Numerical simulation of wave propagation from deep waters to very shallow waters, including changes over real bottoms

Simulação numérica de propagação de ondas desde águas profundas até profundidades muito reduzidas, incluindo alterações sobre fundos reais

by ***José Simão Antunes do Carmo***

University of Coimbra, FCTUC, Department of Civil Engineering, 3030-788 Coimbra, Portugal
email: jsacarmo@dec.uc.pt

ABSTRACT

By the end of the 1970s, due to the lack of sufficiently deep knowledge, but above all for lack of computing power, the use of the linear wave theory for the simulation of phenomena, such as refraction and diffraction of waves, was common practice.

In deep water conditions and for waves of small amplitude, linear theory can produce acceptable results. In deep waters and intermediate water conditions, while $h/\lambda > 0.10$ and also for small amplitude waves, the 2nd and 3rd orders of Stokes wave theory yields sufficiently approximate results for practical applications. These approaches were also widely used at that time.

More recently, in the 1980s, other models that take into account not only the refraction but also the diffraction process have been proposed and commonly used, such as the Berkhoff's model. However, as they are based on the linear theory, those models should not be used in shallow water conditions.

Still at that time, and also in the 1990s, models based on the Saint-Venant equations were frequently used in practical applications. However, as has been widely demonstrated, in shallow water conditions and for some types of waves, models based on a non-dispersive theory are limited and are not usually able to compute satisfactory results over long periods of analysis.

Nowadays, it is generally accepted that for practical applications the combined gravity wave effects in shallow water conditions must be taken into account. In addition, the refraction and diffraction processes, as well as the swelling and reflection of waves, all have to be considered. In fact, to describe the strongly nonlinear dynamics of waves propagating through intermediate waters to the final stages of shoaling and surf zones, fully nonlinear models are required.

Accordingly, in recent decades significant advances have been made in developing mathematical and numerical models to describe the entire phenomena observed in shallow water conditions. As a consequence, there is now a wide range of shallow water wave models in the literature. These fall in certain categories, such as fully- or weakly-nonlinear, non-dispersive or weakly-dispersive, and unidirectional or bidirectional. In addition, models are either based on an *a priori* assumption of irrotationality, using a velocity potential or using the primitive velocity variables – with irrotationality sometimes as a "*hidden*" assumption.

The standard Boussinesq and Serre models are the most commonly used today for this purpose, but the equations solved by both models are weakly-dispersive and therefore restricted to shallow water conditions. Thus, an improvement of the linear dispersion characteristics in these models for applications in intermediate-depths and *quasi*-deep waters is of paramount importance. Also in this context, significant advances have been made recently in developing more powerful models.

Moreover, other phenomena will have to be taken into account for applications under real conditions. Among the main phenomena that should be considered are: (1) a bottom boundary layer generated by the contact of the water flow over a rough surface, where the flow is generally turbulent; (2) wet and dry areas, as is often the case of islands, and (3) the wave breaking process when propagating under very shallow water conditions.

All of these issues will be addressed within this seminar.