Optimum Strength of Screwed Joint in Structural Applications using Finite Element Method

Nunwong P.

Computational Materials Processing and Engineering Research Group (CMERG)
Department of Teacher Training in Mechanical Engineering, Faculty of Technical Education,
King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Yanil S.

Computational Materials Processing and Engineering Research Group (CMERG)
Department of Teacher Training in Mechanical Engineering, Faculty of Technical Education,
King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Abstract

Recently, great effects are undertaken to enhance the strength of structural constructions using the screw joint. Most of screw threads are produced by rolling process. The screwed joint for civil engineering consists of two elements (thread bar and coupler). The aim of this project was to assembly and reinforcement of building structure, etc. Strength optimization of screwed joints was studied by commercial FEA software (ANSYS) and compare with the experimental results. Standard tensile test specimens of screwed joint were used. Depends on failure of the coupler of the optimum-strength criterion can be reduced the dimensions (diameter and pitch size) of the thread bar to obtain the equivalent stress in above both elements. The optimum design was performed by fewer dimensions of coupler and had including influence to failure of the thread bar.

***Keywords**: Optimum design, Strength of materials, Finite element analysis, Screwed joint, Structural construction*

1 Introduction

A screw joint is a device used to connect two or more components in mechanical and civil engineering [1]. The screwed joint for civil engineering consists of two elements (thread bar and coupler). This part aimed to reinforcement of concrete structure, etc. Most thread bar is produced by rolling, having the cutting of continuous spiral grooving onto a cylindrical surface [2]. The design of screwed joint in reinforced concrete structure is of continuing interest to structural engineering because of the implication of dimensions (outside diameter and pitch size) on structural performance. The optimum design can be reduced the cost of the device. In term of optimum design of engineering components, the simulation technique was computed by commercial FEA software [3,4]. This work, we need to find a suitable dimension of a screw joints via the use of the FEA.

2 Experimental Procedure

2.1 *Sample Preparation*

The mild steel (JIS SS400) was selected as the thread bar (Deformed steel bar: DB) according to TIS 24-2548 (classes 1-3) grades are shown in table 1 and then was selected the steel bar (JIS S45C) for the coupler. The dimensions of the coupler, the quality grades are given in tables 2-3. The mechanical properties of the deformed bar as shown in table 5.

2.2 *Finite Element Analysis*

Finite element analysis (FEA) is widely used for simulating the behaviour of materials under different loading conditions and the affects of mechanical and thermal properties [3,4].

The optimum strength of screwed joint, was computed by commercial FEA software, ANSYS and compare with the tensile test, ultimate tensile strength of standard size of screwed joint was applied. For each simulation, the model was prepared using Lagrange & Penalty contact algorithm [4]. The contact property was assumed, which generates the friction (see table 5) by CONTA 172 surface to surface contact. The PLANE 82 solid element was used for load step. The axisymmetric problem was carried out for this analysis. The mechanical properties of deformed bar and coupler as shown in table 4. The flowchart for an optimum designed by optimum-strength criterion is shown in figure 1.

Table 1: The mechanical properties of the deformed bar

Quality Grades	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
SD 30	480	259	17
SD 40	560	390	15
SD 50	620	490	13

Table 2: The dimensions of the coupler as pitch size of 2.5 mm

Nominal Size (mm)	Length (mm)	Diameter (mm)
DB32	70	47 , 48 , 49
DB28	62	36 , 37 , 38 , 39 , 40 , 41
DB25	58	36 , 37 , 38 , 39
DB20	50	26 , 27 , 28 , 29 , 30
DB16	46	22 , 23 , 24 , 25

Table 3: The dimensions of the coupler as pitch size of 3 mm

Nominal Size (mm)	Length (mm)	Diameter (mm)
DB32	70	44 , 45 , 46 , 47 , 48 , 49
DB28	62	38 , 39 , 40 , 41
DB25	58	37 , 38 , 39
DB20	50	28 , 29 , 30, 31
DB16	46	25 , 26 , 27

Table 4: The pull forces at a break from the tensile test

Nominal Size (mm)	Pull Forces (N)
DB32	464,562.4
DB28	348,107.9
DB25	245,681.6
DB20	161,855.2
DB16	103,907.5

Table 5: The mechanical properties of deformed bar and coupler

Materials	Young's modulus (GPa)	Poisson's ratio	Coefficient of friction
SS400	200	0.3	0.15
S45C	206		

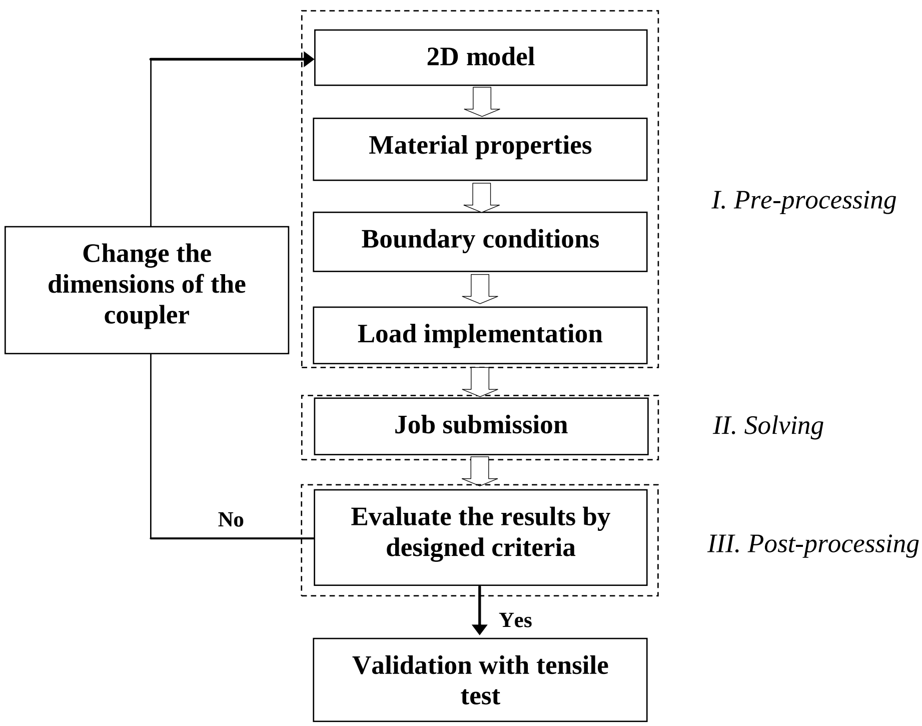

Figure 1: Optimum-strength procedure

The FEA simulation processes consist of three main phases according to pre-processing, solving and post-processing, respectively. The first process is to prepare the FEA analysis. It includes CAD 2D model or constructs the geometry with ANSYS and meshing the model (right element type). Then, applying the loading and boundary conditions and defining the material properties.

The solving step involves numerical computation of the governing equations for all of them elements. The post- processing process of FEA, when solving process was succeeded, the behavior of the materials of interest could be displayed e.g. contour plot, vector plot, etc. The FEA cans show such as stress, strain, displacement, etc. The final process is to decide the best design from criterion of optimal strength of materials.

The criterion of the design depends on failure of the coupler via the use of FEA. This led to the reduction of the dimensions (outside diameter and pitch size) of the deformed bar to obtain the equivalent stress in both coupler and deformed bar. The optimum design was performed by fewer dimensions of coupler, including having influence to failure of the deformed bar. The screwed joints of metric unit of pitch size as 2.5 and 3 mm were modeled. The outside diameters and the length of the coupler were modeled as shown in tables 2-3, respectively. The length of the thread of the deformed bar is identical to the length of the coupler. The applied forces and mechanical properties were conducted for FEA as shown in tables 4-5. The tighten length of screwed joint was established as 70 % and 100% of coupler length.

3 Result and Discussions

3.1 *FEA results and validation*

By considering the need to optimize the strength of the screwed joint. The suitable values of diameter and the length of the coupler are focused in order to reduce the dimensions of the coupler. In this work, the FEA was performed, and the results were compared to the test results according to ASTM A615/A615M-09b [5]. In order to study the optimal-strength design of the coupler, the FEA results are some shown in figures 2- 9. The levels of the stresses were described from the shades of color. Blue represents minimum level of the von Mises stress. Red is the maximum level. The suitable screwed joint was presumed from less dimensions of the coupler that can maintain the strength of material more than the thread bar.

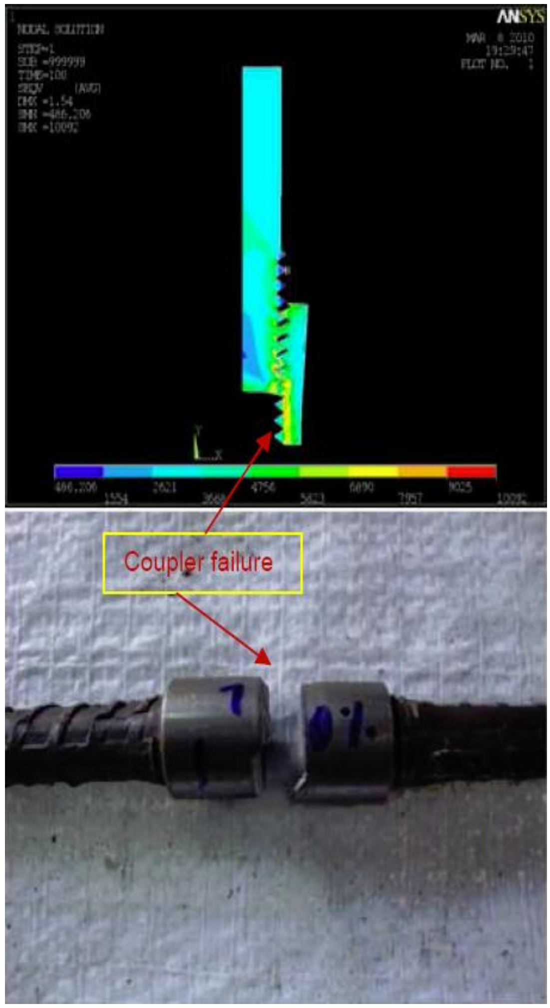

Figure 2: Breaking stress of DB16x2.5 with coupler diameter of 25 mm (Tighten length of 70%).

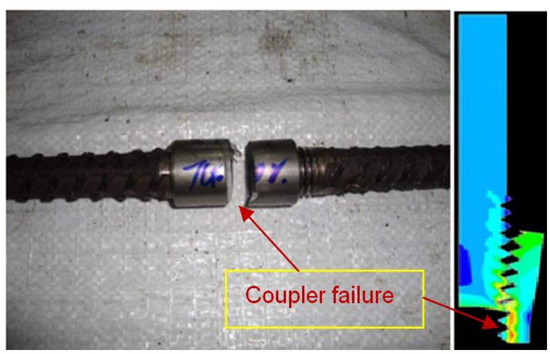

Figure 3: Breaking stress of DB16x3 with coupler diameter of 30 mm (Tighten length of 70%).

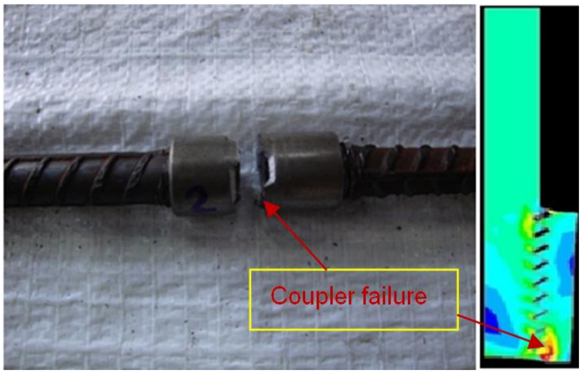

Figure 4: Breaking stress of DB16x2.5 with coupler diameter of 30 mm (Tighten length of 100%).

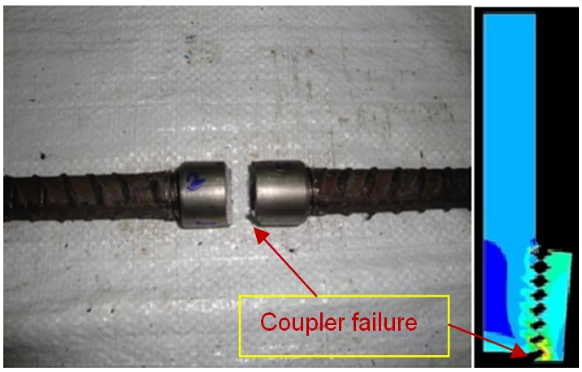

Figure 5: Breaking stress of DB20x3 with coupler diameter of 30 mm (Tighten length of 100%).

Figure 6: Breaking stress of DB20x2.5 with coupler diameter of 30 mm (Tighten length of 70%).

Figure 7: Breaking stress of DB25x3 with coupler diameter of 38 mm (Tighten length of 100%).

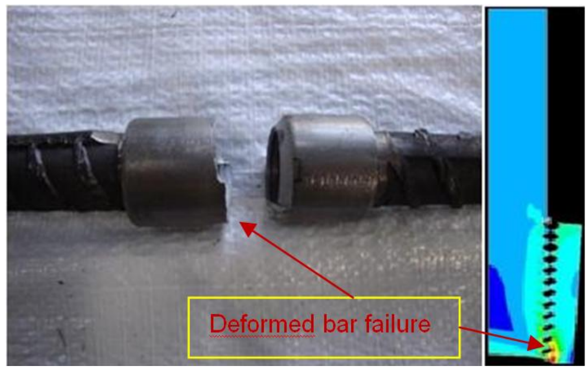

Figure 8: Breaking stress of DB28x2.5 with coupler diameter of 40 mm(Tighten length of 100%).

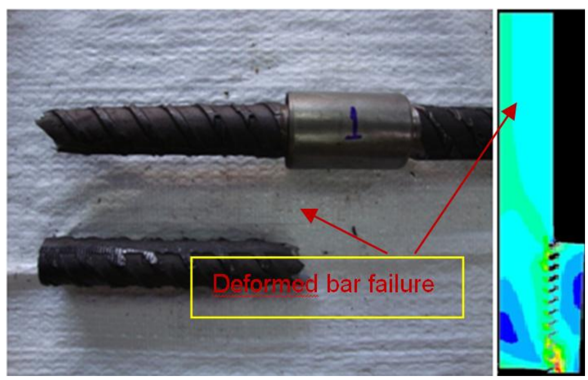

Figure 9: Breaking stress of DB32x3 with coupler diameter of 48 mm (Tighten length of 100%).

The suitable design was performed from less outside diameter and pitch size of the coupler. These can keep the strength of material more than the deformed steel bar. For this analysis, the outside diameter and the pitch size of the coupler, namely DB20x2.5Px30 Dia. of coupler (Tighten length of 70%), DB25x2.5Px40Dia. of coupler (Tighten length of 100%), DB25x3Px38Dia. of coupler (Tighten length of 100%), DB32x3Px48Dia. of coupler (Tighten length of 100%), respectively were optimized.

A FEA contact analysis was used to predict a breaking stress. It was found that the high stress was great enough to cause damage of the screw joints. The breaking stress level was also found to depends on the dimensions and the tighten length of coupler. Sample work pieces in this work are shown in figures 2-9. However, it is very difficult to measure the contact stress in experiment. The part failure can be predicted only at FEA results.

4 Conclusions

The breaking stresses were observed during the pulling of screwed joint specimens via the use of FEA. The FEA contact analysis was used in conjunction with a test experiment to determine the deformation of the coupler element. The results can be concluded as followed:

- The failure of the deformed bar is dependent on the dimensions and the tighten length of coupler.
- The prediction of breaking stress of screwed joint can be obtained by FEA contact analysis.

Acknowledgments

Financial support from the department of teacher training in mechanical engineering, Faculty of technical education, is deeply appreciated. The authors would also like to thank the department of mechanical engineering, KMUTNB for ANSYS software.

References

[1] Chen F.W. and Liu M.E., 2006. *Principles of Structural Design, CRC Press*, Boca Raton, FL.

[2] Khurmi R.S. and Gupta J.K., 2005. *Textbook of Machine Design*, Chand (S) & Co Ltd, India.

[3] Moaveni S., 2008 *Finite Element Analysis: Theory and Application with ANSYS*, 3rd ed., Pearson Education, Inc. Upper Saddle River, NJ.

[4] Zahavi E., 1992. *The Finite Element Method in Machine Design*, Prentice-Hall Inc, Englewood Cliffs, NJ.

[5] ASTM A615/A615M-09b, 2009. *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*, American Society for Testing and Materials Standards. Philadelphia.