.04900	.09311	.5850	.5263	.6189	1.1760	1.026	.9503	1.170	1.456	1.766	.9018	.4746	17.82
.05000	.09416	.5916	.5310	.6267	1.1802	1.023	.9473	1.183	1.479	1.786	.8999	.4779	17.50
.05100	.09520	.5981	.5357	.6344	1.1843	1.019	.9444	1.196	1.503	1.805	.8980	.4811	17.19
.05200	.09623	.6046	.5403	.6421	1.1884	1.016	.9415	1.209	1.526	1.825	.8961	.4842	16.90
.05300	.09726	.6111	.5449	.6499	1.1926	1.013	.9385	1.222	1.550	1.845	.8943	.4873	16.62
.05400	.09829	.6176	.5494	.6575	1.1968	1.010	.9355	1.235	1.574	1.865	.8924	.4903	16.35
.05500	.09930	.6239	.5538	.6652	1.2011	1.007	.9326	1.248	1.598	1.885	.8905	.4932	16.09
.05600	.1003	.6303	.5582	.6729	1.2053	1.004	.9297	1.261	1.622	1.906	.8886	.4960	15.84
.05700	.1013	.6366	.5626	.6805	1.2096	1.001	.9267	1.273	1.646	1.926	.8867	.4988	15.60
.05800	.1023	.6428	.5668	.6880	1.2138	.9985	.9239	1.286	1.670	1.947	.8849	.5015	15.36
.05900	.1033	.6491	.5711	.6956	1.2181	.9958	.9209	1.298	1.695	1.968	.8830	.5042	15.13
.06000	.1043	.6553	.5753	.7033	1.2225	.9932	.9180	1.311	1.719	1.989	.8811	.5068	14.91
.06100	.1053	.6616	.5794	.7110	1.2270	.9907	.9150	1.323	1.744	2.011	.8792	.5094	14.70
.06200	.1063	.6678	.5834	.7187	1.2315	.9883	.9121	1.336	1.770	2.033	.8773	.5119	14.50
.06300	.1073	.6739	.5874	.7266	1.2355	.9860	.9093	1.348	1.795	2.055	.8755	.5143	14.30
.06400	.1082	.6799	.5914	.7335	1.2402	.9837	.9063	1.360	1.819	2.076	.8737	.5167	14.11
.06500	.1092	.6860	.5954	.7411	1.2447	.9815	.9035	1.372	1.845	2.098	.8719	.5191	13.92
.06600	.1101	.6920	.5993	.7486	1.2492	.9793	.9006	1.384	1.870	2.121	.8700	.5214	13.74
.06700	.1111	.6981	.6031	.7561	1.2537	.9772	.8977	1.396	1.896	2.144	.8682	.5236	13.57
.06800	.1120	.7037	.6069	.7633	1.2580	.9752	.8948	1.408	1.921	2.166	.8664	.5258	13.40
.06900	.1130	.7099	.6106	.7711	1.2628	.9732	.8919	1.420	1.948	2.189	.8646	.5279	13.24
.07000	.1139	.7157	.6144	.7783	1.2672	.9713	.8892	1.432	1.974	2.213	.8627	.5300	13.08
.07100	.1149	.7219	.6181	.7861	1.2721	.9694	.8861	1.444	2.000	2.236	.8609	.5321	12.92
.07200	.1158	.7277	.6217	.7937	1.2767	.9676	.8833	1.455	2.026	2.260	.8591	.5341	12.77
.07300	.1168	.7336	.6252	.8011	1.2813	.9658	.8804	1.467	2.053	2.284	.8572	.5360	12.62
.07400	.1177	.7395	.6289	.8088	1.2861	.9641	.7775	1.479	2.080	2.308	.8554	.5380	12.48
.07500	.1186	.7453	.6324	.8162	1.2908	.9624	.7747	1.490	2.107	2.332	.8537	.5399	12.34
.07600	.1195	.7511	.6359	.8237	1.2956	.9607	.7719	1.502	2.135	2.357	.8519	.5417	12.21
.07700	.1205	.7569	.6392	.8312	1.3004	.9591	.7690	1.514	2.162	2.382	.8501	.5435	12.08
.07800	.1214	.7625	.6427	.8386	1.3051	.9576	.7662	1.525	2.189	2.407	.8483	.5452	11.95
.07900	.1223	.7683	.6460	.8462	1.3100	.9562	.7634	1.537	2.217	2.432	.8465	.5469	11.83
.08000	.1232	.7741	.6493	.8538	1.3149	.9548	.7605	1.548	2.245	2.458	.8448	.5485	11.71
.08100	.1241	.7799	.6526	.8614	1.3198	.9534	.7577	1.560	2.274	2.484	.8430	.5501	11.59
.08200	.1251	.7854	.6558	.8687	1.3246	.9520	.7549	1.571	2.303	2.511	.8413	.5517	11.47
.08300	.1259	.7911	.6590	.8762	1.3295	.9506	.7522	1.583	2.331	2.537	.8395	.5533	11.36
.08400	.1268	.7967	.6622	.8837	1.3345	.9493	.7496	1.594	2.360	2.563	.8378	.5548	11.25

Table 2
Rough Slope Runup Correction Factors (Carstea et al. 1975b)

Armor Type	Slope (cot θ)	Relative Size H / K_r[a,b]	Correction Factor r
Quarrystone	1.5	3 to 4	0.60
Quarrystone	2.5	3 to 4	0.63
Quarrystone	3.5	3 to 4	0.60
Quarrystone	5	3	0.60
Quarrystone	5	4	0.68
Quarrystone	5	5	0.72
Concrete Blocks[c]	Any	6[b]	0.93
Stepped slope with vertical risers	1.5	$1 \le H_o'/K_r$[d]	0.75
Stepped slope with vertical risers	2.0	$1 \le H_o'/K_r$[d]	0.75
Stepped slope with vertical risers	3.0	$1 \le H_o'/K_r$[d]	0.70
Stepped slope with rounded edges	3.0	$1 \le H_o'/K_r$[d]	0.86
Concrete Armor Units			
Tetrapods random two layers	1.3 to 3.0	-	0.45
Tetrapods uniform two layers	1.3 to 3.0	-	0.51
Tribars random two layers	1.3 to 3.0	-	0.45
Tribars uniform one layer	1.3 to 3.0	-	0.50

[a] K_r is the characteristic height of the armor unit perpendicular to the slope. For quarrystone, it is the nominal diameter; for armor units, the height above the slope.
[b] Use H_o' for $d_s/H_o' > 3$; and the local wave height, H_s for $d_s/H_o' \le 3$.
[c] Perforated surfaces of Gobi Blocks, Monoslaps, and concrete masonry units placed hollows up.
[d] K_r is the riser height.

Table 3
Suggested Values for Use in Determining Armor Weight (Breaking Wave Conditions)

Armor Unit	n[1]	Placement	Slope (cot θ)	K_D
Quarrystone				
Smooth rounded	2	Random	1.5 to 3.0	1.2
Smooth rounded	>3	Random	1.5 to 3.0	1.6
Rough angular	1	Random	1.5 to 3.0	Do Not Use
Rough angular	2	Random	1.5 to 3.0	2.0
Rough angular	>3	Random	1.5 to 3.0	2.2
Rough angular	2	Special[2]	1.5 to 3.0	7.0 to 20.0
Graded riprap[3]	2[4]	Random	2.0 to 6.0	2.2
Concrete Armor Units				
Tetrapod	2	Random	1.5 to 3.0	7.0
Tripod	2	Random	1.5 to 3.0	9.0
Tripod	1	Uniform	1.5 to 3.0	12.0
Dolos	2	Random	2.0 to 3.0[5]	15.0[6]

[1] n equals the number of equivalent spherical diameters corresponding to the median stone weight that would fit within the layer thickness.
[2] Special placement with long axes of stone placed perpendicular to the slope face. Model tests are described in Markle and Davidson (1979).
[3] Graded riprap is not recommended where wave heights exceed 5 ft.
[4] By definition, graded riprap thickness is two times the diameter of the minimum W_{50} size.
[5] Stability of dolosse on slope steeper than 1 on 2 should be verified by model tests.
[6] No damage design (3 to 5 percent of units move). If no rocking of armor (less than 2 percent) is desired, reduce K_D by approximately 50 percent.

Table 4
Layer Coefficients and Porosity for Various Armor Units

Armor Unit	n	Placement	K_Δ	P (%)
Quarrystone (smooth)	2	Random	1.00	38
Quarrystone (rough)	2	Random	1.00	37
Quarrystone (rough)	≥3	Random	1.00	40
Graded riprap	2[a]	Random	N/A	37
Tetrapod	2	Random	1.04	50
Tribar	2	Random	1.02	54
Tribar	1	Uniform	1.13	47
Dolos	2	Random	0.94	56

[a] By definition, riprap thickness equals two cubic lengths of W_{50} or 1.25 W_{100}.