ABSTRACT

The deformation and failure of structural elements such as beams, plates and shells under impact load are of great practical interest and have been studied extensively. The structural frameworks used in vehicles, aeroplanes, ships and other areas often collide with other objects. In such situations, strength of material beyond yield stress plays an important role in minimising the potential hazard due to impacts. Hence, strength characteristics and deformation process under such loading conditions must be studied in order to evolve proper design criteria. In the present study, the mode of deformation and propagation of plastic fronts along the length of the beams with various boundary conditions subjected to impact loadings are investigated within the context of finite element method. Newmark's time integration technique is adopted to solve the non-linear equations of motion of the impactor and the beam while von Mises yield criterion is used to identify the onset of plastic deformation. The elasto-plastic contact law as well as the Hertzian contact law are used to evaluate the contact force. Apart from the numerical simulation of the impact response of free-free beams and beams on elastic foundation, experimental investigations of impact response of clamped and partially restrained (rotation- free) propped cantilever beams are also carried out.

It is found from the numerical simulations of the free-free beams subjected to symmetrical impact loading that the interaction between faster reflected elastic waves and slower progressive waves determines the final deformed configuration of the beam. The beam subjected to mid-span impact may enter into five-hinge mechanism for short period of time. The speed of the moving plastic front is non-uniform and oscillatory and the average speed of the plastic front decreases with time. The strong and complex interaction between the plastic fronts and elastic wave dominates the beam bending behaviour in the case of two-point impact. For symmetrical two-point impact and asymmetric single point impact, beam shows the stiffest and flexible bending behaviour for impact loading at particular locations of the beam. The material strain rate has significant effect and the material strain hardening has insignificant effect on the evolution and propagation of the plastic fronts. Contact force decreases with the increase of the angle of obliquity (angle measured with respect to vertical).

In the case of beam on visco-elastic foundation, the magnitude of the contact force increases while contact period decreases with the increase of foundation parameters.

The final deformed shape of the beam gradually transforms from a wedge shape to a cylindrical shape as the foundation parameters are decreased. The evolution of plastic front is completely different from that of the free-free beam. The elastic waves have no effect in the evolution and propagation of plastic front at the impact point. However, there is no separation between the beam and the foundation due to the presence of viscous damping.

Experimental investigations are carried out with a view to evaluate the effect of membrane forces on the permanent deformation and to validate the numerical methods. Fifty-four beam specimens are tested to study these aspects. It is found that the rebound of hammer has a little effect on the permanent deformation. The variations of strain and strain rate with time are non-linear. The strain varies almost linearly in the vicinity of impact point. The membrane forces have significant effect on the maximum permanent transverse deflection when order of the deflection is more than the beam thickness. Propped cantilever beam, when subjected to mid-span impact shows linear variation of the maximum permanent deflection (W_f/h) with non-dimensional parameter λ and when subjected to quarter-span impact shows non-linear variation. The present numerical results compare well with the experimental values.