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Steel Plates Fundamentally Further Develop the Effect Obstruction of SCS Sandwich Boards

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Abstract

Background: The intensity trade tubes are polyethylene raised temperature opposition tubes (PERTs) with 20 mm external width and 2 mm thickness. The flat separating of the intensity trade tubes is 25 cm. The outside and inward warming circles had a similar design and area.

Keywords: Epilepsy; Steel.

Introduction

Steel-concrete-steel (SCS) sandwich panels have been achieving increasing attention due to its good impact resistant performance, but there still lacks related research concerning analytical model for SCS perforation. In this paper, numerical and analytical investigations were performed to study the impact resistance of SCS sandwich panels against rigid projectile penetration. FE simulations of concrete-steel perforation were conducted to validate the numerical model in terms of projectile residual velocity and damage mode. With same concrete core, five thickness combinations of front and rear steel plates were numerically studied to explore the sandwich structural effect on the perforation responses [1].

Description

Utilizing spherical cavity expansion analysis and plates petalling theory, a semi-empirical analytical model was developed to describe the perforation on SCS sandwich panels, which was characterized with 7 penetration stages. Agreement was reached between numerical simulation and theoretical model in terms of both projectile deceleration history and residual velocity [2]. On the perspective of structurally absorbed energy, the thickness combinations of front and rear steel plate were further analyzed and discussed. For the same thickness, the rear steel plate was found to consume more energy than the front plate, which provides better protection against projectile impact loadings. For sandwich wall structures, one of the most obvious advantages is less use of material for better mechanical performance [3]. Due to excellent bearing capacity, excellent impermeability and convenience of construction, the steel–concrete–steel (SCS) sandwich panels have been widely used in nuclear power plant, high-rise buildings, offshore structures and fortifications. Consisting of a concrete core connected to two steel plates, SCS sandwich panels were originally conceived during the initial design stages for the Convy River submerged tube tunnel in the UK.

In recent decades, many scholars have investigated the performance of SCS sandwich wall structures and large variety of sandwich structures have been applied in structural engineering. Furthermore, SCS sandwich panels have a good performance in resisting dynamic loadings including penetration and explosion. Under projectile impact, concrete panel usually suffers reflected tensile stress wave induced fracture owning to its brittleness. The confinement on the front and rear free surface of the concrete panel may strengthen the structure against impactive loadings. The local failure mode of SCS sandwich panels under projectile impact differs from monolithic concrete panel, because the steel plates pose a significant influence on cater forming and preventing the pulverized concrete pieces flying away.

There have been a few studies shedding some light on the mechanical performance of concrete-steel composite under dynamic conditions. Without shear connectors connecting steel faceplates and concrete core, the design concept of non-composite SCS sandwich panels were presented by Crawford and Lan to resist blast loading which provided experimental verification for the full-scale blast wall. Remennikov et al. investigated both static and impact performance of non-composite SCS panels whereas the tested panels exhibited tensile membrane resistance at large deformation [4]. came up with a three-step method for designing steel-plate concrete walls against missile impact. This method could be used to evaluate the minimum required steel plate thickness of steel plate composite (SC) walls to prevent perforation. Kim et al. conducted a preliminary study on the local impact behavior of SC walls to comprehensively investigate the dynamic characteristics of steel-concrete walls under local impact conditions. Feng et al. [dealt with the dynamic response of a double-layered target of concrete and armour steel subjected to projectile impact, implying that the spaced targets have a greater residual penetration depth than segmented targets. Conducting a series of drop hammer impact tests and axial compression tests, Zhao and Guo studied impact and post-impact behavior of steel-concrete composite panels to develop the empirical model for residual strength evaluation. It was found that the axial compressive preload could be beneficial to resist the impact loadings.

Although dynamic impact responses of SCS structures have been extensively studied through experiments, there still lacks analytical model for projectile perforation on SCS panels. The role of front and rear steel plate played on energy consumption is not clear either. The knowledge gap hinders the engineering application of such SCS sandwich structure for shelter construction. Although the perforation analysis has been developed based on energy conservation, the projectile deceleration history during perforation cannot be obtained. The analytical model of dynamic response of projectile perforation in terms of explicit form resistant force is thus needed.

Using the non-linear transient dynamic finite element solver LS-DYNA, this work adopted 3 dimensional finite element modeling to analyze SCS sandwich panels with no shear connecting steel faceplates and concrete. By keeping constant total thickness of steel plates, we examined the influence of steel plates by changing the thickness combinations of front and rear steel plates. Finally, a simple but effective semi-empirical analytical model for residual velocity prediction was put forward and validated. The results may shed

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some light on SCS sandwich structure design with better impact resistance performance [5].

Prior to numerical analysis of SCS panels, the FE model for penetration on concrete and steel targets needs to be developed and validated. experimentally investigated hard projectile perforation on the reinforced concrete (RC) panels with a rear steel liner, which is similar to the interested SCS sandwich panels. This work adopted these experiments to validate the FE numerical model for perforation of SCS sandwich panels. This paper chose to simulate the penetration tests with 300 mm thickness RC panels whereas the concrete thickness is chose to the practical shear wall. depicted the target dimension and the locations of its reinforced mesh. 4 layers of two-way square-pattern steel mesh were incorporated where 9 bars with 6 mm diameter were arranged in each direction, and concrete cover was about 15 mm in-depth. A steel plate with 1 mm thickness was welded by four stud bolts onto the rear face of the RC panel. The impact point of projectile was denoted by "×". The unconfined cylinder compressive strength of 15 cm cubic concrete specimens was 41 MPa.

For this penetration tests, the projectile did not hit the reinforcment layers. For 0.5% reinforcement mesh ratio in the investigated tests, the reinforcement mesh has little effect on the terminal ballistic parameters. After penetration, it was found that the blunted lengths and mass losses of projectiles were less than 3.3% and 2.5%, respectively. Therefore, the penetrator of 430 g including projectile and accelerator, could be regarded as rigid body suffering no deformation and erosion for the sequent simulations.

Due to the lack of detailed information of the SC composite target perforation, the imperfections of specimen geometry and boundary conditions were not considered herein. Although geometric imperfection may have some effects in structural load carrying capacity according to Ref, the projectile penetration and perforation work usually ignore such details. Hence, the ideal hard projectile normal impact on edge fixed composite targets was studied.

The widely used explicit solver LS-DYNA was adopted for the penetration simulation whereby 3D solid 164 element was selected to model projectile, concrete slab and steel liner, and element type of the steel mesh was 3D beam 161. The projectile was modelled as a rigid body described by MAT_RIGID in LS-DYNA. The Holmquist-Johnson-Cook (HJC) model which has been extensively applied for concrete penetration simulations was selected to describe the concrete material. The steel liner was modelled by Johnson-Cook (JC) model for its wide adoption in viscoplastic domain. With reference to Zhao et al., the steel mesh was described by MAT_PLASTIC_KINEMATIC. Parameters for HJC model and JC model of 1006 steel were listed in which have been verified against some available penetration tests.

According to the experimental setup, fixed boundary conditions were applied to all the upper and lower surfaces of the target. To ensure the nodes of steel mesh coinciding with concrete element nodes, the element sizes were strictly controlled where the minimum element size is 3 mm for both projectiles and concrete slab. The interactions between the projectile, concrete slab and steel liner were modelled with surface to surface eroding algorithms. A maximum principal strain at failure for concrete was set as the element erosion criteria using MAT_ADD_EROSION. The developed finite element model, including projectile, concrete, reinforcement and steel plate, for penetration test. Finally, element numbers of four parts, i.e., projectile, concrete slab, steel mesh and steel liner.

Compared numerical damage modes with post-test target photo in different views. The actual destructive mode of rear surface of the target while depicted the deformation of the steel liner which was notable that the neighbor region of the liner around the projectile deformed severer.

Discussion

For the cross-section view, showed the damage mode of the target corresponding to the three-stage perforation model which consists of front impact crater, ballistic tunnel (with almost same diameter with projectile shank), and a nearly frustum-of-cone shaped rear crater was numerically verified. In terms of destructive forms and residual velocity, the numerical model had a good consistency with concrete-steel perforation tests, ensuring the feasibility of the sequent penetration modeling of SCS sandwich panels.

Conflict of Interest

None.

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