INDUSTRIALIZED BUILDING SYSTEM (IBS) – THE EFFECT OF PLYWOOD THICKNESS ON THE PROFILED STEEL SHEETING DRY BOARD SCREW STIFFNESS THROUGH PUSH OUT TEST

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ABSTRACT

The issue of the influx of foreign workers has not subsided despite many measures taken by the Government to tackle the problem. The repercussion of the issue has become very apparent such that there are increased outflow of money to other countries, heightened social problems, the low quality, productivity and delay in works and not to mention, the spread of deadly diseases. Moreover, the availability of cheap foreign workers in Malaysia has made the construction players prefer the conventional systems. To solve these problems, IBS has been proposed in several studies as the solution to reduce the construction time and the dependency on foreign workers in construction industry. Industrialized Building System (IBS) technology has changed the past practices of the construction industry which in turns greatly improves the quality and safety of the building sector. Profiled Steel Sheeting Dry Board (PSSDB) system is classified as a one of the IBS. This research goal is to give a better understanding of the behavior of the PSSDB floor panel before it can be regarded as an innovative, competitive system that can increase the acceptance of IBS in the construction sector. The research objectives are, firstly, to determine the strength of the connection screws through the push out test and secondly, to compare the screw stiffness of the sample with different plywood thicknesses. Parametric studies were conducted by using different thicknesses of plywood. For the study of effect of plywood thickness, the Peva45 as Profiled Steel Sheeting is fixed at 0.8 mm, while the thickness of plywood varied at 12 mm, 18 mm and 20 mm. Laboratory experiments results show that there was a 42 % and 5% increase in stiffness of the samples when the plywood thickness is increased from 12 mm to 20 mm and from 12 mm to 18 mm, respectively. The thicker of the plywood, the stiffer the panel will be. This information can add new understanding of the PSSDB system which has the potential to be expanded to better meet the requirement of the IBS construction.

ABSTRAK

Isu kemasukan pekerja asing tidak reda walaupun banyak langkah-langkah yang di ambil oleh Kerajaan untuk menangani masalah tersebut. Kesan yang sangat jelas kelihatan ialah seperti aliran keluar peningkatan wang ke negara-negara lain, masalah sosial yang semakin meningkat, kualiti rendah, produktiviti dan penyebaran penyakit berbahaya. Lebih-lebih lagi, adanya pekerja asing yang gajinya murah di Malaysia telah menjadikan kontraktor dan pemaju pembinaan lebih suka sistem konvensional. Untuk menyelesaikan masalah ini, IBS telah di cadangkan dalam beberapa kajian sebagai penyelesaian untuk mengurangkan masa pembinaan dan pergantungan kepada pekerja asing dalam industri pembinaan. Sistem Bangunan Perindustrian (IBS) teknologi telah mengubah industri pembinaan untuk memperbaiki kualiti dan keselamatan sektor pembinaan. Kepingan Keluli Berprofil Papan Kering (PSSDB) sistem diklasifikasikan sebagai salah satu daripada IBS. Matlamat penyelidikan ini adalah untuk memberi pemahaman tingkah laku sistem lantai PSSDB dengan berbagai kelebihanya, ia boleh dianggap sebagai inovatif, sistem kompetitif yang boleh meningkatkan penerimaan IBS dalam sektor pembinaan. Objektif kajian pula yang pertama, untuk menentukan kekuatan sambungan skru melalui ujian tolak keluar dan kedua, untuk membandingkan ketegangan skru sampel dengan ketebalan papan lapis yang berbeza. Kajian parametrik dijalankan dengan menggunakan ketebalan papan lapis yang berbeza. Untuk kajian kesan ketebalan papan lapis, yang Peva45 sebagai kepingan keluli Steel ditetapkan pada 0.8 mm, manakala ketebalan papan lapis diubah pada 12 mm, 18 mm dan 20 mm. Eksperimen makmal Keputusan menunjukkan bahawa terdapat peningkatan 42% dan 5% pada kekukuhan sampel apabila ketebalan papan lapis itu meningkat daripada 12 mm hingga 20 mm dan 12 mm dari 18 mm, masing-masing. Semakin tebal papan lapis, panel akan menjadi lebih keras. Maklumat ini boleh menambah kefahaman baru sistem PSSDB yang mempunyai potensi untuk diperluaskan untuk lebih memenuhi keperluan pembinaan IBS.

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LIST OF ABBREVIATIONS

PSSDB	Profiled Steel Sheeting Dry Board
SS	Steel Sheeting
DB	Dry Board
IBS	Industrial Building System
FKASA	Faculty of Civil Engineering and Earth Resources
UMP	Universiti Malaysia Pahang
UKM	Universiti Kebangsaan Malaysia

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Industrial Building System or widely known as IBS, has been implemented by in the Malaysian construction industry since the last few decades. Profiled Steel Sheeting Dry Board (PSSDB) system is classified as a one of the IBS and has been utilised in many government and private residential projects. However, in line with the concept of continuous improvement, more needs to be done in order to understand and advance the system. This research is about the effect of plywood thickness on the PSSDB screw stiffness through push out test. Push out test is used to determine the screw stiffness which in turn will affect the floor panel stiffness.

This chapter will summarize the background of the study, problem statement, objectives, scope of study and significant of study.

1.2 BACKGROUND

Nowadays, IBS technology has changed the past practices of the construction industry which greatly improves the quality and safety of a building. IBS is defined as the complete assembly construction, where the components or structure of building are manufactured at factories on or off site and are transported and assembled into a structure with minimum work and workers (CIDB 2003).

However, this method has yet to be fully applied in the construction industry in Malaysia. This obviously shows that the major players in the construction industry is not yet ready to adopt new technologies and systems but still tied to the conventional method that brings many disadvantages.

The benefit of IBS comparisons to conventional method are (Awang and Badaruzzaman 2010) as follows:

i. shorter construction time
ii. less dependent on heavy equipment on job site
iii. fewer specialised trades
iv. simplified utility installation
v. greater structural integrity
vi. earlier completion and earlier occupancy
vii. excellent thermal and sound barrier
viii. environmentally intelligent
ix. better quality buildings
x. reduce on site labour time and costs
xi. simple construction methods
xii. less wastage of materials
xiii. more durable
xiv. avoid using formwork, etc

The main challenge in applying IBS is the lack of skilled workers or professionals to assemble it. In addition, the lack of exposure or knowledge to design among professionals (architects, engineers) of the IBS system and the lack of skilled workers in the assembly of components have added to the problem at site.

In order to fulfill the requirement of a fully IBS, the PSSDB system has been expanded to be an easy to install prefabricated system. Moreover, PSSDB system has the characteristics of simple construction and does not require much talent. This system has the potential to be developed to better meet the needs of the construction of IBS (Norhaiza 2014).

1.3 PROBLEM STATEMENT

The Annual Labor Force Survey conducted by the Department of Statistics indicated that the number of foreign workers has increased to 1.1 million in year 2000 compared to about 136,000 persons in the early eighties. According to Construction

Industry Development Board (CIDB) Malaysia 69% (552,000) out of total 800,000 of registered construction workers as at June 2007 is a foreign worker (CIDB, 2007b). The danger of the foreigner workers influx has become very apparent. It causes the outflow of money to other countries, social problems such as fighting, drug abuse, and squabbles may occur between foreigners and citizen, low quality, productivity and delay in works and the outbreak of deadly diseases such as hepatitis and AIDS (Wan Hamidon 2008).

Moreover, a lot of cheap foreign workers in Malaysia have made the construction players become reluctant to use IBS. These construction players prefer the conventional systems. Hence, the local workers are not keen in joining the construction industry because of the low emphasizes on occupational safety, health and wage. This case has created an image of dirty, difficult and dangerous of the construction industry.

To solve these problems, PSSDB as an IBS has been proposed in several studies as the solution to reduce construction time and the dependency on foreign workers in the construction industry.

1.4 RESEARCH OBJECTIVES

Based on the research, there are a few things that have to be studied and analysed. Two objectives are expected in the end of the research:

i. To determine the strength of the connection screws through the push out test.
ii. To compare the screw stiffness of the sample due to different plywood thickness.

1.5 SCOPE OF STUDY

The scope in this research is focused on laboratory experiments to determine the strength of the connection screws through the push out test. The experiments on this system will be carried out to involve some specific parameters. A Parameter that will be evaluated in this project is the effect of plywood thickness. A laboratory experiment

involves testing the strength of the push out test will be conducted to identify the influence of the parameters of the proposed system. Peva45 as profile steel sheeting of the fixed thickness of 0.8 mm was taken as controls to study the effects of plywood thickness towards the screw stiffness. PSSDB panel and some parametric tests conducted to determine the effect of parameters on the behavior of connectors screw.

1.6 SIGNIFICANT OF STUDY

The construction industry now is facing the issue of foreign workers. It has financial repercussion caused to some contractors and developers by the foreign labor supply disruption.

In addition, the use of IBS for in the long run will bring considerable benefits to Malaysia society both socially and economically. However, there is still a lack of awareness of these benefits among the contractor and developer in construction sector. Thus, this study will provide a better understanding of the behavior of the system pre-fabricated PSSDB floor panels before it can be regarded as an innovative competitive system that can increase the acceptance of IBS in the construction sector.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter focuses an analysis of the previous researches that have been conducted. A discussion on the definition and description of IBS will be given as well as the review of the major components of PSSDB floor.

2.2 INDUSTRIALIZED BUILDING SYSTEM (IBS)

According to Warszawski, (1999), IBS can be defined as a set of interrelated element that act together to enable the designated performance of the building. Industrialized Building System also can be defined as a building system which involves industrialized production of building elements or component as well as erection and assembly of these elements into a desired building structure through mechanical means using as little in-situ construction as possible. The elements are thus precast of prefabricated either in an off-site factory or in an on-site casting yard (Trikha & Abang 2004).

Besides that, IBS program was established with the purpose to justify the construction sector to maximize quality, productivity, safety and competitiveness while reducing reliance on unskilled foreign labor (CIDB 2007).

The most important benefits of this system, as mentioned in several studies such as (Warszawski 1999), (CIDB 2005), (CIDB 2003b) and (Thanoon et al, 2003) are high quality and good acceptance, reduced on-site worker, cost and waste material and increased quality of building and neater site. However, there is still lack in awareness of

these benefits among players in the construction sector. According to government statistics, IBS has not achieved the targets. Therefore, PSSDB as a form of IBS product is being proposed as a variable alternative system. PSSDB was successfully implemented in two school classroom modules at Sekolah Kebangsaan Telok Mas, Melaka, Malaysia and other projects. It has a promising future to be implemented as an IBS.

2.2.1 Profiled Steel Sheeting Dry Board (PSSDB) Floor

PSSDB floor consist of three major components such as dry board, profiled steel sheeting and screw connectors. Each component has its own characteristics. When all three components are combined, they form a composite panel behavior influenced by the interaction of these three components. It is also very light, easily transportable and can be erected quickly by semi-skilled labour. PSSDB serves as an alternative and provide more practical solution to existing traditional forms of construction.

2.2.1.1 Dry Board (DB)

The idea of dry floor system using profiled steel sheet was commenced by Wright and Evans (1986) in United Kingdom. In their study, the dry board, as a structural component had been used in the form of Profiled Steel Sheeting Dry Board (PSSDB) system as a replacement of timber joist flooring for small-scale domestic building. A study done by Wan Badaruzzaman et, al. on type of cement bonded board, Cemboard, manufactured locally in Malaysia indicates that this board is good in weather, fungal and insect resistance. It is also good in fire resistance and is classified as highly fire-resistant by the German and British Standards.

A new type of dry board, namely Prima*flex* (also manufactured locally) with the thickness of 9 mm is introduced as an alternative to the other types of dry boards normally used in the PSSDB system. The Young's modulus of Prima*flex* is 8000 MPa, which is higher than the usual dry board used by others researchers such as Cemboard (4800 MPa). Prima*flex* is made from top grade cellulose fibres, Portland cement and

finely ground sand. It will not deteriorate when exposed to sun, rain, wind, dampness and dryness.

Dry board is a very important component in the PSSDB system which provides for a flat surface to carry load. The board is attached to the profiled steel sheeting by self-drilling and self-tapping screws. It interacts compositely with the profiled steel sheet to form a composite section resulting in either full or partial interaction behavior. It is also very instrumental in delaying local buckling of the thin profiled steel sheet under compressive load and elastic deflection of the PSSDB system besides carrying a small portion of the load (Awang and Wan Badaruzzaman 2010). The properties comparison of the materials of the four chosen types of dry boards is shown in Table 2.1 below.

Table 2.1: Structural properties of dry board

Type of dry board	Young's modulus (Mpa)		Shear strength (Mpa)	
	Parallel to the grain	Perpendicular to the grain	Parallel to the grain	Perpendicular to the grain
18 mm Plywood	5300	9775	40.4	66.5
18 mm Chipboard	1950	1950	11.4	11.4
12mm Cemboard	4800	4800	8.4	8.4
9 mm prima*flex*	8000	8000	14	22

Source: Awang and Wan Badaruzzaman 2010

2.2.1.2 Profiled Steel Sheeting (PSS)

Profiled steel sheeting is formed from flat steel 'cold' or 'strip' folded into continuous ridged profiles. In Malaysia, profiled steel sheeting is largely used as non-load bearing roof and wall cladding in buildings. Ahmed (2003) has conducted a study

that described the profiled steel sheeting as the strongest element of the three components. Hence, profiled steel sheeting plays an important role in determining the PSSDB floor panel ability to endure the load. In Malaysia, profiled steel sheeting is commonly used for conventional cast in situ concrete composite slab system. BHP Steel Building Products produces profiled steel sheeting including Bondek II that is locally available.

Bondek II is rolled to form from hot dipped zinc coated, chromate passive, high-strength grade. The steel has metal thickness of 0.6, 0.75, or 1 mm with a minimum tensile strength of 550MPa in compliance to both BS En 10147 and Australian Standard AS 1397: 1993. Because of the re-entrant shape, various infill materials can conveniently be filled in the troughs to increase the fire resistance and sound proofing. Moreover, in terms of yield strength per unit cost, high strength steel is cheaper than the other types. The characteristics of the profiled steel sheeting is represented in Table 2.2 below.

Table 2.2: The comparison of characteristic Profiled Steel Sheeting

	Thickness	**Bondek 11**	**Peva**
Weight	1.00 mm	13.3	13.3
	0.75 mm	10.3	-
	0.80 mm	-	10.67
Minimum yield strength N/mm2		550	350

Source: Ahmed 2003

Wan Badaruzzaman (2003) conducted studies of structural performance and applications of Bondek II/ Cemboard Composite Floor Panel (BCCFP) system by using a variety of types and thickness of the dry board as shown in Figure 2.1. The primary objective of the study was to identify aspects of the most important performance of the panel. It considers flexural strength and the influence of types and thickness of board, the effect of attachment of the dry board and the effect of spacing of connectors to the panel stiffness.

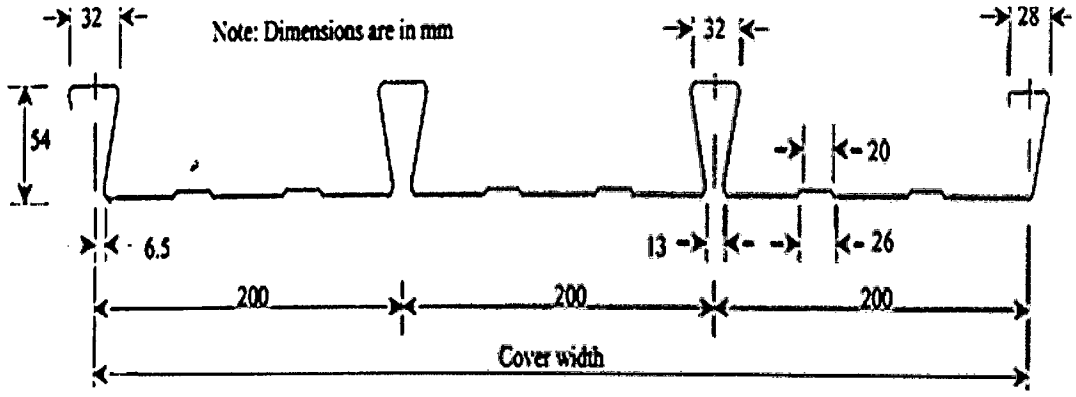


Figure 2.1: Modified Bondek II Profiled Steel Sheeting

Source: Wan Badaruzzaman 2003

Research on cold-formed thin-walled members is now moving towards using to a more economical, exploit power of the storage and find the exact design but simple. The specific study among the researchers of cold formed steel includes the aspect of imperfections and failure mode.

Aspect of imperfections has been studied by Bernard er al. (1999), Dubina & Ungureanu (2002), Lechner & Pircher (2005) and Schafer & Pekoz (1998) and they had found that a little imperfections only in the production of steel sheeting can influence the behavior of cold-formed thin-walled members (Norhaiza 2014).

2.2.1.3 Connectors

Self-drilling and self-tapping screws are simple mechanical connectors which are arranged in small grids of usually 100 to 300 mm and have been used to connect the dry board to the steel sheeting to form a composite unit. The screw connector is the smallest element but it is very important in determining the overall behavior of PSSDB panel system. It is locally produced in Malaysia and has various sizes and shapes. The use of screws ensures easy, fast and efficient connection between the profiled steel sheeting and dry board. The screw in the PSSDB panel system will transfer the horizontal shear force between profiled steel sheeting and dry board (Wan

Badaruzzaman et al. 2003). Properties of screw DX14 screw connector is shown in Table 2.4 below.

Table 2.3: Properties of DX14 screw connector

Properties	
Material	Carbon steel
Surface coating	10-15 mm Zinc chromate
Length	25 mm
Diameter of thread	4.2 mm
Tensile breaking load	6.3 kN
Shear breaking load	4.35 kN
Twist-off Torque	4.7 Nm
Pull-out load from 1 mm steel plate	1.0 kN

Source: Powerdrive 1991

Ahmed (1996) studies the effect of the screw distance in three type of interaction of the composite panel. In his research, the PSSDB panel consists of Bondek as profiled steel combined with three different dry boards. The interaction percent for distance of screw is tabulated in Table 2.5 below.

Table 2.4: The effect of screw distance to the percent of composite panel interactions

Type of composite panel	**Distance of screw**		
	50 mm	100 mm	200 mm
Bondek-Plywood	42.5 %	16.2 %	4.5 %
Bondek-Cemboard	52.9 %	21.3 %	5.8 %
Bondek-Chipboard	61.0 %	22.1 %	6.5 %

Source: Ahmed 1996

It is found that the smaller the screw distance is 50 mm has the higher percentage of composite panel interaction compare with a distance of screw 100 mm and 200 mm. Hence, Bondek-Chipboard has a higher percentage of composite panel interaction compared to others, such Bondek-Cemboard and Bondek-Plywood.

2.2.2 Specified studies of Profiled Steel Sheeting Dry Board (PSSDB) system

Push out test was carried out to determine the stiffness of the connection screws. Besides that, push out test also was carried out to understand the behaviour of the sample. The information obtained from these tests includes the maximum load and the stiffness.

2.2.2.1 Push out test

Wright et al. (1989) had previously study the suitability of some types of connector's such as screw, nails and bolts. They concluded that the most suitable connector for PSSDB is self-drilling and self-tapping screw. Experimental specimens detail is tabulated in Table 2.6 below.

Table 2.5: Experimental specimens detail

	Types	**Thickness/ Size**
Profiled steel sheeting	PMF	Not specified
Plywood	Plywood	18 mm
	Chip board	18 mm
Screw	Self-drilling and self-tapping	Not specified
	Nail	
Size of sample	Not specified	
Number of test	3	
Number of sample	More than 14	

Source: Wright et al. 1989

Wright et al. (1989) also detects different failure modes of the connectors. The sample using screws failed when the screw torn out of profiled steel sheeting. However, these experiments were conducted in the United Kingdom and materials that are different in nature from the local products of Malaysia. The value of strength from push out test is tabulated in Table 2.7 below.

Table 2.6: The value of strength from push out test

Types	**Value of strength (N/mm)**
Plywood-nail	267
Chipboard-nail	175
Plywood-screw	760
Chipboard-screw	550

Source: Wright et al. 1989

Research done by Norhaiza (2013) found the value of stiffness is almost the same when using different dry board although the profiled steel sheeting is fixed. The values of stiffness were tabulated in Table 2.8 below.

Table 2.7: The values of stiffness

Researchers	**Material**	**Stiffness (kN/mm)**
Norhaiza 2013	0.8 mm Peva45 18 mm Cemboard	0.77
Norhaiza 2013	0.8 mm Peva45 18 mm Plywood	0.61

Source: Norhaiza 2014

2.3 CONCLUSION

In this chapter, the definitions of IBS were discussed. It is system where the components are manufactured at the factories on or off site and transported and assembled into a structure with minimum additional work and workers. PSSDB system is classified as one of the IBS. The PSSDB floor components consist of three major components such as dry board, profiled steel sheeting and screw connector are also discussed. The works of the previous researchers were also reviewed.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methods used in carrying out the study. A carefully and thoroughly planning and scheduling had been organized. This chapter begins with a description of the push out test, preparation of specimen and test procedure.

The methodology procedure is to ensure that the information obtained from this study is relevant and acceptable for evaluation.

3.2 DESCRIPTION OF THE SAMPLE

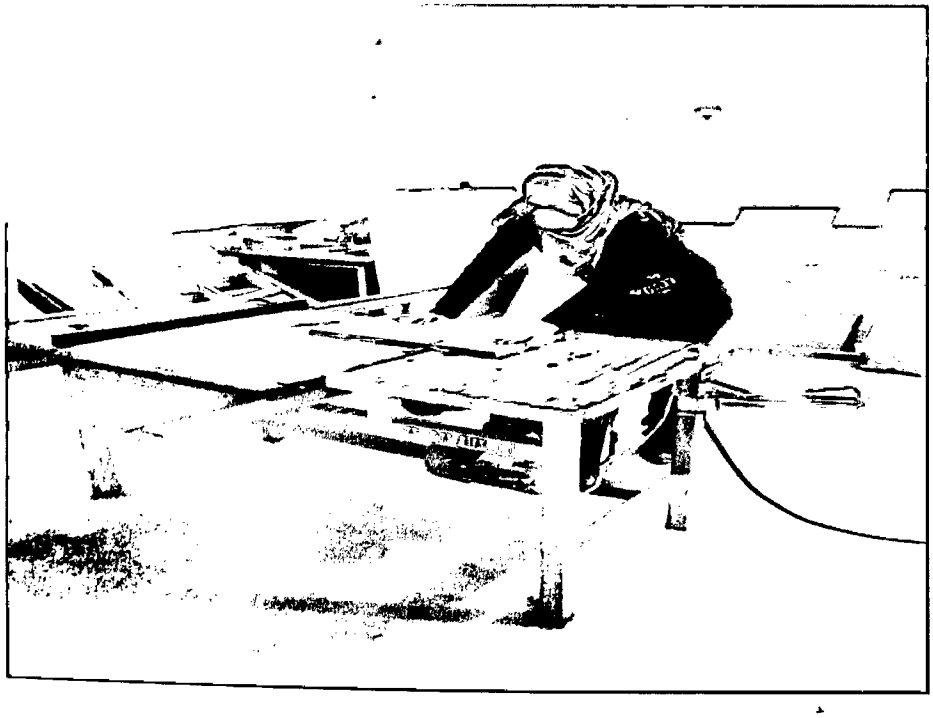
The specimens for the dry slab system were made by combining profiled steel sheeting and plywood panel using self-drilling screws. There are 9 specimen that consist of three difference thickness of plywood which is repeated three times. The thickness of plywood is 12 mm, 18 mm and 20 mm. The Peva45 as profiled steel sheeting is fixed at 0.8 mm. The materials used in push out test were tabulated in Table 3.1 below.

Table 3.1: The materials used in push out test

No.	Material	Properties	Thickness / Diameter	Quantity
1	Dry board	Plywood	12 mm	3
			18 mm	3
			20 mm	3
2	Profiled steel sheeting	Peva45	0.8 mm	9
3	Screw	MK Fasteners	30mm/4.2 mm	81

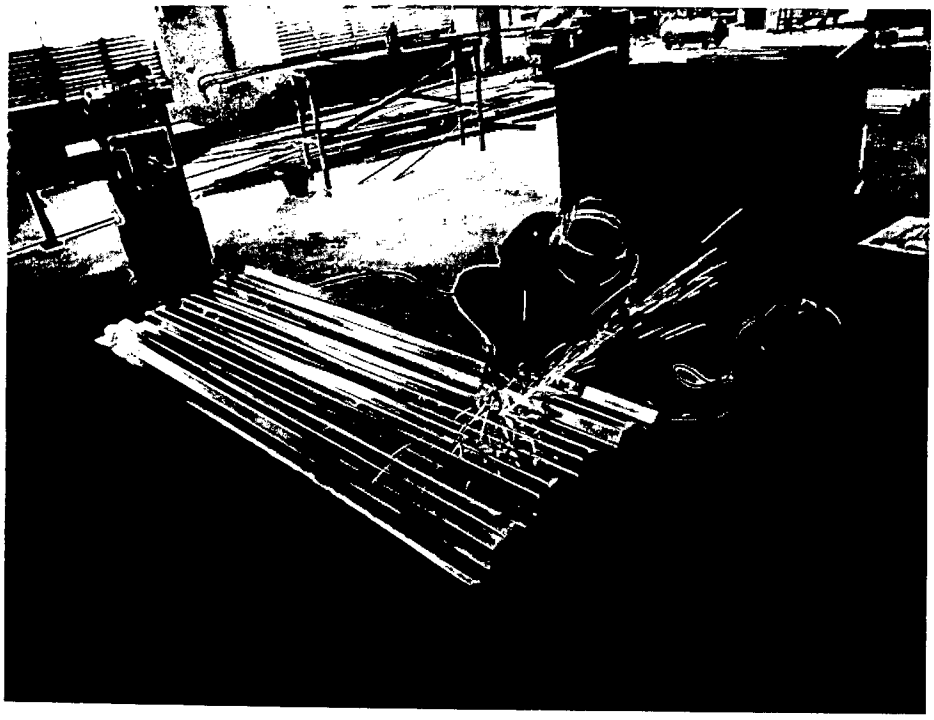
The preparation of sample Peva45-Plywood was carried out at University Malaysia Pahang (UMP) laboratory. Firstly, Plywood is marked with 250 mm x 275 mm. The usual size of plywood is 1.2 m x 2.4 m (4 ft x 8 ft). The plywood was cut to obtain the desired width and length using power hand saw as shown in Figure 3.1 below.

Figure 3.1: The plywood was cut using power hand saw



Secondly, the Peva45 as profiled steel sheeting was cut using grinder to the size of 250 mm x 325 mm as shown in Figure 3.2 below. Health and safety policy in the UMP laboratory requires the need to wear the helmet and glove during the cutting process.

Figure 3.2: The Peva45 was cut using grinder



Lastly, the plywood was attached to the top flange of the steel deck using self-drilling screw as shown in Table 3.3 below. The screws were driven at a spacing of 50 mm from center to center by electric powered screw drivers. There are 9 specimens and each specimen has 9 screws. Total screw that was used for 9 specimens is 81 screws.