Stability of Dolos Slopes

Brorsen, Michael; Burcharth, Hans F.; Larsen, Torben

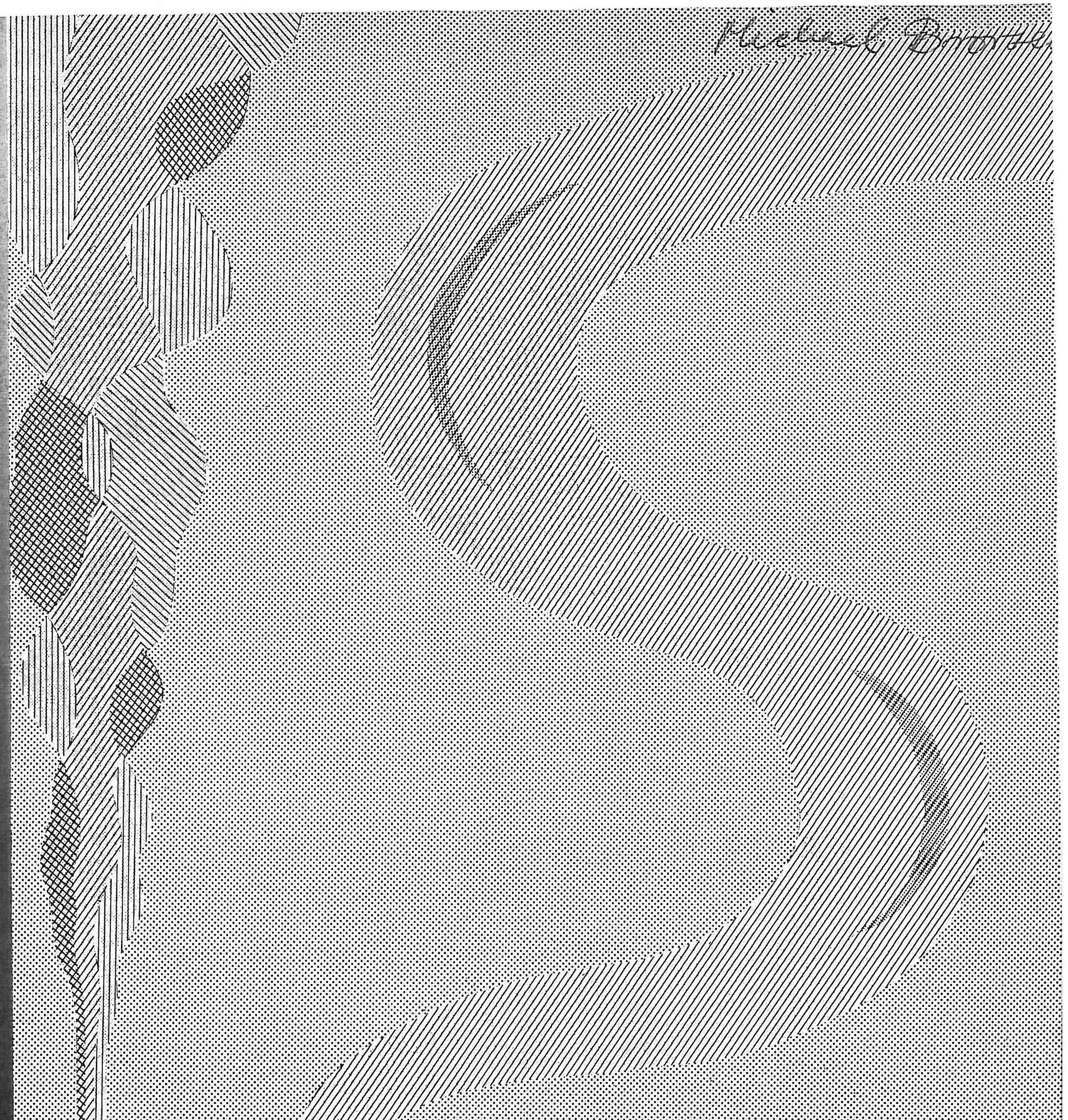
Publication date:
1974

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Brorsen, M., Burcharth, H. F., & Larsen, T. (1974). *Stability of Dolos Slopes*. Laboratoriet for Hydraulik og Havnebygning. Bulletin No. 9

Michael Brorsen



BULLETIN NR. 9

MICHAEL BRORSEN
H F BURCHARTH
TORBEN LARSEN

STABILITY OF DOLOS SLOPES

AALBORG UNIVERSITETSCENTER
LABORATORIET FOR HYDRAULIK OG HAVNEBYGNING
DANMARKS INGENIØRAKADEMI DANMARKSGADE 19 9000 AALBORG DANMARK

DK: 627.6

DANISH ENGINEERING ACADEMY AALBORG UNIVERSITY

Danmarksgade 19 DK 9000 Aalborg Danmark telefon (08) 160533

HYDRAULICS LABORATORY

Professor H. F. Burcharth

M. Brorsen, H. F. Burcharth, Torben Larsen

BULLETIN No. 9

STABILITY OF DOLOS SLOPES

AUGUST 1974

This paper was presented on the 14th International Conference on Coastal Engineering, Copenhagen, June 1974.

CONTENTS

Abstract	page 1
Introduction	page 2
Definitions of damage	page 2
Influence of slope	page 3
Irregular waves	page 4
Dolos, natural stones and concrete cubes	page 6
Concrete and plastic modelblocks	page 7
Hudson's formula	page 9
Fieldinvestigation by photogrammetry	page 10
Literature	page 10

STABILITY OF DOLOS SLOPES

by

Michael Brorsen, M.Sc., res.eng.

H.F. Burcharth, professor

Torben Larsen, M.Sc., res.eng.

Hydraulics Laboratory

Danish Engineering Academy - Aalborg University

DK-9000 Aalborg, Denmark

Abstract

The stability of dolos armour blocks against wave attack has been investigated in wave model studies.

Simple definitions to describe the block movements are introduced and the following results are discussed:

1. The stability of dolos slopes against regular waves and the influence of the slope.
2. The stability of dolos slopes against irregular waves that are not Rayleigh distributed.
3. Comparison between the stability of dolos, natural stones and cubes.
4. The influence of the surface roughness of the dolos model blocks.
5. The applicability of Hudson's formula.

Introduction

This paper includes results from model tests which have been carried out in the Hydraulics Laboratory at the Danish Engineering Academy in Aalborg, Denmark. The paper also includes results from tests carried out by two former students at the Engineering Academy Mr. Springborg and Mr Jepsen. Below, the most important data of the experimental set up are summarized:

Dolos height	4,5 cm
Dolos, cube and natural stone weight	38 g
Dolos and cube density	2,3 t/m^3
Natural stone density	2,65 t/m^3
Water depth	25-40 cm
Wave period	0,7-1,2 sec
Wave flume bottom	horizontal
Number of block layers	2
Under layer	broken stones

Definitions of damage

After some initial tests it was decided to describe the dolos movements by the following terms:

1st degree	No movements at all.
2nd degree	Blocks can rock, but will not move from mean position.
3rd degree	A few blocks will move, but the armour layer remains stable.
4th degree	Blocks are moved continuously until the armour layer is destroyed.
5th degree	The armour layer is destroyed in a short time.

This system of definitions is almost the same as the system applied by Hydraulics Research Station [7] and Paul and Baird [5].

1st and 2nd degree do not require further explanation, but in the 3rd degree it was remarked that at the start of the test a few blocks were removed, but later on nothing more happened, and this was valid for both regular and irregular waves.

In 4th degree the armour layer is unstable, but the blocks are moved slowly one by one. For prototype conditions it would be expected that the slope would still be able to resist smaller waves after a short storm with waves corresponding to 4th degree. For 5th degree total failure will occur in a short time.

It is natural to try to compare these definitions with the wellknown percentage of damage. The 0-percentage is found on the transition between 2nd and 3rd degree. The 3rd degree will be equal to approximately 2-4% damage, but in the 4th and 5th degree the damage is dependent on time and therefore the percentage of damage will increase with increasing duration of the test.

Influence of slope

Figure no 1 shows the stability conditions due to regular wave attack perpendicular to the slope. H is the wave height, h is the dolos height and a is the slope defined as cotangent to the angel between horizontal and the slope. The grey screen on the figur in the transition between the degrees of damage indicates the inaccuracy of the tests. The figur includes own results and results from the accessible literature. All the tests have been carried out with almost the same density, so it was possible to use the simple parameter H/h to compare the results. It is remarkable that the stability is independent of the slope if the accuracy is considered.

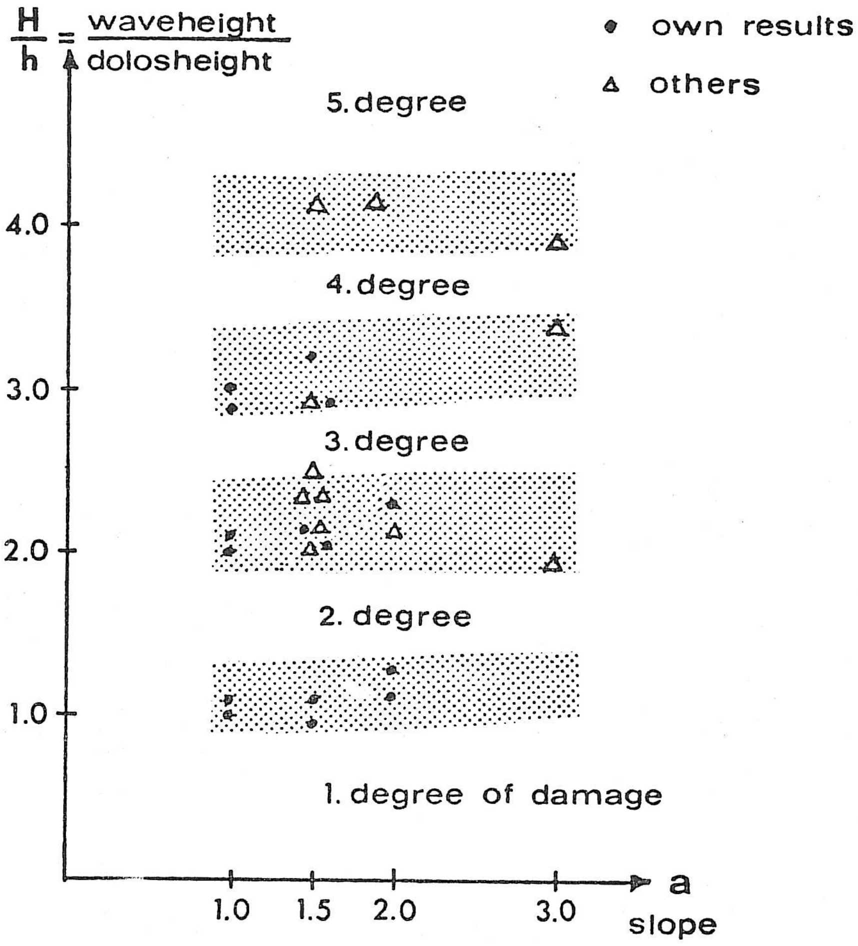


Fig. no 1

Irregular waves

Figur no 2 shows the waveheight distribution obtained in irregular wave tests. H_s is the significant waveheight defined as the average height of the highest third part of the waves. $\bar{H}$ is the average waveheight. ε is the spectral width parameter defined as $\varepsilon^2 = 1 - (T_c/T_z)^2$ where T_c is the top-top period and T_z the zero upcrossing period. It is remarkable that the distribution differs from the Rayleigh-distribution especially for the higher part of the waves.

The wavespectrum was not recorded, but the wavegenerator was fed

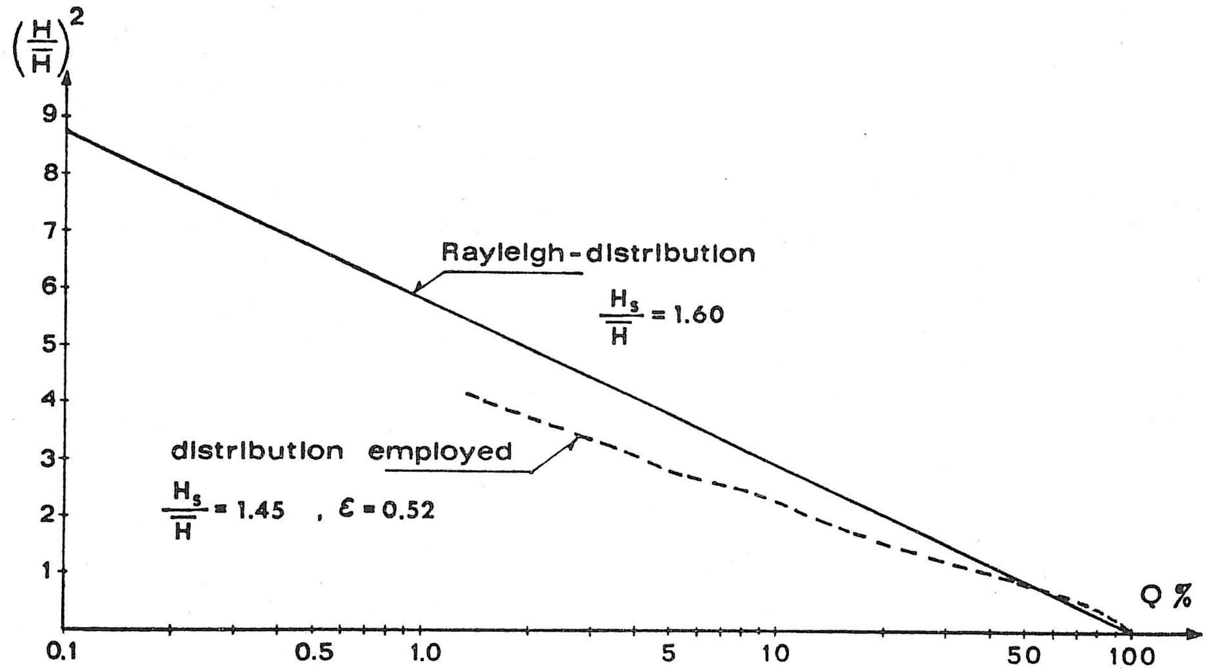


Fig. no 2

with a signal which was estimated to give a Moskowitz spectrum in front of the wavegenerator. The electrical inputsignal consisted of 10 discrete frequencies and the transferfunction was estimated after Biesels small amplitude wavegeneration theory.

Figur no 3 illustrates the general result obtained when the effect of regular and irregular waves was compared.

The result was that irregular waves with a significant waveheight H_S will cause the same damage as regular waves with the height $H = 0,8\ H_S$ and the factor 0,8 was the same for all slopes and blocks compared if the accuracy was considered. The conclusion is therefore that in the sphere of the tests regular waves are probably satisfactory to compare the stability of different slopes and blocks relativly.

Refference [7] and [12] have found that the ratio between regular wave height and significant irregular wave height causing the same damage was equal to 1.0. The explanation of this devia-

DOLOS CONCRETE

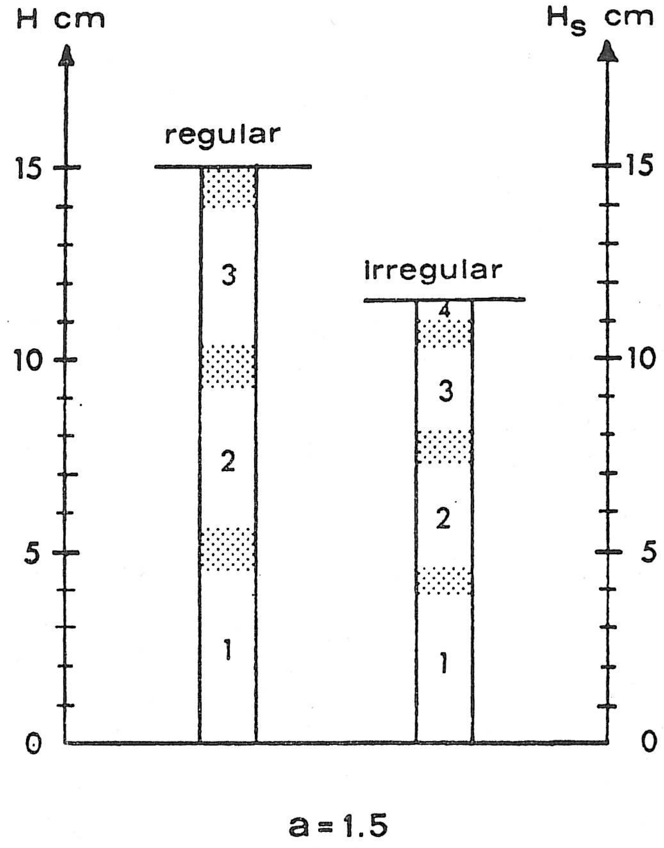


Fig. no 3

tion between the results proberly is due to the differens in waveheight distribution used in the different tests.

Dolos, natural stones and concrete cubes

The stability of dolos, natural stones and concrete cubes has been directly compared in the model test by having the different blocks simultanously attacked by the same waves. Figur no 4 shows the results of the tests. The blockweight was 38 g for all the blocks and the density of the concrete dolos and cubes was 2,3 t/m³ and density of the natural stones was 2,65 t/m³ corresponding to prototype conditions.

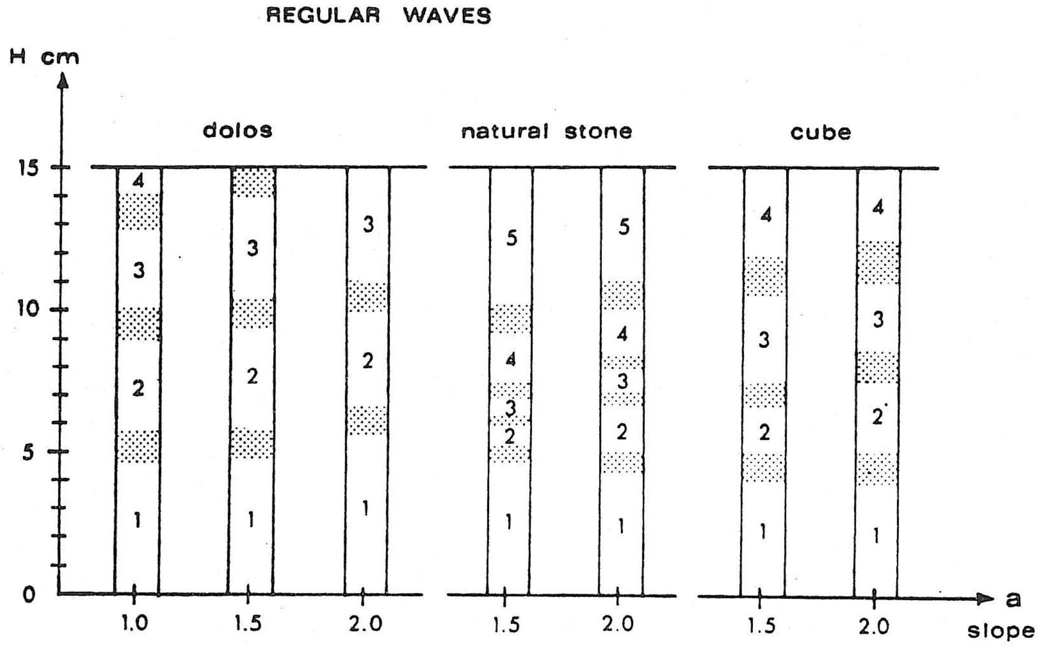


Fig. no 4

The results of the stability of natural stones and cube are in good agreement with results from the literature.

First figur no 4 shows the better stability of the dolos. Moreover it is significant that dolosslopes are less sensitive to overloading than e.g. natural stones.

The results in figur no 4 can be transfered to other scales by use of Froudes model scale law simply by multiplying the waveheight by the scale and multiplying the blockweight by the third power of the scale.

Concrete and plastic modelblocks

Fig. no 5 shows the stability of concrete and plastic model

IRREGULAR WAVES

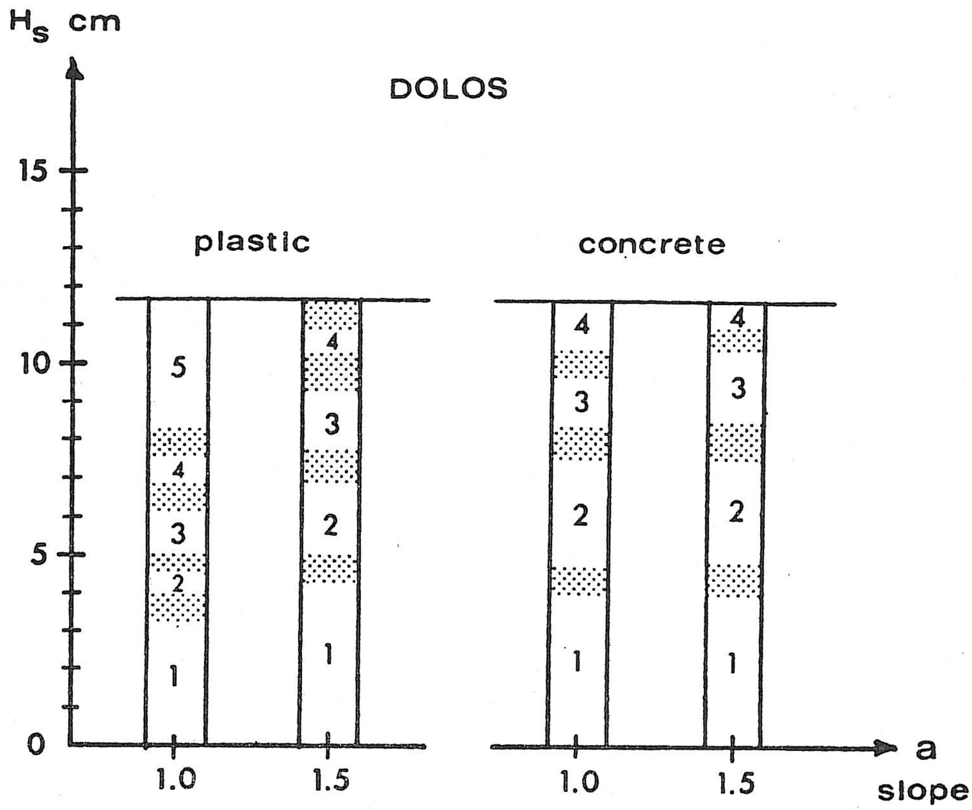


Fig. no 5

blocks. A significant lower stability for plastic-dolos can be observed at the 1 in 1 slope.

A satisfactory unique physical explanation of this cannot be given at the moment. But it can directly be observed that wet plastic dolos are much more smooth than the concrete ones and a reduction of the friction between the blocks will of course reduce the stability, especially a reduction of the interlocking capability should be expected to be important.

The influence of the surface roughness seems to be important in certain circumstances and in the authors opinion further research on this point is recommendable.

Hudson's formula

In fig. no 6 calculations of the stability factor K in Hudson's wellknown formula is plotted against the slope.

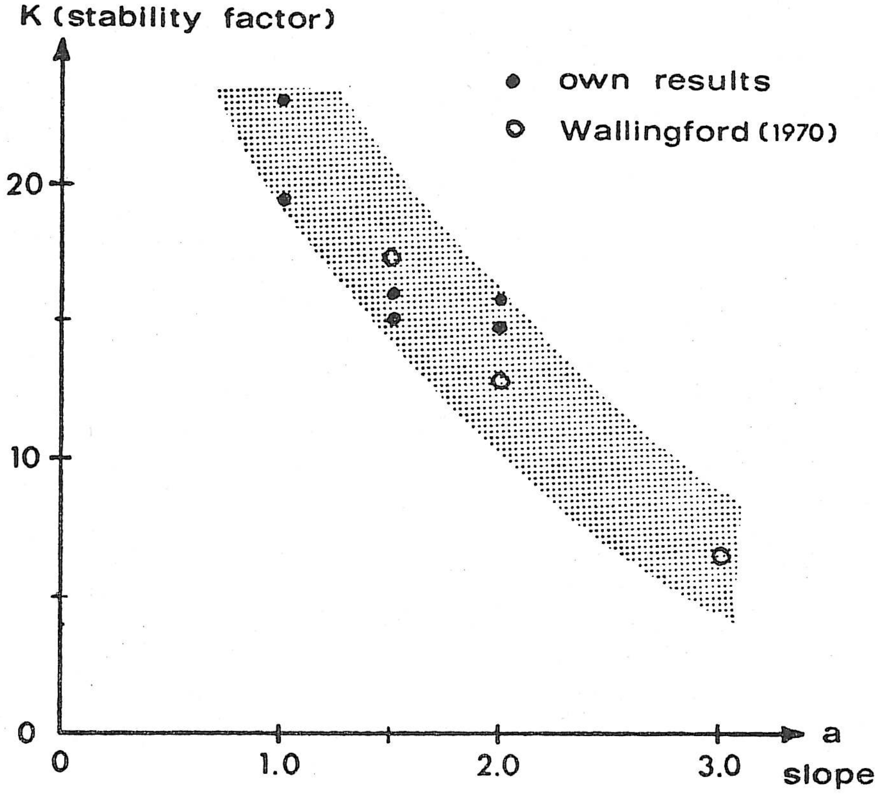


Fig. no 6

In spite of the considerable inaccuracy in the tests, which is strongly amplified by the third power-influence of the wave-height in the stability factor, it is clear that Hudson's formula does not describe the stability of dolos slopes satisfactory. The reason for this is probably the interlocking between the blocks and the high porosity of the armour layer.

As the results show that other forces are involved than assumed for the set up of Hudson's formula, the stability as function of the density cannot be expected to be the same as expressed by Hudson's formula.

The dependence of the third power on the waveheight is of course not affected if the Froudes scalelaw is assumed to be valid.

Fieldinvestigation by photogrammetry

In order to follow up abovementioned modeltest a fieldinvestigation of the dolos-breakwater in Hirtshals harbour, Northjutland, Denmark was started in 1973. The purpose of the investigation which is in progress is to registrate both damage and small movements of the blocks in the armour layer. At the same time the waveheight is measured. The block movements are determined after photogrammetrical records from a height of approximately 300 m. In this case it is possible to registrate movements with a mean error of 1,5 cm.

Literature

[1] Merrifield, E.M., Zwamborn, J.A. (1966): "The economic value of a new breakwater armour unit Dolos", Proc. of 10th Conf. on Coastal Eng. Tokoy 1966.

[2] Merrifield, E.M. (1968): "Dolos concrete armour protection", Civil Engineering, Dec. 1968.

[3] Merrifield, E.M. (1970): "Dolos - a new breakwater and coastal protection block", The Dock and Harbour Authority, April 1970.

[4] Mangoon, O.T., Shimizu, N. (1971): "Use of Dolos Armour units in rubble-mound structures e.g. for conditions in the arctic", Proc. of 1st int. conf. on port and ocean eng. under arctic conditions. Trondheim 1971.

[5] Paul, M.W., Baird, W.F. (1971): "Discussion on breakwater armour units", Proc. of 1st int. conf. on port and ocean eng. under arctic conditions. Trondheim 1971.

[6] Paape, A., Walther, A.W. (1962): "Akmon armour unit for cover layers of rubble mound breakwaters", Hydraulics Laboratory Delft, publ. no 27, 1962.

[7] Hydraulics Research Station, Wallingford (1970): "High Island water scheme - Hong Kong. A study on the use of dolos armour units for wave protection on the seaward face of the Eastern Dam", Report no EX 532.

[8] Hudson, R.Y. (1959): "Laboratory investigation of rubble-mound breakwaters", Proc. A.S.C.E., Waterways and Harbours division, sept. 1959.

[9] Brorsen, M., Burcharth, H.F., Larsen, T. (1973): "Stability of dolos slopes" (in Danish), Hydraulics Laboratory, Bulletin no 3, Danish Engineering Academy, Aalborg, Denmark.

[10] Zwamborn, J.A., Beute, I. (1972): "Stability of dolos armour units", ECOR symposium, Stellenbosch, nov. 1972.

[11] Jepsen, H.S., Springborg, N.J. (1974): "Model test on the stability of dolos slopes" (in Danish), Master thesis, Danish Engineering Academy, Aalborg, Denmark.

[12] Quellet, Y. (1972): "Effects of irregular wave trains on rubble-mound breakwaters", Proc. A.S.C.E., Waterways, Harbours and Coastal Engineering Division, feb. 1972.

Bulletiner fra Laboratoriet for Hydraulik og Havnebygning:

Bulletin nr. 1	H. F. Burcharth og Torben Larsen "Introduktion af laboratoriet" december 1971
Bulletin nr. 2	H. F. Burcharth og Torben Larsen "Elementær laboratoriepraktik for bygningsingeniør-studerende" april 1972
Bulletin nr. 3	Michael Brorsen, H. F. Burcharth og Torben Larsen "Stabilitet af dolosskråninger" marts 1973
Bulletin nr. 4	Strandby havn Ny forhavn Modelforsøg med bølgeuro, april 1973
Bulletin nr. 5	Referat af studierejse til Holland, efteråret 1973
Bulletin nr. 6	Helsingør Nordhavn Modelforsøg med bølgeuro, april 1974
Bulletin nr. 7	H. F. Burcharth "Forslag til lystbådehavne i Aalborg, august 1974
Bulletin nr. 8	K. Erling Navntoft "Metode til samtidig måling af hastighed og sedimentkoncentration i stationære strømninger med sediment i suspension" august 1974
Bulletin nr. 9	M. Brorsen, H. F. Burcharth og Torben Larsen "Stability of dolos slopes" august 1974