Alexandria Engineering Journal (2014) 53, 95–105

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

A new strain based brick element for plate bending

L. Belounar [a,1], K. Guerraiche [b,*]

[a] Civil Engineering Department, University of Biskra, BP 145, Biskra 07000, Algeria
[b] Mechanical Engineering Department, University of Biskra, BP 145, Biskra 07000, Algeria

Received 31 July 2013; revised 13 October 2013; accepted 21 October 2013
Available online 18 November 2013

KEYWORDS

Brick element;
Strain approach;
Plate bending;
Transverse shear;
Static condensation

Abstract This paper presents the development of a new three-dimensional brick finite element by the use of the strain based approach for the linear analysis of plate bending. The developed element has the three essential external degrees of freedom (*U*, *V* and *W*) at each of the eight corner nodes as well as at the centroidal node. The displacement field of the developed element is based on assumed functions for the various strains satisfying the compatibility equations and the static condensation technique is used for the internal node. The performance of this element is evaluated on several problems related to thick and thin plate bending in linear analysis. The obtained results show the good performances and accuracy of the present element.

1. Introduction

Great attention has been oriented to the plate elements based on the Reissner/Mindlin theory [1,2] which takes into account the shear effect. Other research works have been given to the three-dimensional elements [3,4], for the thick plates in bending. However, these elements tend to cause undesirable shear locking phenomena when dealing with thin plates. By using higher order elements, these locking phenomena are reduced but the computational effort becomes larger. Most of the attempts to alleviate this problem have resorted to the use of techniques based on reduced integration [5]. Other formulations have been established to develop robust three-dimensional elements [6–16], which allow preventing shear locking when dealing with thin structures.

As an alternative for displacement models, the strain based approach has been used to develop robust elements. The first elements developed are curved elements [17,18] then extended to plane elasticity [19–21], three-dimensional elasticity elements [22] and Reissner/Mindlin plate elements [23]. As the continuation of developing strain based elements, many attempts were made by other researchers [24–29]. The formulation of the finite elements based on the strain approach is that in this approach we start interpolating the strains that allow having better accuracy on stresses, strains and displacements [17–29]. There are two essential components to any displacement field. The first component relates to rigid body modes of displacements and the second component is due to the straining of the element. The strain based approach

* Corresponding author. Tel./fax: +213 772 80 61 43.
E-mail addresses: belounarl@yahoo.com (L. Belounar), guer.khelifa@yahoo.com (K. Guerraiche).
[1] Tel./fax: +213 666 25 61 45.
Peer review under responsibility of Faculty of Engineering, Alexandria University.

Production and hosting by Elsevier

1110-0168 © 2013 Production and hosting by Elsevier B.V. on behalf of Faculty of Engineering, Alexandria University.
http://dx.doi.org/10.1016/j.aej.2013.10.004

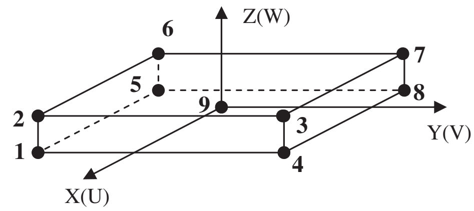

Figure 1 Brick element with *U*, *V*, and *W* degrees of freedom at each of the nine nodes.

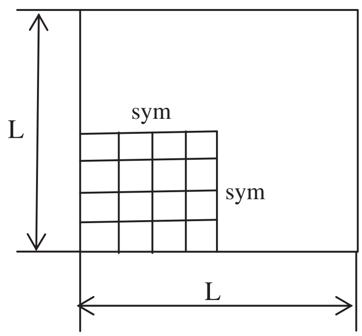

Figure 2 Square plate bending with various conditions ($E = 10.92$, $v = 0.3$ and the shear factor $k = 5/6$).

provides many advantages which are as follows: easy satisfaction of the convergence criteria, independent functions for the various components of strain insofar as it is allowed by the compatibility equations and enrichment of the displacement field by higher order terms without introducing non-essential degrees of freedom. The displacement field is obtained by integrating the strains.

In this paper a new brick finite element based on the strain approach and with a modified elasticity matrix [22,6,30,15] is presented for the linear analysis of either thin or thick plate bending. This new element named SBB (Strain Based Brick) possesses eight corner nodes as well as the centroidal node with the three essential external degrees of freedom (*U*, *V* and *W*) at each node. In developing the present element the static condensation technique [20,29,31] is used and the in-plane bending strains (ε_x, ε_y and γ_{xy}) have been enriched with terms in x and y that produce further improvement in the convergence of the results. This element is examined and compared with other elements through a deep numerical evaluation which confirms the good performance of the strain based approach.

2. Theoretical considerations

The strain components and the compatibility equations for the three-dimensional linear analyses are respectively given by the following:

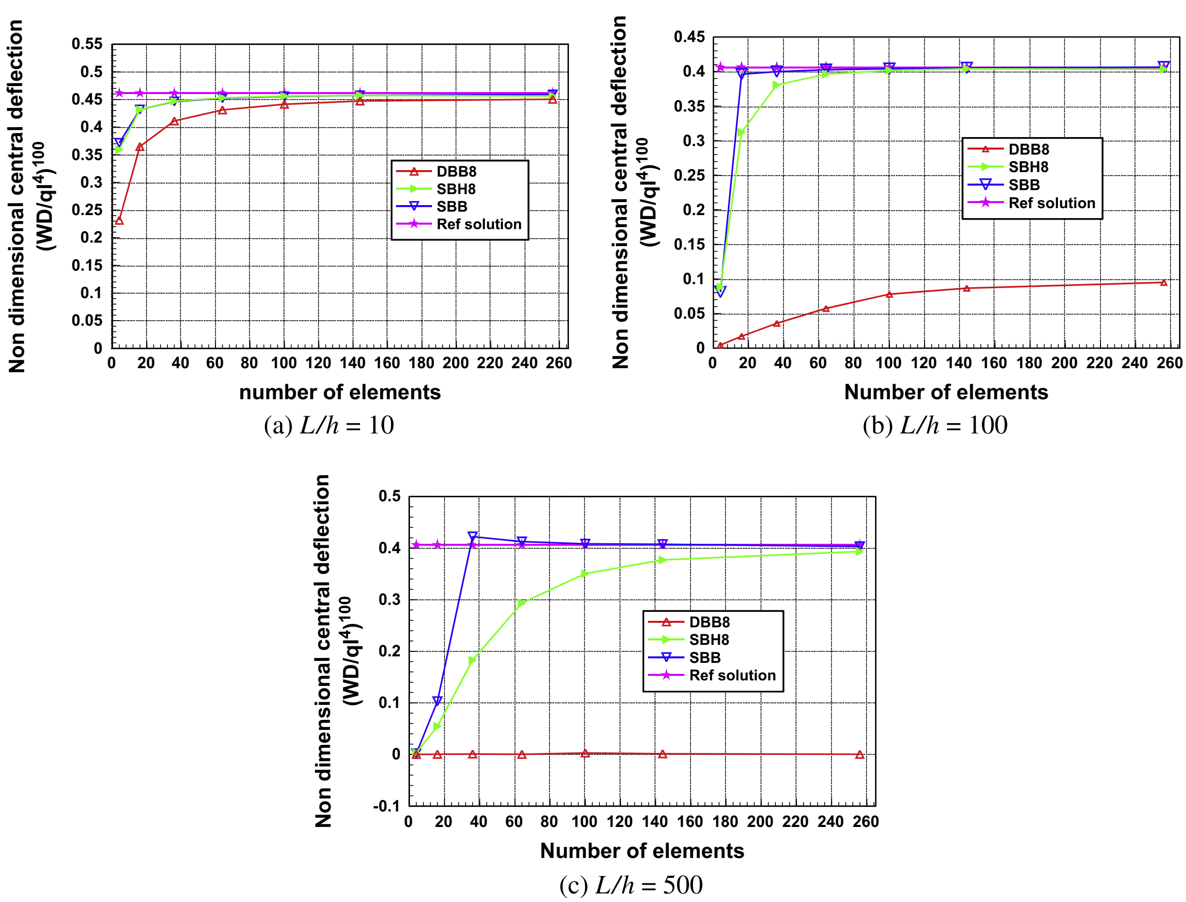

Figure 3 Non-dimensional central deflection of a simply supported plate with a uniform load ($(WD/ql^4) \times 100$).