BLAST LOAD ANALYSIS OF CONCRETE-STEEL COMPOSITE BRIDGES: FOCUS ON SHEAR CONNECTORS OF SLAB-BEAM INTERSECTIONS

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 07/01/2026

The above candidate has carried out research for the Master's thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. P. L. N. Fernando

Signature of the Supervisor: Date: 09/01/2026

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ABSTRACT

In the present context, increasing attention is being paid to the structural response of infrastructure under blast loading, with bridges recognized as particularly vulnerable due to their exposed locations and essential role in transportation networks, economic stability and emergency operations. This research focuses on concrete-steel composite bridges, which are widely used in urban and highway networks, yet lack explicit blast resistance provisions in current Eurocode 4 design standards. Unlike previous studies that have mainly examined the effects of blast loads on individual components such as slabs, girders, and piers, this study addresses the blast response at the critical slab–beam intersection locations particularly susceptible to localized failure during explosive events. A representative concrete-steel composite bridge, designed according to Eurocode guidelines, was selected as the basis for a detailed numerical investigation. A detailed numerical framework was developed using LS-DYNA with CONWEP blast loading and verified through a three-stage validation process involving a reinforced concrete slab, a steel girder, and the slab–beam interaction mechanism. Building on the validated modeling approach, a progressive blast analysis was performed, beginning with isolated slab and girder models, followed by a combined slab–girder system without shear connectors and a full composite model with shear connectors to simulate realistic composite action. Key results demonstrate that the inclusion of shear connectors significantly improves blast resistance by enabling effective load transfer, reducing localized damage at the slab–beam interface, and promoting controlled redistribution of blast energy across the composite system. A comprehensive parametric study was conducted by varying explosive charge mass, standoff distance, and stud row spacing to evaluate how these parameters influence the blast response of the bridge and to highlight the effectiveness of current Eurocode design standards. The blast analysis results were compared with key Eurocode design resistance values, including mid-span cross-section shear, stud connector shear, and longitudinal interface shear. While several scenarios remained safely within Eurocode limits, localized exceedances were observed under extreme explosive loading combined with wider stud spacing, particularly at blast-proximal locations. These findings confirm the reliability of current Eurocode provisions for moderate blast scenarios while highlighting the need for optimized connector layouts and explicit blast-resistance considerations to enhance the resilience of composite bridge slab–beam intersections under severe explosive events.

Keywords: Blast loading, Concrete-steel composite bridge, Slab-beam intersection, Stud shear connectors, Eurocode

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LIST OF ABBREVIATIONS

Abbreviation	Description
AASHTO	American Association of State Highway and Transportation Officials
ANFO	Ammonium Nitrate Fuel Oil
ASCE	American Society of Civil Engineers
CEN	European Committee for Standardization
CONWEP	Conventional Weapons Effects Program
CSCM	Continuous Surface Cap Model
ELFORM	Element Formulation
FEA	Finite Element Analysis
FEM	Finite Element Modeling
FEMA	Federal Emergency Management Agency
GTD	Global Terrorism Database
KCC	Karagozian and Case Concrete
LBE	LOAD_BLAST_ENHANCED
LSTC	Livermore Software Technology Corporation
PNA	Plastic Neural Axis
RC	Reinforced Concrete
SCC	Steel-Concrete Composite
SPC	Single Point Constraint
TNT	Trinitrotoluene
UFC	Unified Facilities Criteria
ULS	Ultimate Limit State