ANALYTICAL SOLUTION OF DAM BREAK WAVE WITH FLOW RESISTANCE. APPLICATION TO TSUNAMI SURGES

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Surge waves resulting from dam breaks have been responsible for numerous losses of life. Related situations include flash floods, flood runoff in ephemeral streams, debris flow surges, surging waves in the swash zone, rising tides in dry estuaries and tsunami surges on dry coastal plains. In all cases, the surge front is a shock characterised by a sudden discontinuity and extremely rapid variations of flow depth and velocity. Albeit major "concerted" actions, there has been a lack of basic theoretical and physical studies for the past 40 years. For example, current knowledge of dam break wave surging down rough surfaces remains rudimentary and there are still some arguments of the unsteady turbulent flow fundamentals. Modern predictions of dam break wave rely too often on numerical predictions, validated with limited data sets.

The present work is focused on a simple solution of the dam break wave problem using the Saint-Venant equations and the method of characteristics. Analytical solutions are developed for an instantaneous dam break with a semi-infinite reservoir in a wide rectangular channel. The dam break wave flow is analysed as a wave tip region where flow resistance is dominant, followed by an ideal-fluid flow region where inertial effects and gravity effects are dominant. The analytical results were validated by successful comparisons between several experimental data sets obtained in large-size facilities and theoretical results in terms of instantaneous free-surface profiles, wave front location and wave front celerity. The former comparison with instantaneous free-surface data is considered to be the most accurate for the estimation of the flow resistance and the best validation technique. In the second part of the paper, the analytical developments are applied to tsunami surges. The calculations are compared with observed surge data during the 26 December 2004 tsunami catastrophe. A reasonable agreement was observed in terms of surge front celerity and free-surface profile (Fig. 4). Such an approach may provide emergency services with accurate real-time predictions of tsunami flooding that may be vital in catastrophic situations.

The present development offers several advantages over existing methods. First the theoretical results for real-fluid flows yield simple explicit analytical expressions that compare well with experimental data and more advanced theoretical solutions. Second the proposed development is a simple pedagogical application of the Saint-Venant equations and method of characteristics, linking together the simple wave equations yielding RITTER's solution, with a diffusive wave equation for the wave tip region. Both the simple wave and diffusive wave equations constitute relatively simple lecture materials that may be introduced in advanced undergraduate subjects (e.g. HENDERSON 1966, CHANSON 2004). Third, these explicit analytical solutions may be used to validate numerical solutions of the method of characteristics applied to the dam break wave problem. This is important in dam break wave calculations where the wave tip is a flow singularity with zero water depth. Further most numerical models must be calibrated in terms of flow resistance. Some comparison between numerical results, analytical solutions and experimental results under controlled flow conditions may assist in the accurate selection of flow resistance coefficient. Fourth the simplicity of the equations may allow the extension of the method to non-Newtonian fluids. For example, CHANSON et al. (2004) applied successfully the mathematical treatment of HUNT (1982) to dam break wave of non-Newtonian thixotropic fluids. Relevant applications include mud flows, self-flowing concrete and debris flows in civil engineering. Fifth the development may be extended to sloping channels, within some assumptions (CHANSON 2005). Applications include wave runup on upward sloping beach faces and dam break wave on mild slope valleys.

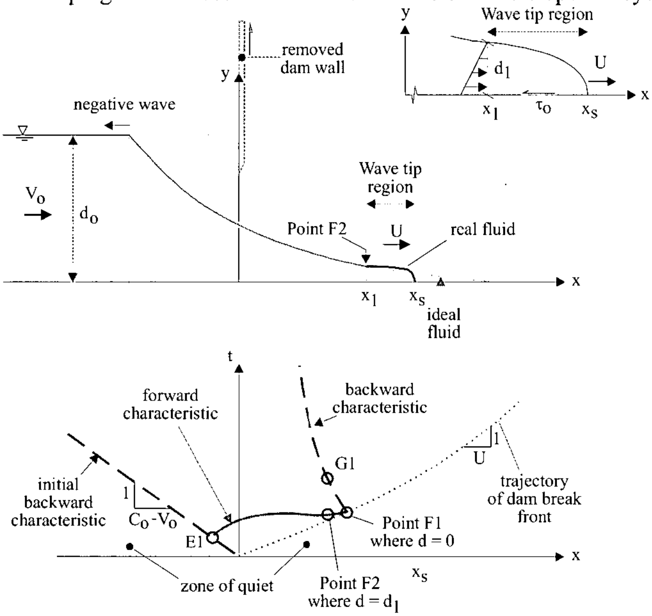

Fig. 1 Dam break wave in horizontal channel: definition sketch

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