

RECENT ELEMENT DEVELOPMENTS

by

RICHARD H. MACNEAL

PRESENTED AT

MSC/NASTRAN USERS CONFERENCE

MARCH 1989

LOS ANGELES, CALIFORNIA

RECENT ELEMENT DEVELOPMENTS

**RICHARD H. MACNEAL
CHAIRMAN
THE MACNEAL-SCHWENDLER CORPORATION**

ABSTRACT

Recent developments with regard to the MSC/NASTRAN elements include a new four-noded membrane element, which is delivered with Version 66, and a companion three-node membrane element which is in the breadboard testing phase. In addition, the entire 2D and 3D element library is under review with an eye toward the elimination of such design deficiencies as locking and failure to pass the patch test by the incorporation of recent theoretical advances.

The paper summarizes these recent advances and indicates how they have been applied to the design of the QUAD4R and TRIA3R membrane elements. Test results are presented which show the improvement in accuracy of the new elements over the older QUAD4 and TRIA3 elements.

RECENT ELEMENT DEVELOPMENTS

- **QUAD4R IN VERSION 66**
- **TRIA3R IN BREADBOARD TESTING**
- **ENTIRE LIBRARY OF 2D AND 3D ELEMENTS UNDER REVIEW**

STATUS OF 2D ELEMENTS

ELEMENT	LOADING	DATE OF LAST MAJOR DESIGN MOD.	DESIGN FLAWS
TRIA3	MEMBRANE BENDING	1967 1976	TOO STIFF O.K.
QUAD4	MEMBRANE BENDING	1973 1978	LOCKING O.K.
TRIA6	---	1980	LOCKING, FAILS PATCH TEST
QUAD8	---	1980	LOCKING, FAILS PATCH TEST

STATUS OF 3D ELEMENTS

ELEMENT	DATE OF LAST MAJOR DESIGN MOD.	DESIGN FLAWS
HEXA(8)	1982	LOCKING
HEXA(20)	1976	LOCKING
TETRA(4)	1970	TOO STIFF
TETRA(10)	1986	O.K.
PENTA(6)	1976	TOO STIFF
PENTA(15)	1976	TOO STIFF?

RECENT ELEMENT RESEARCH HAS EMPHASIZED

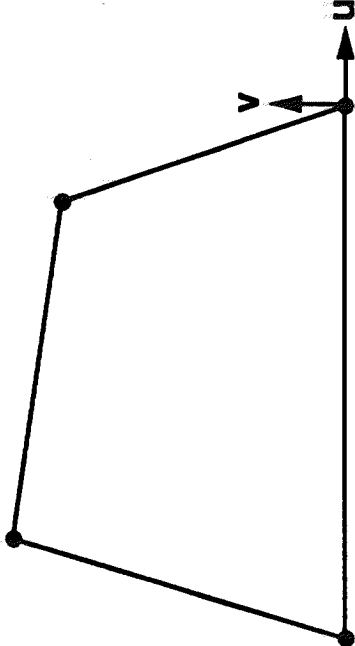
- **THE PREVENTION OF LOCKING**
- **PASSING THE PATCH TEST**

SPECIFIC AREAS OF RESEARCH AT MSC

- **BUBBLE FUNCTIONS TO ELIMINATE LOCKING**
- **LEAST SQUARES FITTING AS A SUBSTITUTE FOR
SELECTIVE REDUCED-ORDER INTEGRATION**
- **DRILLING FREEDOMS**

QUAD4 CASE HISTORY

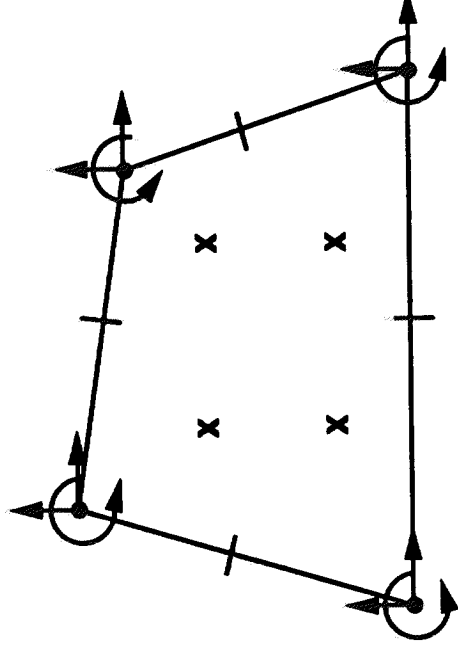
- THE ELUSIVE 4-NODE MEMBRANE ELEMENT THAT:
 - PASSES THE PATCH TEST
 - HAS NO SPURIOUS MECHANISMS
 - DOESN'T LOCK FOR ARBITRARY SHAPE



- WE FINALLY PROVED IT WAS IMPOSSIBLE WITHOUT ADDITIONAL EXTERNAL DEGREES OF FREEDOM.

QUAD4 CASE HISTORY

THIS DISCOVERY LED US TO CONSIDER THE FOUR NODE QUAD WITH DRILLING FREEDOMS.



- INTERNALLY, THE ELEMENT IS AN EIGHT-NODE QUAD.
- EDGE NODE TRANSLATIONS RIGIDLY INTERPOLATED FROM CORNER NODE TRANSLATIONS AND ROTATIONS.

PERFORMANCE OF THE QUAD4R

- **COMPLETE LINEAR STRAIN FIELD**
- **PASSES THE PATCH TEST**
- **DOESN'T LOCK**

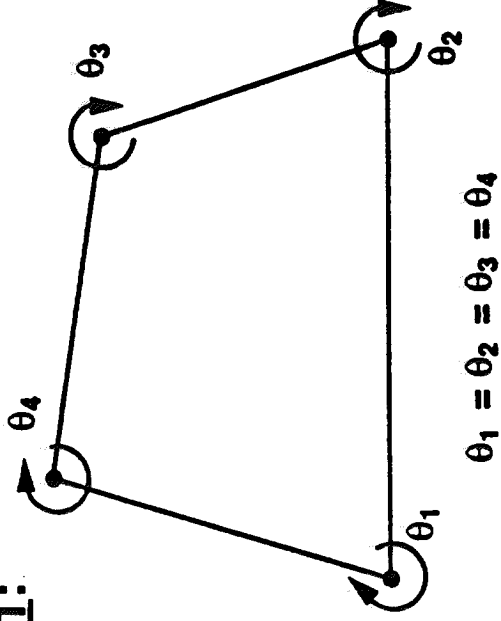
QUAD4R REFINEMENTS

- LEAST SQUARES FITTING
- BUBBLE FUNCTIONS
- SPURIOUS MODE SUPPRESSION

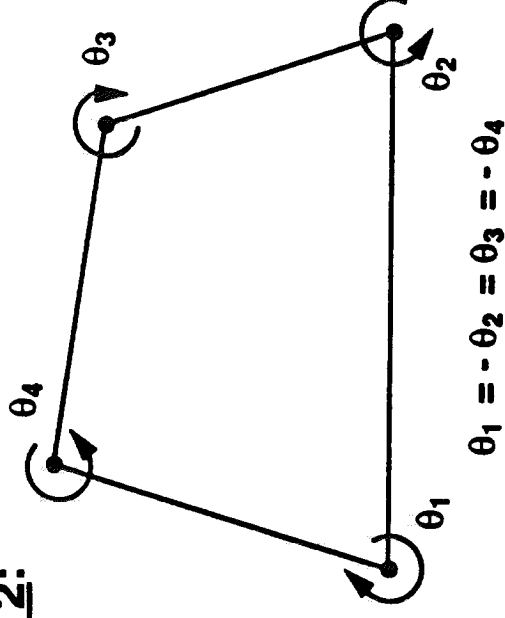
REFERENCE: MacNeal, R.H., and Harder, R.L., "A Refined Four-Noded Membrane Element with Rotational Degrees of Freedom," Computers and Structures, Vol. 28, No. 1, pp 75-84, 1988.

THE QUAD4R HAS TWO SPURIOUS MODES

MODE 1:



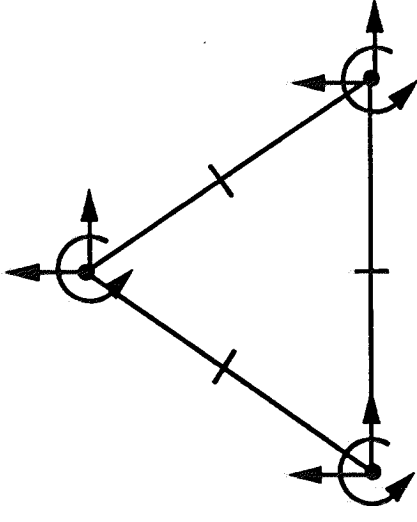
MODE 2:



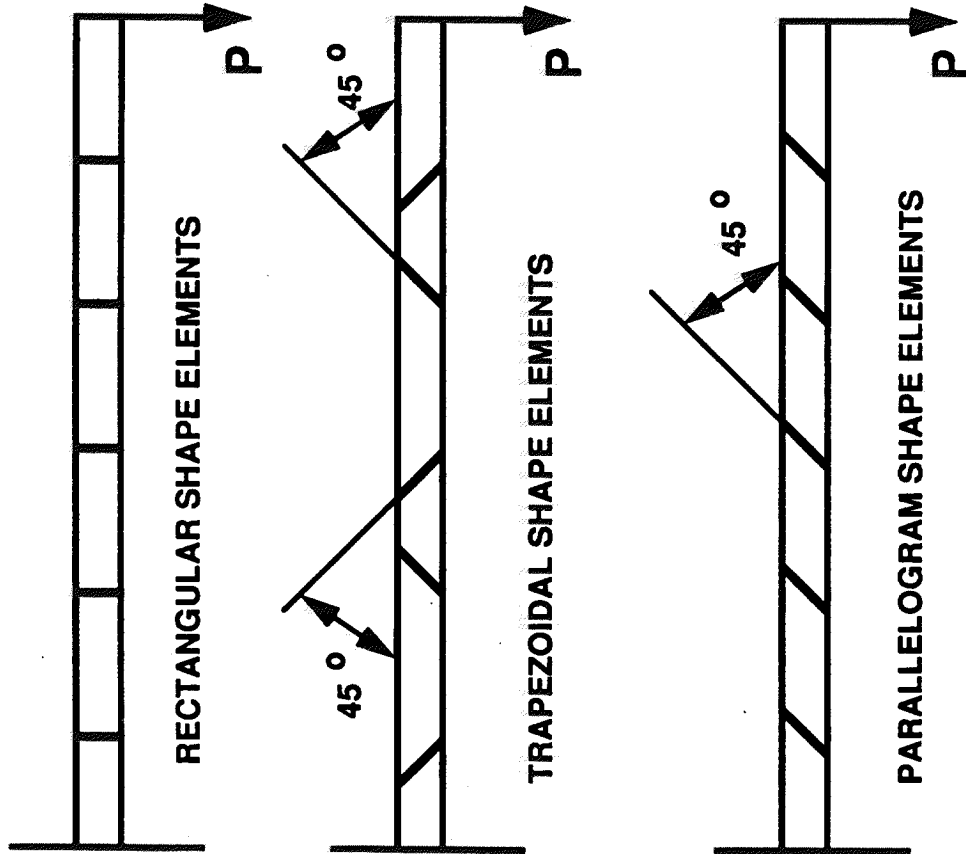
- SPURIOUS MODE SUPPRESSION IS SUPPLIED BY PENALTY STIFFNESS.
- THE DEFAULT PENALTY STIFFNESS IS VERY SMALL.
- THE PHYSICAL SIGNIFICANCE OF THE ROTATIONS IS SUSPECT.

THE TRIA3R

- COMPANION TO THE QUAD4R
- HAS ONE (SUPPRESSED) SPURIOUS MODE
- PERFORMANCE MUCH BETTER THAN THE TRIA3, BUT NOT AS GOOD AS THE (OLD) QUAD4



CANTILEVER BEAM TEST



ELEMENT NAME	RECTANGULAR ELEMENTS	TRAPEZOIDAL ELEMENTS	PARALLELOGRAM ELEMENTS
QUAD4	.904	.071	.080
QUAD8	.987	.946	.995
QUAD4R	.993	.954	.973
TRIA3	.032	.015	.022
TRIA3R	.554	.276	.374
EXACT	1.000	1.000	1.000

PERFORMANCE ON THE MACNEAL-HARDER TEST PROBLEMS

TEST	ELEMENT SHAPE	ELEMENT			
		QUAD4	QUAD4R	TRIA3 TRIA3R	
PATCH TEST	--	A	A	A	
STRAIGHT BEAM, EXTENSION	ALL	A	A	A	
STRAIGHT BEAM, BENDING	REGULAR	B	A	D	
STRAIGHT BEAM, BENDING	IRREGULAR	F	F	F	
CURVED BEAM	--	C+	A	D	
TWISTED BEAM	--	A	A	B	
SCORDELIS-LO ROOF	--	B	B	B+	
HEMISPHERICAL SHELL	--	A	(B)	(F+)	
THICK-WALLED CYL. ($\nu=.4999$)	--	F	A	C	
NO. OF FAILED TESTS (C'S & D'S)		2	0	3	
GRADE ERROR	A <2%	B <10%	C <20%	D <50%	F > 50%

WHAT'S NEXT?

- **LOWEST ORDER SOLIDS WITH CORNER ROTATIONS**
- **BETTER 20-NODE BRICK (NO ROTATIONS)**
- **BETTER CURVED SHELL ELEMENTS (QUAD8 AND TRIA6 REPLACEMENTS)**