International Journal of Solids and Structures 000 (2016) 1–16

Contents lists available at ScienceDirect

International Journal of Solids and Structures

journal homepage: www.elsevier.com/locate/ijsolstr

Stability analysis of three-layer shear deformable partial composite columns

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ARTICLE INFO

Article history:
Received 3 August 2016
Revised 26 October 2016
Available online xxx

Keywords:
Critical buckling load
Imperfect bonding
Interlayer slip
Partial interaction
Composite column
Shear deformation

ABSTRACT

This paper is focused on the effect of imperfect bonding and partial composite interaction between the sub-elements of a box-type column on the critical buckling loads. The box column is modelled as a symmetric three-layer composite structure with interlayer slips at the interfaces, based on the Engesser–Timoshenko theory with uniform shear deformation assumptions. Linear shear springs or slip modulus is considered at the interfaces to model the partial interaction between the sub-elements of the structure. The minimum total potential energy principle is utilized to obtain governing equations and boundary conditions. A direct analytical solution of the original governing equations is presented for obtaining exact buckling characteristic equation of the three-layer partial composite column with different end conditions including clamped-pinned end conditions. Also, the coupled equations are recast into an efficient uncoupled form and shown that there is a strong similarity with those for the two layer element. It is shown that the obtained formulae are converted to the known Euler column formulae when the slip modulus approaches infinity (i.e. perfect bonding) and no shear deformations in the sub-elements are considered. A differential shear Engesser–Timoshenko partial composite model is also employed and critical buckling loads, obtained from an inverse solution method, are compared to examine the validity and accuracy level of the uniform shear model. Comprehensive dimensionless numerical results are presented and discussed.

1. Introduction

Timber structural systems are increasingly used in multi-storey buildings. A Scandinavian glued-laminated (glulam) manufacturer, Moelven Töreboda AB, has developed a prefabricated beam and post system named “Trä8”, especially for the market of non-residential timber buildings. The system is based on rectangular modules, with maximum spans of 8 *m* (hence the name Trä8 = timber8), which offers flexibility, variety and simplicity of building design. The system is standardised and optimised, which reduces the average design time for the individual project (Girhammar and Atashipour, 2015).

The stabilising wall element of the Trä8 system is a box-type composite structure comprising of frame members of glulam and sheathing of laminated veneer lumber (LVL) (with the commercial name Kerto), Fig. 1. The framing of this wood-based panel element consists of three vertical members and short horizontal members (noggins) placed at the bottom and top of the element, i.e. at the level of each floor. The sheathing is glued and/or screwed to the framing members. The empty spaces between the frame members are filled with soft insulating material, e.g. mineral wool (usually, their mechanical stiffness values are negligible) (Girhammar and Atashipour, 2015). The length of the element, which is continuous, is dependent on the height of the designed building.

The buckling of the stabilising wall element can be considered as one of the possible failure modes of this structural element. Apparently, the part of the wall element at the ground floor is usually most critical. The stabilising element can buckle in the weak direction between the floors (or foundation) and the element is considered simply supported at each floor level (or foundation). In the strong direction, the element is considered as a cantilever. Here we will only analyse the case when the axial load is applied at the top of the element independent of the number of storeys. The case when the axial load is applied as a discrete load at each storey (or distributed along the height of the building) will be treated in another paper. So for these two cases, results will be presented in detail. However, in this study we will also generalize the problem

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http://dx.doi.org/10.1016/j.ijsolstr.2016.11.018
0020-7683/

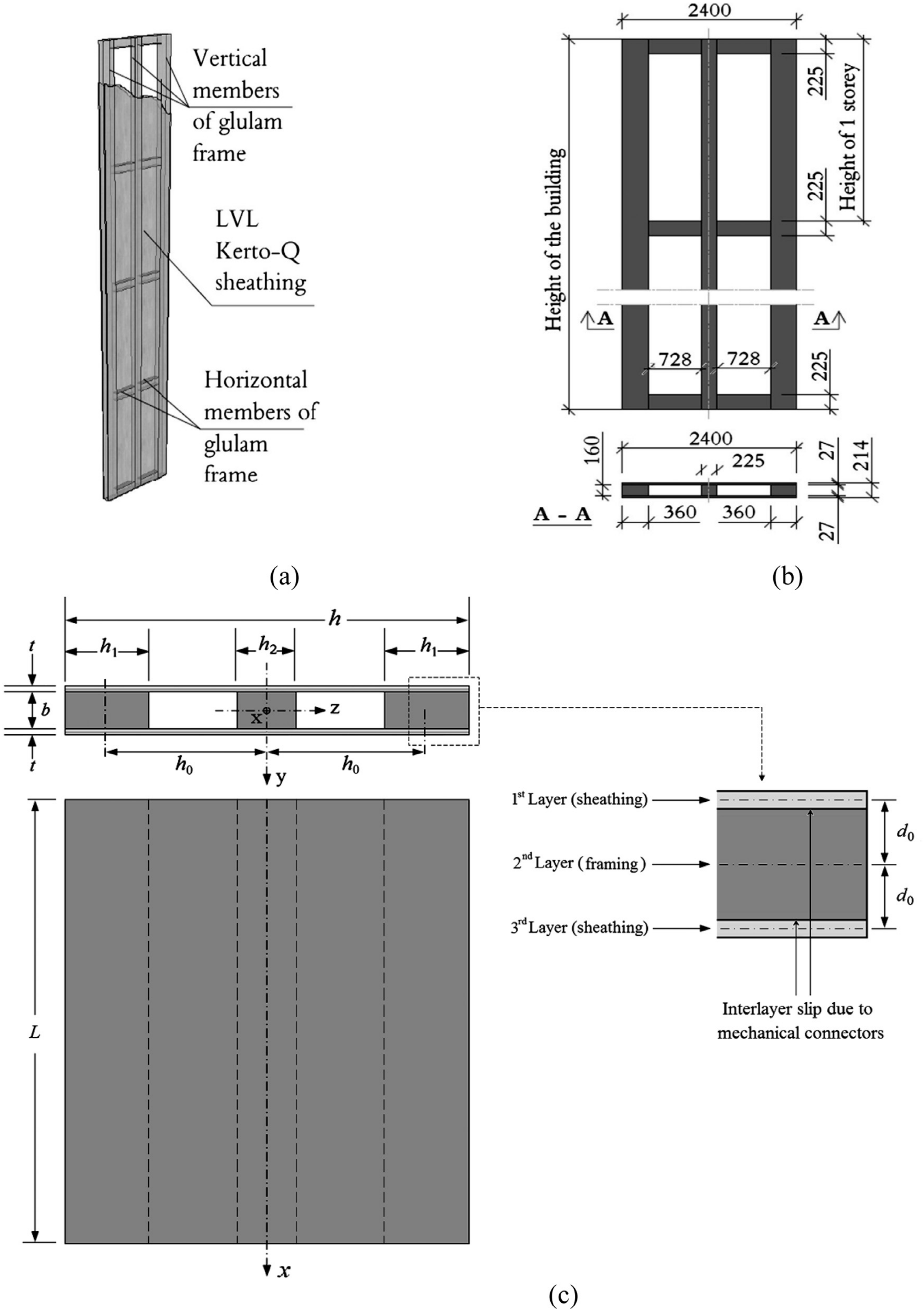

Fig. 1. Geometrical configuration and cross-section of the Trä8 symmetrical composite stabilising wall element: (a) basic element in a multi-storey building (here shown as a four-storey building); (b) dimensions of the stabilising element; and (c) partial composite action model in the weak direction with possible slip due to mechanical connectors and notations for the cross-section.