Benchmark 4: Laboratory: Solitary Wave on a Simple Beach

Problem description

This benchmark is the lab counterpart of BM1 (Analytical: solitary wave on a simple beach).
Fig. 1 is a reproduction from BM1 that shows the domain used in this test.

In the experiments, the 31.73 m-long, 60.96 cm-deep, and 39.97 cm-wide California Institute of Technology, Pasadena, California wave tank was used. The bottom of the tank consisted of painted stainless steel plates. Carriage rails run along the whole length of the tank, permitting the arbitrary movement of instrument carriages. A ramp was installed at one end of the tank to model the bathymetry of the canonical problem of a constant-depth region adjoining a sloping beach. The ramp had a slope of 1:19.85 (i.e. cot β=19.85). The ramp was sealed to the tank side walls.

A total of more than 40 experiments with solitary waves running up the sloping beach were performed, with wave depths ranging from 6.25 cm to 38.32 cm. The problem can be completely described with 3 parameters: the offshore depth d, the height of the solitary wave H, and the beach slope β. Other variables can be non-dimensionalized using these parameters; e.g., the length scale is d, velocity scale is $U=\sqrt{gd}$, and time scale is $T=\sqrt{d/g}$ etc. In the experiments, H/d ranged from 0.021 to 0.626. Breaking occurs when $H/d>0.045$ for this particular beach.

The origin of the x-axis is located at the initial shoreline with the axis pointing offshore (Fig. 1). Therefore the depths at the beach is $h=x \tan \beta$ ($x \le x_0 \equiv d \cot \beta$). Initially the solitary wave is centered at a distance from the toe of the beach, $x=x_s=x_0+L$ with

$$L = d \cosh^{-1}(\sqrt{20})/\gamma,$$

$$\gamma = \sqrt{\frac{3H}{4d}} .$$

$$\cosh^{-1} a = \log(a+\sqrt{a^2-1})$$

The initial condition is

$$\eta(x,0) = H \operatorname{sech}^2 \gamma(x-x_s)/d$$

$$u(x,0) = -\eta(x,0)\sqrt{g/d} .$$

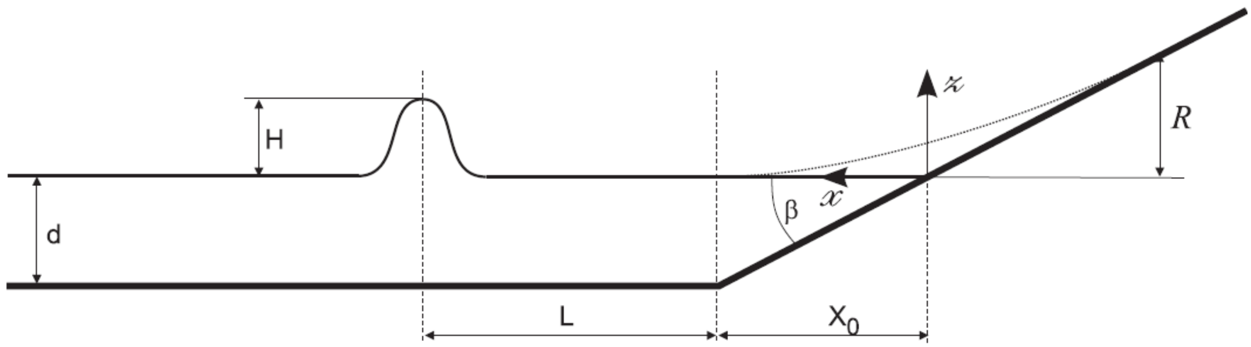


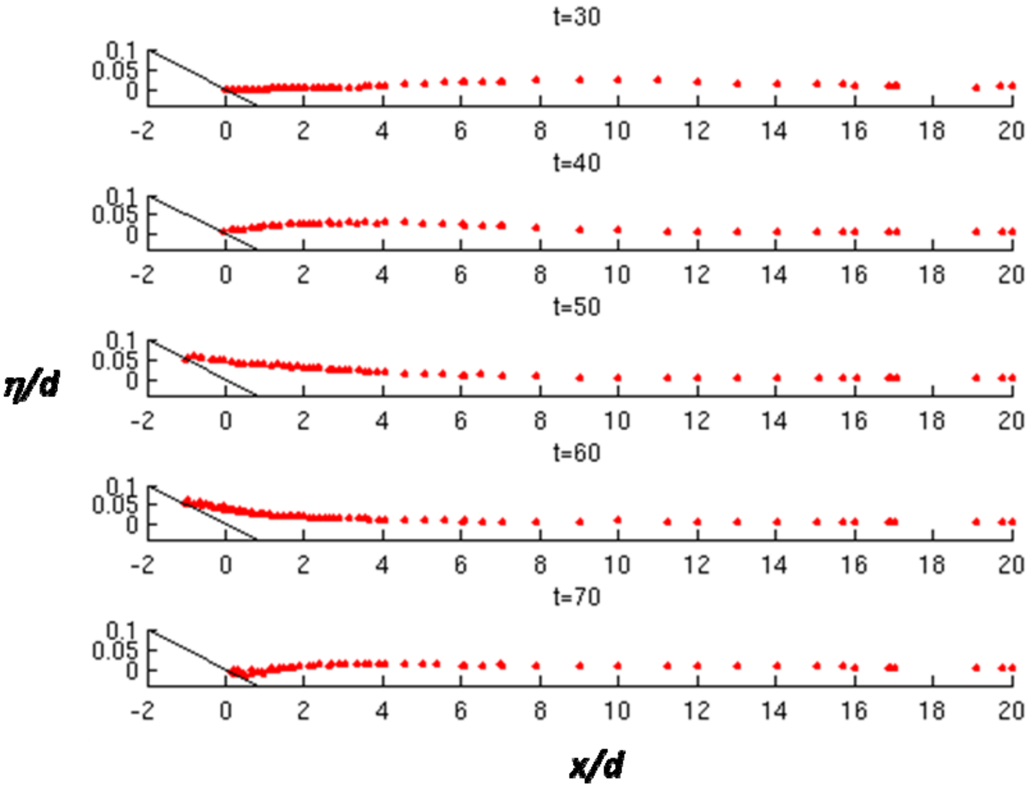
Figure 1 Domain sketch.

Tasks

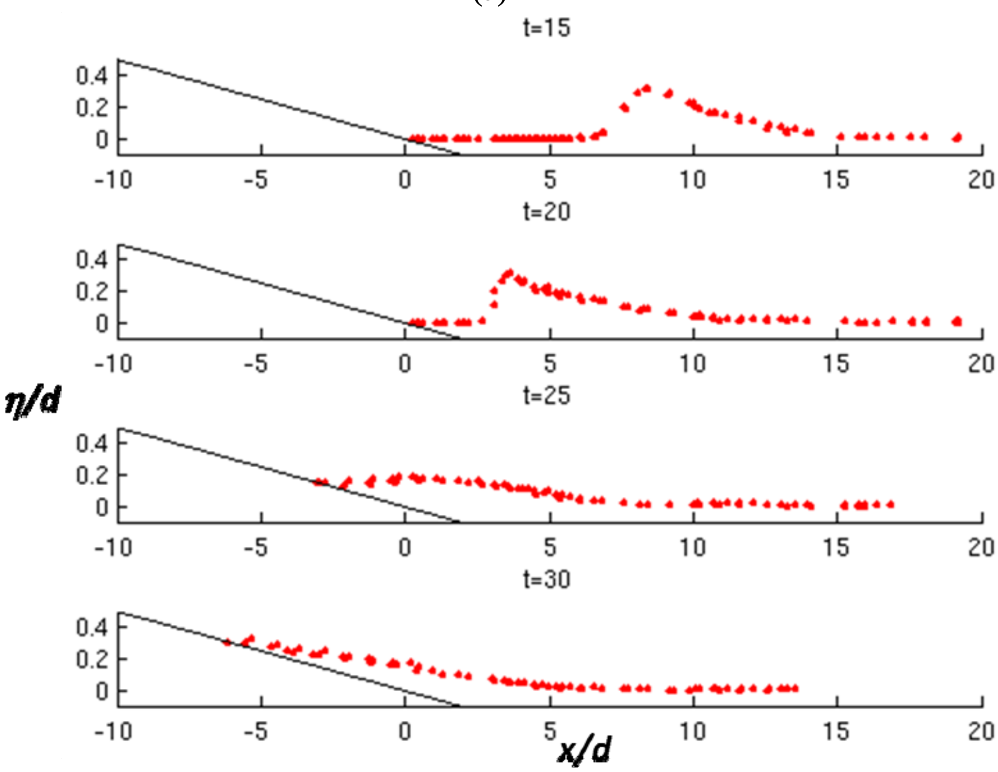
a. Compare numerically calculated surface profiles at *t*/*T*=30:10:70 for the non-breaking case *H*/*d*=0.0185 with the lab data. The choice for *d* is somewhat arbitrary (see c below) but the depth used in the experiment is $d \approx 30\,\text{cm}$;
b. Compare numerically calculated surface profiles at *t*/*T*=15:5:30 for the breaking case *H*/*d*=0.3 with the lab data ($d \approx 15\,\text{cm}$ in the experiment);
c. (optional) demonstrate the scalability of the code by using different *d*;
d. Compute maximum runups for at least one non-breaking and one breaking wave case. For example, use *H*/*d*=0.0185 and 0.3 as in a-b.

Files description

1. profs.tgz: all surface profile lab data for a-b; upon uncompressing, each file contains one profile at a particular time for the two cases, with the 1st column being the dimensionless time (i.e. *t*/*T*) and the 2nd column the dimensionless elevation (η/d). Fig. 2 shows the data;
2. Lab_runup.txt: maximum runups measured in the experiments (Fig. 3).



(a)



(b)

Figure 2 Free surface profiles at various (dimensionless) time for (a) H/d=0.0185 and (b) H/d=0.3.

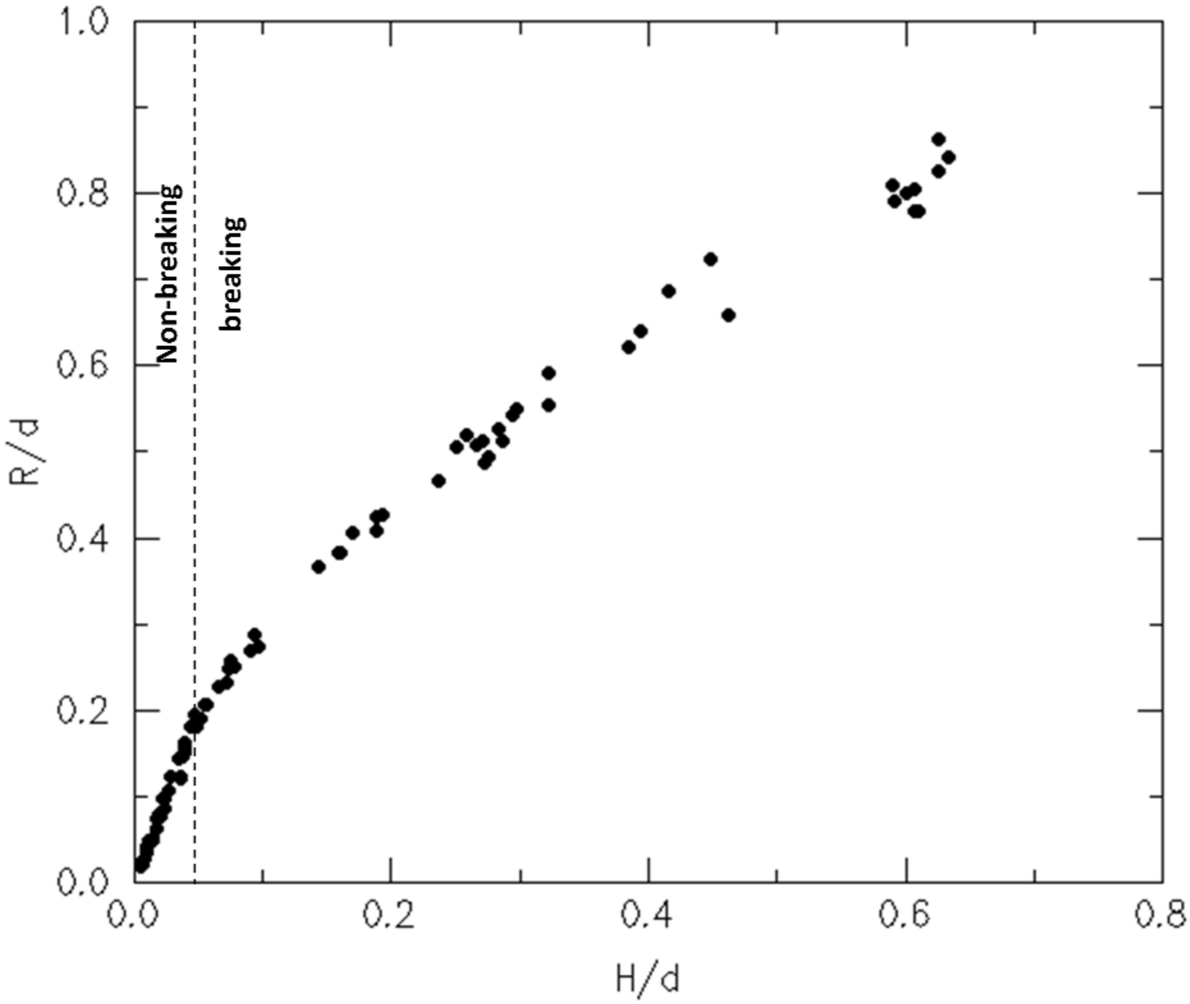


Figure 3 Maximum runups as a function of H/d from the experiments.

References

Synolakis, C.E. (1986): The Runup of Long Waves. Ph.D. Thesis, California Institute of Technology, Pasadena, California, 91125, 228 pp.

Synolakis, C.E. (1987): The runup of solitary waves. *J. Fluid Mech.*, *185*, 523-545.