Advances in civil engineering and sustainable Architecture

ACESA, Vol. 1, No. 1, March 2018, 3–4 publication.petra.ac.id/index.php/ACESA

Extended Abstract

Development of the Q4-CNS for Reissner-Mindlin Plate Bending

Richo M. Soetanto[1], Foek Tjong Wong[2] and Januar Budiman[3]

[1] Student
Petra Christian University
Surabaya 60236 Indonesia
Richoms034@gmail.com

[2] Assistant Professor
Petra Christian University
Surabaya 60236 Indonesia
wftjong@petra.ac.id

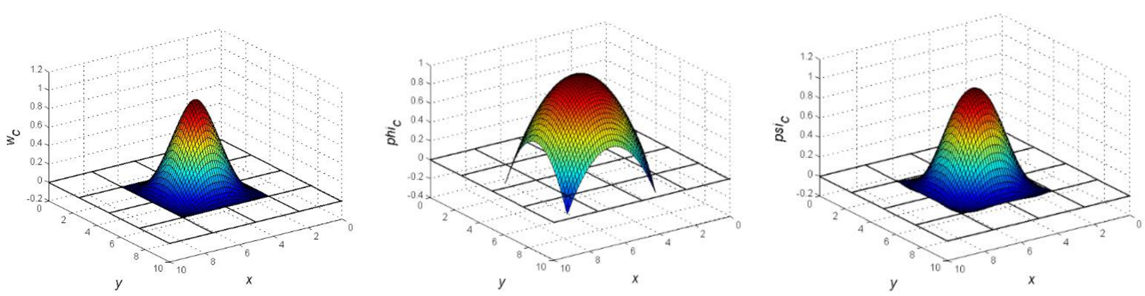
[3] Assistant Professor
Petra Christian University
Surabaya 60236 Indonesia
januar@petra.ac.id

Keywords: *Q4-CNS, finite element method, Reissner-Mindlin plate, shear locking, discrete shear gap.*

The four-node quadrilateral element with continuous nodal stress (Q4-CNS) can be regarded as a combination between the finite element and mesh-free methods based on the concept of partition of unity [1]. This combination can overcome the drawbacks of both the finite element and mesh-free methods. The mesh-free shape functions used in the Q4-CNS are a combination of the constrained orthonormalized least square (CO-LS) approximations and the non-conforming finite element shape function based on the four-node Kirchhoff rectangular plate element. The formulation of the Q4-CNS shape functions can be expressed as

$$\boldsymbol{\chi} = \mathbf{w}\,\boldsymbol{\Phi} \tag{1}$$

where $\mathbf{w}$ is the 1×4 matrix of the non-conforming shape functions, $\boldsymbol{\Phi}$ is the $4 \times n$ matrix of the CO-LS shape functions, n is the number of supporting nodes, and $\boldsymbol{\chi}$ is the $1 \times n$ matrix of the Q4-CNS shape functions. The examples of the shape functions are shown in Fig. 1.



(a) (b) (c)

Figure 1. Examples of (a) non-conforming shape function, (b) CO-LS shape function, and (c) Q4-CNS shape function

In the original paper [1], the Q4-CNS element has been developed and applied to the plane stress problem. It has several advantages as follows: (1) passes patch test (2) has a high convergence rate, (3) has continuous nodal stress at the nodes. In the present research, the Q4-CNS element is developed for analysis of Reissner-Mindlin plates. To eliminate the effect of shear locking, which is the main difficulty in developing Reissner-Mindlin plate elements, the discrete shear gap (DSG) technique is utilized. The Q4-CNS element for the analysis of Reissner-Mindlin plates is implemented using Matlab program.

Several plate bending benchmark problems are tested to assess the accuracy and convergence rate of the developed element compared to other methods. A benchmark problem for testing the element is a rhombic plate with the length-to-thickness ratio L/h=1000 (Fig. 2). The resulting normalized displacement and máximum moment are shown in Fig. 3 together with those obtained using other methods. The results show that the Q4-CNS Reissner-Mindlin plate element gives more accurate results for both the displacement and moment. The results also show that the Q4-CNS has good convergence characteristic.

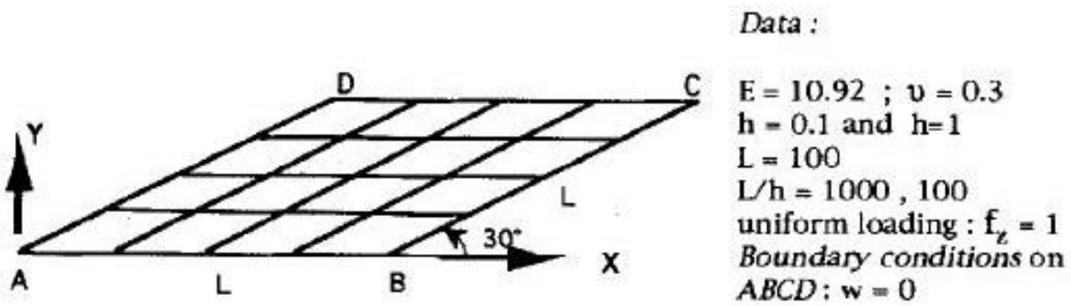
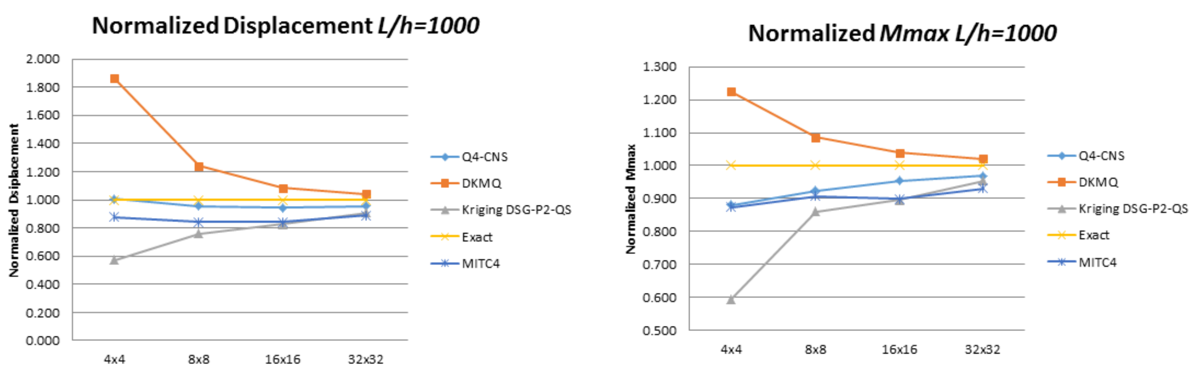


Figure 2. Dimension and properties of rhombic plate. Source : Katili [2]



(a) (b)

Figure 3. The normalized displacement and máximum moment

The Q4-CNS element has been developed to analyze Reissner-Mindlin plate bending. The characteristics of the Q4-CNS element are free from shear locking after using the DSG method, have high accuracy, high convergence rates, continuous moment contours, and have better resistant to distorted meshes than the plate bending element in SAP 2000v14. Furthermore, the Q4-CNS can be extended to analyze other 2D problems such as shells and folded plates

References

[1] Tang, X.H., Zheng, C., Wu, S.C., and Zhang, J.H., "A Novel Four-Node Quadrilateral Element with Continuous Nodal Stress", *Applied Mathematics and Mechanics* (*English Edition*), Springer, Vol. 30, 2009, pp. 1519–1532.

[2] Katili, I., "A New Discrete Kirchhoff-Mindlin Element Based on Mindlin-Reissner Plate Theory and Assumed Shear Strain Fields-Part II: An Extended DKQ Element for Thick-Plate Bending Analysis". *International Journal for Numerical Methods in Engineering*, Wiley, Vol. 36, 1993, pp. 1885-1908.