Experiment Instructions

HM162.39  Artificial Roughened Bed Section

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Experiment Instructions

Please read and follow the safety comments before the first installation!

This apparatus is meant to be used only for Education, Teaching or Research.
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1 Introduction

The accessory unit **HM 162.39 artificial roughened bed section** is used to simulate a very rough, heavily absorbent flume bed in the modular flow channel HM 162. Combined with a wave generator, e.g. HM 162.47 (accessory) and beach fittings, investigations of the breaking behavior of waves can be carried out in the offshore area, and the hydraulic effects of rough beds can be investigated in hydraulic engineering.

The flow bed consists of stainless steel and has pyramid-shaped epoxy resin bodies bonded to it which absorb the flow energy of the water. Two carrying handles guarantee safe transport of the unit by two persons.

The following **subject areas** are covered by the accessory unit HM 162.39 flow bed (in some cases combined with other accessories):

- Effect of the absorption of energy on the water flow rate in open flumes
- Effects of a rough bed on the breaking behavior of waves (offshore)
- Wave velocities
- Energy transport in a wave
2 Unit description

The accessory unit **HM 162.39 Artificial roughened bed section** is a model of a rough surface of a flume bed. It is designed for installation in the modular flow channel HM 162.

2.1 Components

The accessory HM 162.39 flow bed consists of the components

- **Flow bed** (1) made of stainless steel with bonded-on pyramid-shaped **absorption bodies** (2) made of epoxy resin
- **Inlet/outlet plates** (3)
- Removeable **carrying handle** (4)
- Hexagon socket-head screws M8

2.2 Assembly

- The flow bed is inserted into the flow channel with the aid of the carrying handles.
- Due to the intrinsic weight, it is not necessary to fix the longitudinal axis.
- Remove the carrying handles.

**Important:** The flow bed is very heavy. It should therefore always be lifted into and out of the channel by two persons.
In all circumstances, it is essential to prevent screws or other small parts from being rinsed into the outlet opening of the flow channel HM 162 by water. **This would destroy the centrifugal pump.** Therefore, always follow the safety instructions below:

- The fittings may only be installed and removed when the water has drained off.
- Do not leave any tools in the flow channel after assembly or disassembly.
- Always secure fittings with all screws in order to prevent damage to the fittings.
- Always transport the flow bed with two persons. Otherwise, due to its weight, spinal injuries may result.
As with all G.U.N.T. instructions, the outlines of the theoretical background and possible experiments are intended to be ideas for students, teachers or researchers to experiment and learn themselves. In this sense, we make no claim to completeness, but we do state that the material outlined is correct.

4.1 Definition of terms

In the case of the propagation of a wave, it must be assumed that the individual water particle does not carry out a continuous movement. Rather, its movement is more ellipsoid, in other words rotational (1). This means that it largely remains in its place while, for example, the wave crest (2) moves. The movement velocity of the wave crest is designated with wave velocity $w$ in contrast to the flow velocity $v$.

The wave length $L$ is the distance between two wave crests (2) or wave troughs (3). Therefore, if a water particle requires the time $t$ for a full rotation, it follows that

$$w = \frac{L}{t}.$$  \hspace{1cm} (4.1)

4.2 Wave types

Whereas translatory waves primarily arise in flumes as surge or recess phenomena, e.g. when a weir suddenly opens, the surface or gravity waves are particularly significant in offshore engineering. In general, they are caused by local disturbances of the water surface which expand with the wave velocity $w$. Gravity waves can be further subdivided into undulating waves, in which there is practically no mass transport in the direction of movement, and transfer waves in which the water particles are displaced in the wave propaga-
tion direction (e.g. surf waves). In the undulating waves dealt with below, a further subcategorization is made into deep water and shallow water waves.

4.3 Wave velocity

4.3.1 Calm water

Assuming an eddy-free flow and an ideal liquid, the Press wave velocity can be calculated as

\[ w = \sqrt{\frac{gL}{2\pi} \tanh \left( \frac{2\pi h}{L} \right)} . \]  \hspace{1cm} (4.2)

In the case of deep water waves (e.g. above sea floor) \( h / L >> 1 \), i.e. the **Wave velocity of deep water waves** is

\[ w = \sqrt{\frac{gL}{2\pi}} . \] \hspace{1cm} (4.3)

In the case of shallow water waves (e.g. in flumes or near to the beach) \( h / L << 1 \), i.e.

\[ \tanh \left( \frac{2\pi h}{L} \right) \approx \frac{2\pi h}{L} . \] \hspace{1cm} (4.4)

This gives the **Wave velocity for shallow water waves** as

\[ w = \sqrt{gh} . \] \hspace{1cm} (4.5)

Provided that the wave height \( H \) is low, the **wave velocity of deep water waves** is therefore only dependent on the wave length \( L \), in other words the frequency of the wave sequence, and the **wave velocity of shallow water waves** is only dependent on the water depth \( h \).

Both wave types are distinguished from each other as follows:

\[ h / L > 0.5 \quad \text{Deep water waves} \] \hspace{1cm} (4.6)

\[ h / L < 0.5 \quad \text{Shallow water waves} \]
4.3.2 Flowing water

If we are not, as has so far been assumed, dealing with calm water, a flow velocity $v$ instead being present, the wave velocity is

$$\begin{align*}
\text{upstream:} & \quad w - v \\
\text{downstream:} & \quad w + v
\end{align*} \quad (4.7)$$

As has already been mentioned, no wave expansion is possible upstream in the case of supercritical outflow. The wave velocity is negative. Fig. 4.2 shows the extension of the wave front under conditions of calm (a), subcritical (b), limit (c) and supercritical outflow (d).

4.4 Changing water depth

The changeover of a wave from a deep-water wave to a shallow-water wave with the subsequent wave-breaking is, in practice, the most important case and is therefore dealt with in more detail (Fig. 4.3).

In the case of wave propagation towards a bank or a beach, the bed rises gradually in most cases and the water depth $h$ decreases, causing the wave velocity $w$, wave length $L$ and wave height $H$ to change.

If the water depth reaches, in accordance with the equation (4.6), the value of half the wave length $L$ the limit between the shallow water and deep water range is reached. The wave velocity $w$ now decreases, whereas the wave height $H$ increases. The waves become increasingly steeper until a point is reached above the further-rising bed at which the waves break. This is the start of the surf zone.
4.5 Energy transport in the wave

Ideally, we assume that the wave energy is preserved in the range of the smooth shallow-water wave (Fig. 4.3) before the break point. The energy transport has been mathematically recorded for this case. However, due to its complexity, it is not shown here. In truth however, this mainly does not apply, particularly in the case of water-permeable or rough beds (e.g. sand beaches). Here, an energy loss occurs on the bed which, in contrast to the ideal case, primarily manifests itself directly in front of the break point in the form of a reduced wave height $H$.

The wave movement in the break point zone is associated with significant energy losses. In addition to the losses caused by the friction of the liquid particles, the mixing losses in air absorption play a significant role, together with the sound emission (sea noise) and the forced vibration of the bed when the wave breaks.

Structures near to the break point are known to be subject to high stresses in the area above the rest level, because the wave energy is concentrated here particularly in the form of kinetic energy, thereby giving rise to great wave pressure forces which attack at a high level.

A displacement of the break point by a sufficient water depth behind the structure (e.g. by dredging the bed) or displacement of the break point a sufficient distance in front of the structure by an artificial arrangement of slopes, shallows or similar prevent this problem.
4.6 Breaker types

When the break point is reached, the behaviour of a wave changes dramatically. Due to the influence of the reduced wave velocity and the back-flow of the preceding wave, different breaker types form, which Mason divided up into three different categories:

- **Foam breaker** (a): The front side of a wave reaches a critical steepness at which the closed surface, starting at the crest of the wave, breaks open. Foam forms on a wide front which passes through the entire surf zone with a constant front steepness.

  In leisure sports, surfers use this type of breaker to "ride" for as long as possible with their boards on the wave top.

- **Fall breakers** (b): When air is absorbed, the incline of the front side continues to increase until an approximately vertical position is reached, causing the wave to fall. Only now does intensive air mixture occur, most of the wave's energy being taken from it. Leisure sport has this type of breaker to thank for the spectacular pictures showing surfers riding in a hair-raising way below crashing waves (particularly on Hawaii).

- **Surge breakers** (c): The wave begins to absorb air in the same way as with the foam breaker, but as it progresses neither the front steepness is preserved nor does the wave crash over. The water-air mixture on the front side is significantly more extended than is the case with the foam breaker and it moves up the beach like a homing surge.
4.7 Experiments with the channel fittings

In conjunction with wave experiments on beaches, G.U.N.T. offers a wide range of fittings as accessories which enable the wave patterns on different beaches to be simulated:

- Generating and observing the various breaker types with the beach fittings
- Installing shallows or a sand bank in front of a beach fitting (HM 162.44) or an energy-absorbing bed in front of a beach (HM 162.39)
- Comparison of different beach material (HM 162.42 smooth, impermeable beach, HM 162.43 impermeable substrate such as sand, HM 162.48 absorbent substrate)
- Measuring the wave velocities at different water depths

Another tip is that we recommend that you use the accessory level metering unit HM 162.50, together with the instrument holder HM 162.59, in order to measure water levels and that you use the Prandtl tube HM 162.50 with HM 162.59 in order to measure flow velocities.
5 Appendix

5.1 Technical data

Material: Plate: Stainless steel
Absorption body: epoxy resin

Shape of the absorption bodies:
pyramid-shaped

Dimensions (LxWxH)
2500x300x90 mm

Weight: approx. 20 kg

5.2 Literature references

- Press, Schröder: Hydromechanik im Wasserbau, Verlag von Wilhelm Ernst & Sohn, Munich 1966