โครงถักเหล็กสามมิติจากเศษเหล็กข้ออ้อยเพื่อใช้เป็นคานถ่ายแรง

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บทคัดย่อ

คานถ่ายแรงตามมาตรฐานวิธีการทดสอบโครงสร้างต่าง ๆ เช่น การทดสอบความแข็งแรงแรงดัดของคอนกรีตตามมาตรฐาน ASTM โดยทั่วไปแล้วผลิตจากเหล็กรูปพรรณ Wide flange ซึ่งมีน้ำหนักมากและราคาแพง ขณะที่เศษเหล็กข้ออ้อยจากการทดสอบการรับแรงดึงจำนวนมากยังสามารถรับแรงได้แม้ท่อนที่ถูกดึงจนยืดตัวเกินจุดคราก จึงนำเศษเหล็กข้ออ้อยนี้มาประดิษฐ์เป็นโครงถักสามมิติขึ้นเพื่อใช้ทดแทนคานที่ผลิตจากเหล็ก Wide flange โดยโครงถักที่ประดิษฐ์มีขนาด 0.2x0.3x1.0 เมตรและ 0.2x0.3x1.5 เมตรจากการวิเคราะห์และทดสอบโครงถักสามมิติที่ประดิษฐ์ขึ้นนี้พบว่า สามารถถ่ายแรงกระทำที่กึ่งกลางช่วงขนาด 10 ตันและ 15 ตันได้โดยการแอ่นตัวเกิดขึ้นเพียงเล็กน้อยโดยมีขนาด 0.53 มิลลิเมตรและ 0.97 มิลลิเมตรตามลำดับซึ่งอยู่ในเกณฑ์กำหนดการใช้งานในช่วง 1.7-2.5 มิลลิเมตร (L/600) และไม่พบว่าเกิดการแตกร้าวของรอยเชื่อมหรือ เกิดการโก่งตัวของชิ้นส่วนของโครงถัก จึงสามารถนำโครงถักนี้ไปใช้ในการถ่ายแรงเพื่อการทดสอบโครงสร้างอื่นตามมาตรฐานการทดสอบนั้น

คำสำคัญ: ความแข็งแรงแรงดัด โครงถักสามมิติ เศษเหล็ก แรงดึง แรงอัด

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Built-up 3D Trusses from Scrap Bars Used as Transfer Beams

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Abstract

The transfer beam used in structural testing such as ASTM method of testing for flexural strength of concrete using simple beam with third-point loading are generally built-up from structural steel using wide flange shapes which are generally expensive and heavy. There are a lot of scrap bars left over from the tensile test and these bars virtually can be used to resist load even through they are tested until yielding occurs. Alternative transfer beams built-up from scrap deformed bars of diameter 25 millimeters were made in the form of 3D trusses with sizes of 0.2x0.3x1.0 meters and 0.2x0.3x1.5 meters. Each truss was analyzed and tested under a single point load of 10 tons and 15 tons with the corresponding deflections at mid-span of 0.53 millimeters and 0.97 millimeters respectively. The testing results showed that both trusses performed elastically. The maximum deflections were within the required limit of 1.7-2.5 millimeters (L/600) . Cracking or failure of welds and buckling of truss members did not occur. Both trusses can be used as transfer beams.

Keywords: 3D Trusses, Scrap Bars, Compressive Forces, Tensile Forces

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1. Introduction

In the tensile test of steel bars there are a lot of scrap of the tested bars which have the length of 30-50 centimeters and these tested bars are usually got rid of by selling as scrap and are not used for other purposes.

Theoretically, mechanical properties of general mild steel under tension in the form of stress-strain curves are shown in figure 1. Herein, it is assumed that the behavior of the tested steel bar under compression is similar to that tested under tension. It shows that the bar behaves elastically and linearly before yielding at point 2. After that it elongates without increasing loading until the strain hardening begins to occur at point3. Further loading, the load gradually increases and reaches the maximum load at point 7. After that the load gradually decreases until breaking occurs. Before yielding, if the load is released the bar returns elastically to its original position. After yielding, when the load is released, the bar partly returns and the permanent set occurs. The size of the permanent deformation depends on the point of load releasing. After yielding, when the bar is reloaded, the stress-strain curves of the reloading (3-4, 5-6) are virtually parallel to that of the initial loading (1-2). At point 4 and point 6, in fact, have some effects of plastic deformation known as Bauschinger effect causing slight deviation of the curve from the linearly elastic curve. However, for further loading the bar can still sustain the load at least equal to the yield load. From this behavior, it reveals that the bar tested until breaking occurs can still be used to sustain loading. Each portion of the broken bar may retain the residual stress, however, it is assumed that this stress is small and ignored in this study. Roughly, it can be expected that each portion of the broken bar can be used to sustain loading more or less equal to the yielding load which large deformations may occur and the tested bar in the form of 3D truss may cause large deformation but each member can still sustain load. Hence 3D trusses from scrap bars may be used as load resisting beams with allowable deformation. So scrap bars can eventually be reused.

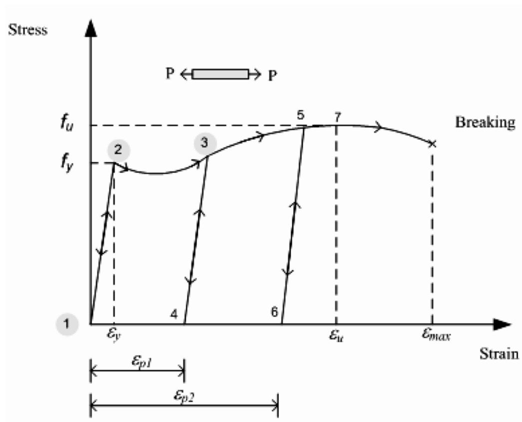


Figure 1 Typical stress-strain curves of mild steel

In structural testing, the transfer beam is placed between the hydraulic jack and the specimen [1] as shown in figure 2. The beam can transfer the load from the hydraulic jack to the specimen through supporting points 1 and 2. Practically, this transfer beam should be small size but it should be stronger than the specimen and ideally, the rigid beam behavior is preferable. In general laboratory, this beam is built-up from wide flange shape stiffened by steel plates and such the beam is expensive and heavy difficult in handling. Alternative transfer beams built-up from scrap bars were studied so that lighter beams and cheaper beams may be achieved. The lengths of any studied specimens are varied and the suitable lengths of transfer beams are varied accordingly. Transfer beams with the length of 1.0 meter and

1.5 meters may be suitably used for three point loading with the specimen length of 3.0-6.0 meters. So, the built up 3D trusses with the length 1.0 meter and 1.5 meters were built-up.

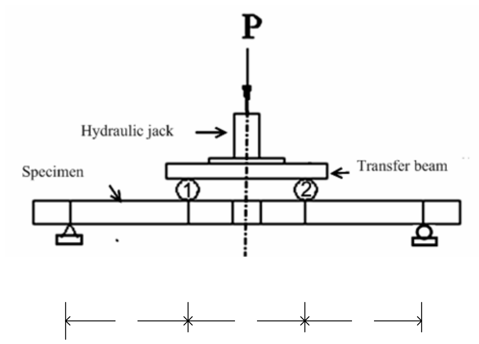


Figure 2 Typical test set-up of structural testing

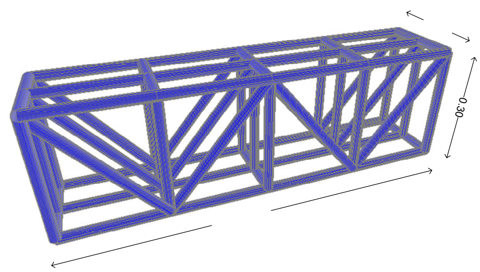
2. Objectives

This paper presents the results of analysis , design and test of the 3D trusses built-up from scrap bars.

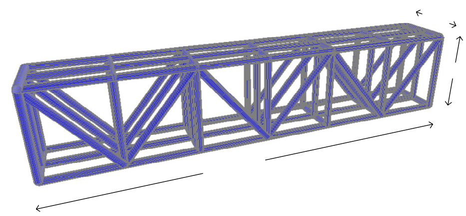
3. 3D Trusses

3.1 Sizes of 3D Trusses

Practically, the truss should be small sizes to ease manual handling but it must be strong to resist the load about 5-6 tons which are the loading ranges for moderate sizes of tested specimens. The maximum deflection of the truss at the ultimate load of tested specimens should be small so that the truss behaves as a rigid beam in load transferring mechanism. In this study the criterion for deflection control is arbitrarily specified for small deflections and the ranges of less than L/500-L/600 were preferable where L is the span length of the truss. In preliminary study, various configurations of space trusses were modeled analyzed and designed and it found that under the same sizes compared between the complex member arrangement trusses and the simple ones, there were no significant advantages in load resisting capacity.The configuration shown in figure 3 were selected to ease the making and to minimize numbers of truss members to be welded at the same joint. These two trusses were built-up from the scrap bars with the diameter of 25 millimeters and with the dimensions as shown. Each truss member was connected by electrical welding.



(a) 1.0 m truss



(b) 1.5 m truss

Figure 3 Dimensions of 3D trusses

3.2 Analysis and Design of 3D Trusses

3.2.1 Analysis models of the 3D trusses

The built-up frames are to be loaded at joints and assumed to behave as space trusses which flexural capacity of each member is small and ignored. The two trusses were analyzed under elastic realm using commercial software, SAP2000 [2]. Each member of the trusses was modeled by using the frame element which has six degree of freedoms (DOF) at each end. These DOF are the translations in three orthogonal directions and three rotations about each axis (figure 4). Connections between these members were assumed to be hinged. The support at each member end was a hinge and a roller (figure 5) and three single loads were at mid-span.

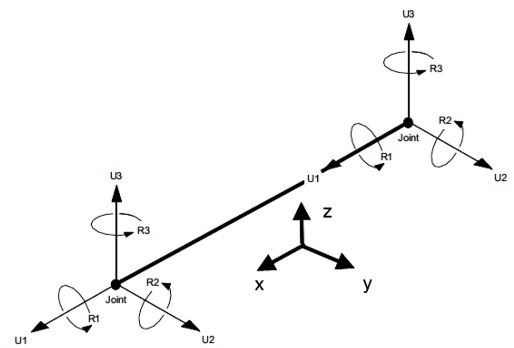


Figure 4 Frame element with six DOF at each end

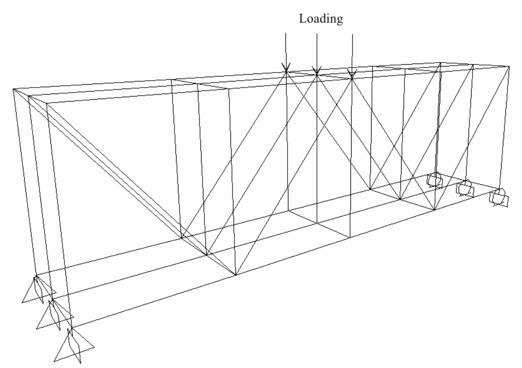
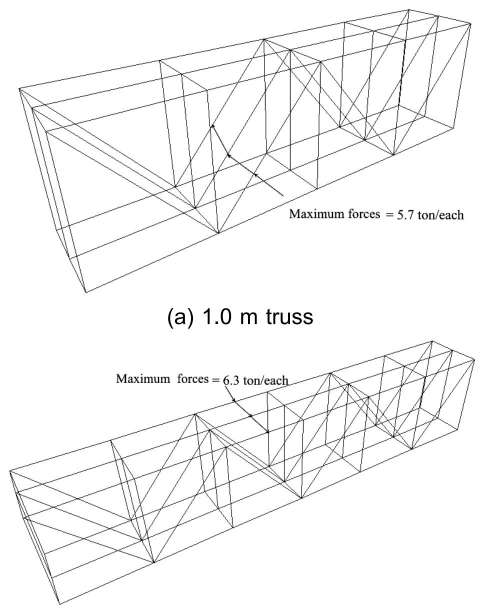


Figure 5 Loading in a truss model

3.2.2 Analysis results

The truss models were analyzed under load ranges of 5-30 tons. The 1.0 m truss showed the maximum compressive force occurred in the diagonal members near the mid-span. (figure 6a) and the length of these members was 0.39 m. The 1.5 m truss showed the maximum forces occurred at top chord members (figure 6b) and the length of these member was 0.25 m. According to the design using the allowable stress method complied with the standard of the Engineering Institute of Thailand [3], it is found that these members can resist the maximum compressive force of 5.7 tons and 6.3 tons for 1.0 m truss and 1.5 m truss respectively. The analysis results shown as load-deformation curves of both trusses (figure 7 and figure 8) show that at maximum member forces, the maximum loads that each truss can theoretically sustain are 27.6 tons and 17.5 tons and the corresponding maximum deflections at the mid-span are 1.1 mm and 1.5 mm for 1.0 m truss and 1.5 m truss respectively.



(a) 1.0 m truss

(b) 1.5 m truss

Figure 6 Maximum forces in truss members

3.3 Built-up 3D Trusses from Scrap Bars

All bars used as truss members were scrap having the diameter of 25 millimeters with the length of about 50 centimeters. The trusses were built-up step by step; a) The deformed bars without rust and in good shape were selected;

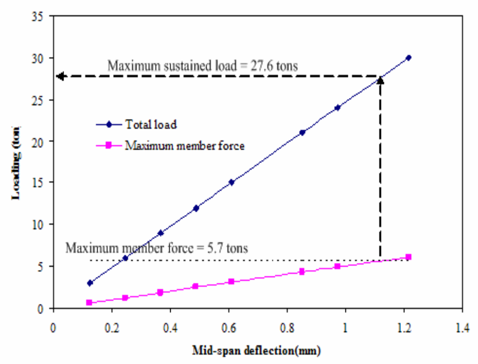


Figure 7 The relation between the maximum member forces, total load and the mid-span deflection of 1.0 m truss

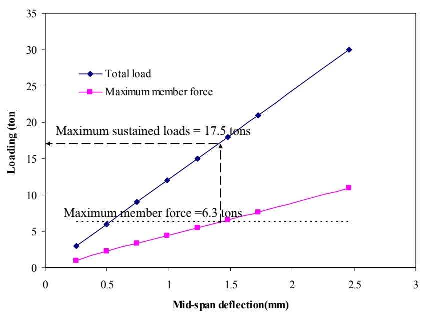


Figure 8 The relation between the maximum member forces, total load and the mid-span deflection of 1.5 m truss

b) The selected bars were cut into the required length as per design; c) and d) The cut bars were connected by electrical welding; and e) Cover plates with the thickness of 6 millimeters were welded to the trusses at the mid-span and at each end of the trusses, (figure 9).

4. Load Test of the 3D Trusses

To verify the capacity of the built-up trusses, the two trusses were then tested under single loading at mid-span (figure 10). The trusses were gradually loaded to the maximum loads of 10 tons and 15 tons and the corresponding deflections at mid-span

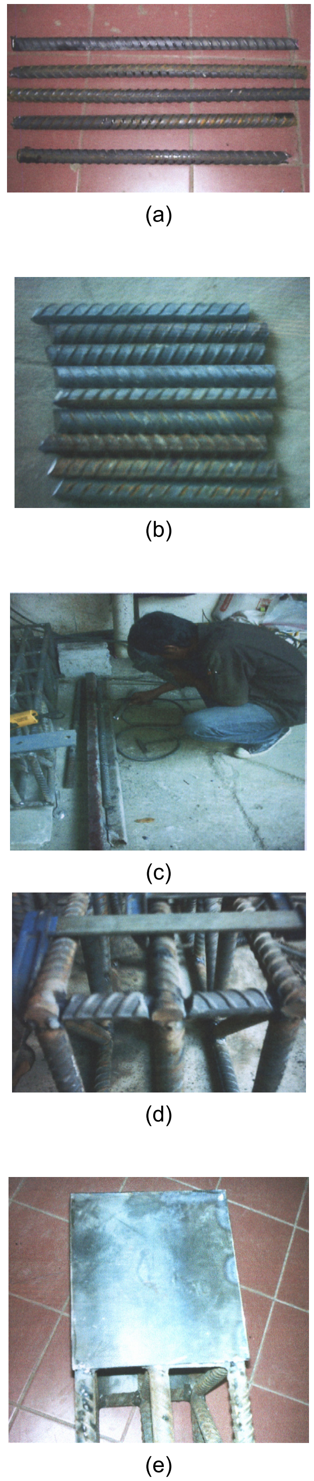


Figure 9 Steps of built-up the 3D truss

were 0.53 millimeters and 0.97 millimeters for 1.0 m truss and 1.5 m truss respectively. These loads were about 40% and 85% of theoretical capacity of 1 m truss and 1.5 m truss respectively and these load ranges were expected to be the maximum loads using in testing of moderate size specimens. Both trusses performed elastically and returned to original positions when the loads were released. Cracks at welded joints and buckling of the truss members did not occurred. The testing results and the analysis results were plotted (figure 11) and it shows that there are discrepancies between these two results. For the 1 m truss the mid-span deflection from the testing was larger than that from the analysis but the 1.5 m truss gave the result in the opposite direction. The 1 m truss behavior was consistent with the load history of the truss members which reloaded members tend to give large deformations affected from the previous loading and the truss as a whole yielded the deflection higher than that from the analysis. The 1.5 m truss showed higher stiffness compared to that from the analysis result. However the differences between the testing results and the analysis results of both trusses are small in fractions of a millimeter and less than L/600 which are about 1.7 millimeters and 2.5 millimeters for 1 m truss and 1.5 m truss respectively.

5. Conclusions

Scrap bars from the tensile test were reused as truss members by welding connections. The built-up trusses can resist service loads without failure at 10 tons and 15 tons for 1.0 m truss and 1.5 m truss respectively. Corresponding maximum deflections of both trusses were small and less than L/600, hence the two trusses can be used as transfer beams for the load ranges of 10-15 tons.

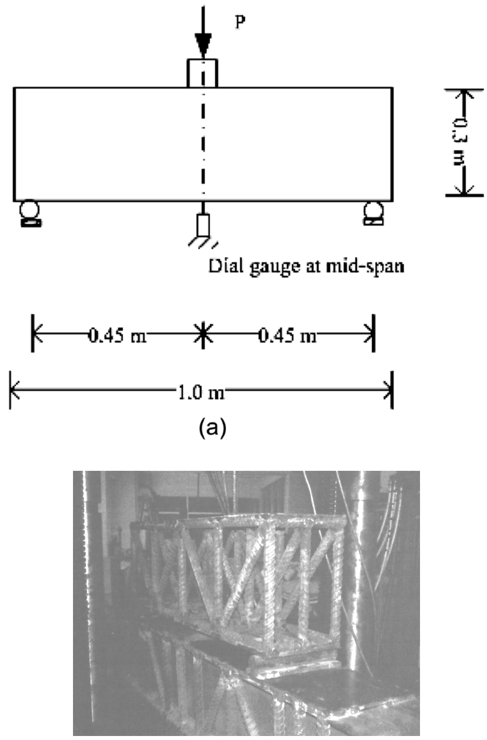


Figure 10 Typical test set-up for 1.0 m truss

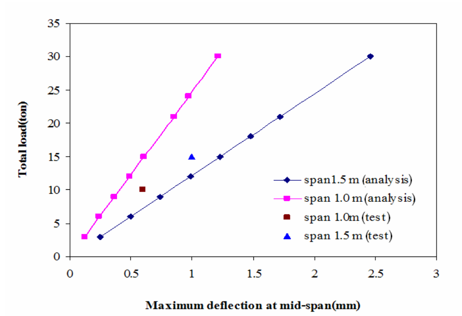


Figure 11 The relation between the total forces and the mid-span deflections

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