iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: VII Month of publication: July 2021

DOI: https://doi.org/10.22214/ijraset.2021.36799

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

Evaluation of Stress Intensity Factor of Cracked Plates

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Abstract: Structures are subjected to undesirable changes in their structural properties mainly due to errors in design and construction, heavy loads, fatigue or other degradation. Plate structures are highly sensitive to the formation of cracks and its growth which adversely affects its performance. Notches, induced or self occurring defects, holes acts as stress concentration zone which initiates the crack formation. Knowledge about the severity of cracks is important to predict the component's life. According to linear elastic fracture mechanics, a key parameter in determining the crack severity is stress intensity factor. Years ago , high factor of safety was chosen to account for unforeseen factors. Development of fracture mechanics enables a designer to use a lower factor of safety, thereby reducing structural components cost. The components weight is also reduced and their reliability is thus enhanced. In this work, experimental and analytical determination of combination of stress intensity factors for rectangular plates with inclined through crack subjected to uniaxial load at failure is found out.
Keywords: Stress concentration zone, stress intensity factor, factor of safety

I. INTRODUCTION

Cracks are obvious in any structures. Specially, plates are highly prone to crack. But all cracks are not dangerous. It depends upon the potency of a crack. There are various methods describing the potency of a crack. This includes displacement related approach such as Crack Tip Opening Displacement (CTOD) or stress related approach in which stress intensity factor is a key parameter.

II. STRESS INTENSITY FACTOR

The stress intensity factor predicts the state of stress near the crack tip caused by a remote load or residual stresses. It is denoted by K. For inclined cracks,

$$KI = \sigma (\sqrt{\pi}a) \sin^2\beta \ f(a/w) \quad (1.1)$$

$$KII= \sigma(\sqrt{\pi}a)\sin\beta\cos\beta \ f(a/w) \quad (1.2)$$

Where ,
σ= applied stress,
β= angle between vertical and crack
a = half crack length

III.EXPERIMENTAL STUDY

Experimental study was conducted to determine the stress intensity factor of brittle material. Ceramic tile was chosen as brittle material. The size of specimens for tile were 250mm x 60mm x 8mm with an inclined through crack of 20mm size with various inclination angle. The specimens were tested in Universal testing machine having a capacity of 400 kN for tension test. The following figures shows the brittle specimens with cracks in various inclinations, load displacement graph and the cracked specimens.

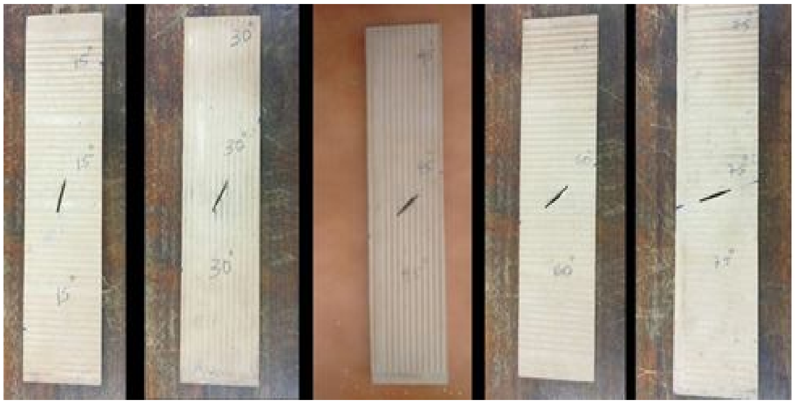

Fig. 1 Brittle specimens with various crack inclination angle

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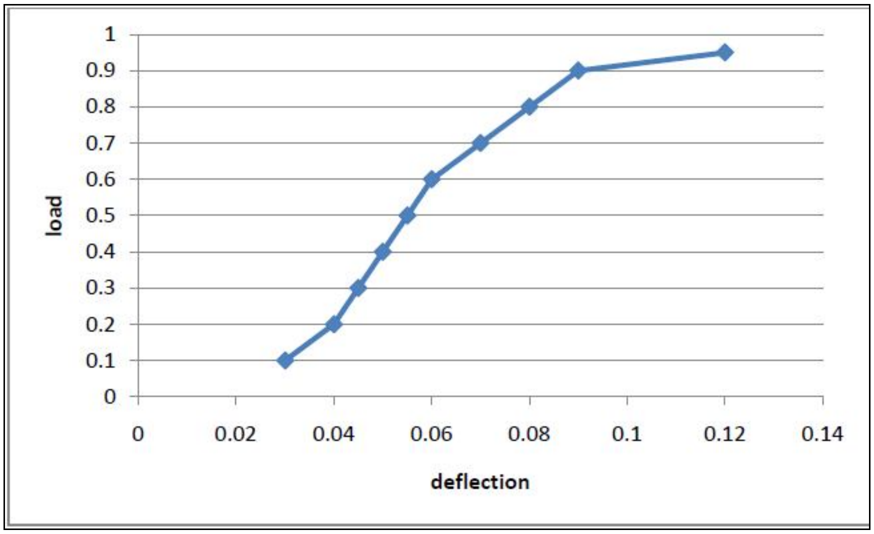

Fig. 2 Load displacement graph of brittle Specimen

Fig. 3 Cracked brittle specimens with various inclination angle

IV. EXPERIMENTAL RESULTS FOR BRITTLE MATERIAL

Ultimate tensile stress and stress intensity factor of brittle specimen are tabulated as follows.

TABLE I
ULTIMATE TENSILE STRESS OF TILE

β	Ultimate tensile load (KN)	Ultimate tensile stress (KN/mm^2)
15	1.8	3.75
30	1.3	2.7
45	0.95	1.97
60	0.85	1.77
75	0.72	1.5

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TABLE III
SIF OF TILE

β	KI / f(a/w)	KII / f(a/w)
15	1.407	5.25
30	3.78	6.55
45	5.52	5.52
60	7.44	4.295
75	7.84	2.1

V. FINITE ELEMENT ANALYSIS OF BRITTLE MATERIAL

An analytical study was done to determine the stress intensity factor for brittle material. Ansys Workbench 15.0 software package was used for the modeling, analysis and post processing of crack. Modeling of cracked plate was done using ANSYS design modeler. Cracks were developed by using Fracture tab available in the model window. The specimens were loaded using appropriate boundary conditions. The value for SIF was obtained by using Fracture tool. Five rectangular plates with crack of varying inclinations were used for the analysis. The following figures represent the cracked model, meshed crack model, loading diagram and results.

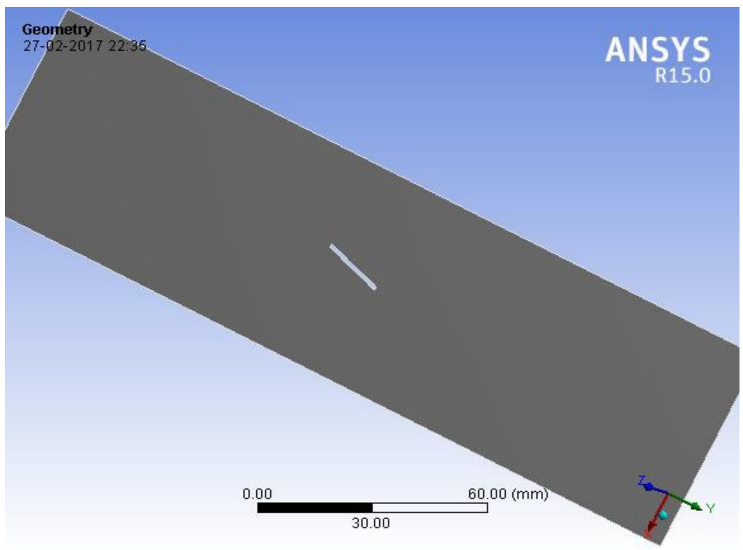

Fig. 4 Tile with 15degree inclined crack

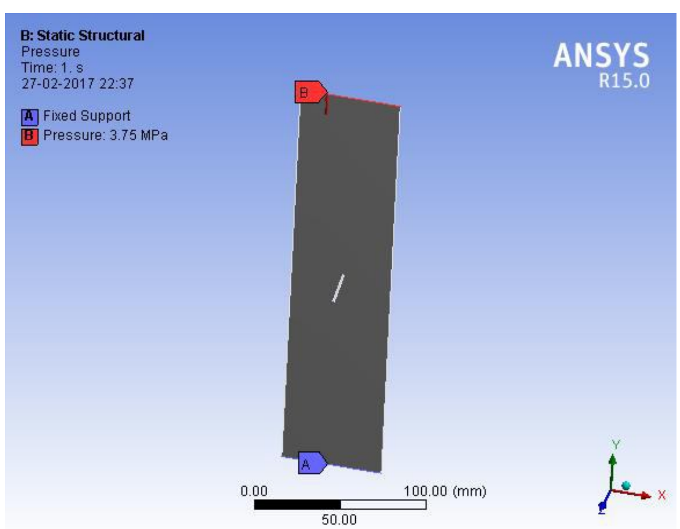

Fig. 5Boundary and loading condition for tile with 15 degree inclined crack

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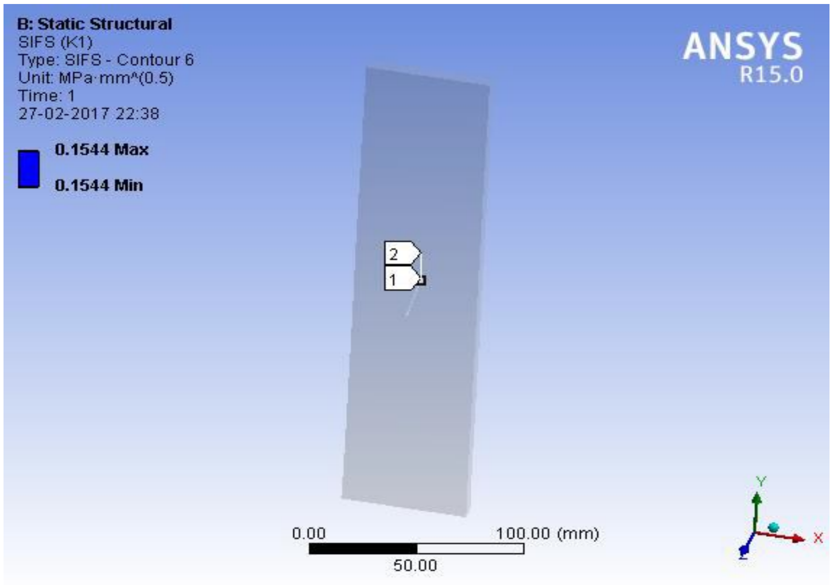

Fig. 6 K1 for tile with 15 degree inclined crack

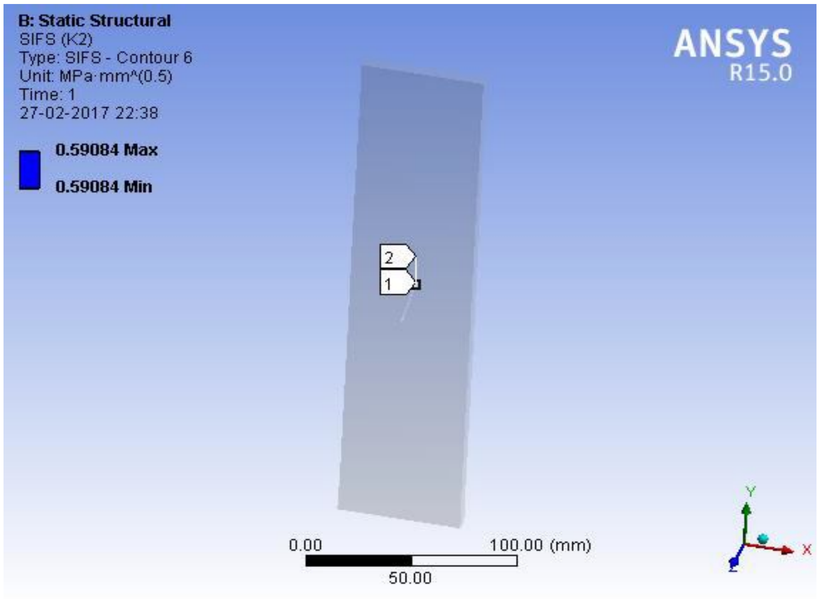

Fig. 7K2 for tile with 15 degree inclined crack

VI. ANALYTICAL RESULTS FOR BRITTLE MATERIAL

Stress intensity factor of brittle specimen are tabulated as follows.

TABLE IIIII

SIF OF TILE

β	KI / f(a/w)	KII / f(a/w)	f(a/w)
15	0.1544	0.590	0.11
30	1.0146	1.7577	0.26
45	1.88	1.8682	0.34
60	3.1442	1.7905	0.42
75	3.8665	1.0306	0.49

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VII. GRAPHICAL RESULT

The combination of KI and KII of brittle specimen at which failure occurred was plotted and the equation at failure was obtained.

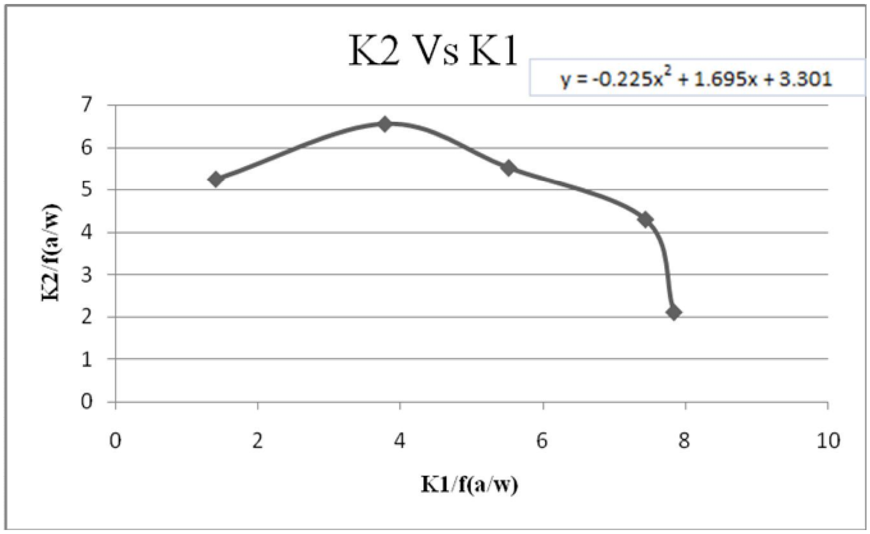

Fig. 8 KII Vs KI for brittle material

VIII. CONCLUSIONS

The factors which affect stress intensity factor are applied stress, crack length and a dimensionless parameter. Stress intensity factor for mode I and mode II were obtained analytically for various crack inclination angles and values for f(a/w) were obtained by comparing with experimental results. Also, it was observed that with increase in crack inclination angle, KI increases whereas KII increases upto 45 degree and then decreases. Further, the combination of KI and KII at which failure occurs was plotted and an equation was obtained for the failure combination.

IX. ACKNOWLEDGMENT

The Author wish to express their special gratitude to Dr E M S Nair, Professor, SCMS School of Engineering & Technology, Ernakulam, Mr Abyin Ampadiyil, MD,SNIT Adoor, Ms Riyana M S, HoD and Assistant Professor, SNIT Adoor.

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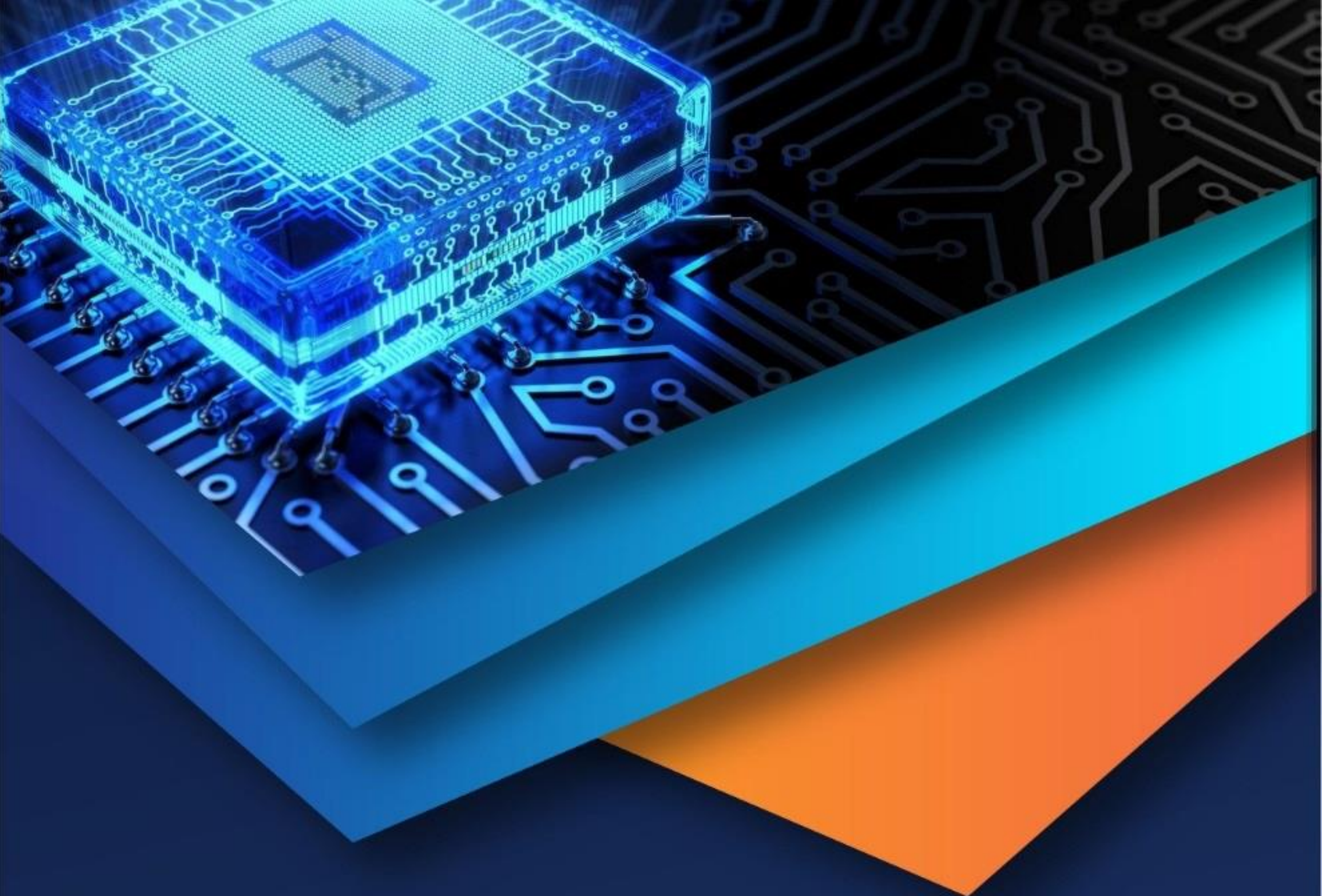

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