THE EFFECT OF SCREW SPACING ON THE PROFILED STEEL SHEET DRY BOARD (PSSDB) WITH FOAMED CONCRETE INFILL FLOOR PANEL STIFFNESS

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Thesis submitted in a fulfillment of the requirements for the award of the
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JUNE 2015

ABSTRACT

Profiled steel sheeting dry board is the new technology that had been used in civil engineering field as slab, roof and wall structure. Profiled steel sheeting dry board panel is a composite structural system consisting of profiled steel sheet (PSS) connected to dry board by simply mechanical connector. It had been used in United Kingdom to substitute the usage of timber formwork on the construction site. Previous researchers were done to determine fire resistance performance and strength of the panel by using different type of methods and material such as dryboard, profiled steel sheeting (PSS), concrete as infill and screw size. This experiment was conducted to determine the stiffness performance on the PSSDB panel when foamed concrete is used as an infill and the result was compared with the PSSDB floor panel without infill. It was also conducted to determine the effect of the screw spacing toward stiffness performance of the floor panel system. This experiment used three (3) samples with differences screw spacing that are Sample 1(100mm), Sample 2 (150mm) and Sample 3(200mm). Compressive strength cube test was done to obtain the strength of the foamed concrete used. Another experiment is bending test, conducted by using Magnus Frame and Apparatus 30 tonnes and attached with transducer to get the data of deflection. The Whiffle-Tree method was use simulate uniformly distribution load to the whole panel system. All the data collected and analyzed to show the performance of the panels system in stiffness. The result shows that the stiffness for Sample 1 is 192 kNm^2/m, Sample 2 is 168 kNm^2/m and Sample 3 is 162 kNm^2/m. It shows that when the screw spacing used increase, the stiffness of the PSSDB floor panel system increased. This is because of the profiled steel sheeting and dry board was stick together firmly by the screw.

ABSTRAK

Kepingan keluli berprofil papan kering merupakan teknologi baru yang telah digunakan dalam bidang kejuruteraan awam sebagai papak, bumbung dan struktur dinding. Berprofil keluli cadar papan kering panel adalah sistem struktur komposit yang terdiri daripada kepingan keluli berprofil (PSS) yang berkaitan kering lembaga dengan penyambung hanya mekanikal. Ia telah digunakan di United Kingdom untuk menggantikan penggunaan acuan kayu di tapak pembinaan. Penyelidik sebelumnya telah dilakukan untuk menentukan prestasi ketahanan api dan kekuatan panel dengan menggunakan pelbagai jenis kaedah dan bahan seperti dryboard, kepingan keluli berprofil (PSS), konkrit sebagai isian dan saiz skru. Eksperimen ini dijalankan untuk menentukan prestasi kekakuan pada panel PSSDB apabila konkrit berbusa digunakan sebagai isian dan keputusan yang telah dibandingkan dengan panel lantai PSSDB tanpa isian. Ia juga telah dijalankan untuk menentukan kesan skru jarak ke arah prestasi kekakuan sistem panel lantai. Eksperimen ini digunakan tiga (3) sampel dengan perbezaan skru jarak yang Sampel 1 (100mm), Sampel 2 (150mm) dan Sampel 3 (200mm). Mampatan ujian kekuatan kiub dilakukan untuk mendapatkan kekuatan konkrit berbusa digunakan. Satu lagi eksperimen ujian lenturan, yang dijalankan dengan menggunakan Magnus Frame dan Peralatan 30 tan dan dilampirkan dengan transduser untuk mendapatkan data pesongan. Kaedah "Whiffle-Tree" adalah penggunaan simulasi beban pengedaran seragam kepada sistem panel keseluruhan. Semua data yang dikumpul dan dianalisis untuk menunjukkan prestasi sistem panel dalam kekakuan. Hasil kajian menunjukkan bahawa kekakuan untuk Contoh 1 adalah 192 kNm^2/m, Contoh 2 adalah 168 kNm^2 m dan Contoh 3 adalah 162 kNm^2/ m. Ini menunjukkan bahawa apabila jarak skru yang digunakan meningkat, kekukuhan lantai PSSDB sistem panel akan meningkat. Ini kerana kepingan keluli berprofil dan papan kering telah sentiasa bersama dengan kukuh oleh skru.

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, many technologies used are involving composite elements and it used in as structure in building construction. One of the new technologies in construction structure is precast concrete floor system. A conventional precast concrete floor system consists of 2 main elements that are hollow core (HC) slabs and inverted-tee (IT) beams that supported the slab and supported on column corbels or wall ledges. This floor system allows rapid construction of multi-story buildings that are economical, durable, fire-resistant, and that have excellent deflection and vibration characteristics. The top surface of the HC floor system can either be a thin non-structural cementitions topping or casting- in-place (CIP) concrete composite topping that also provides a continuous level surface. The conventional methods for construction of floor are inefficient, dull, dirty, dangerous, low quality, noisy, disruptive, an environmental unfriendly and is also labour intensive.

Other than precast concrete floor system, there is another floor system named as Profile Steel Sheet Dry Board (PSSDB) slab system. Wright and Evans (1989) had started the research about the composite structure and had been continued by Wan Hamidon and his group researcher (1995) by using local materials to form composite structure and used it in construction of wall structure and roof structure.

This research had been winning the price in the international level by using Bondek II / Cemboard Composite Floor Panel (BCCFP) system and it was successfully developed and marketed. From this result, they continued the research by using PSSDB component as a slab structure. The profiled steel sheeting dry board (PSSDB) system is made up from a thin-walled, lightweight composite structure consisting of profiled steel sheet connected to dry boards by means of mechanical connectors.

Besides that, Profiled Steel Sheeting Dry Board (PSSDB) had tested to apply as slab system in construction. This system had been tested and experimental by using different parameter such as thickness of dry board (DB), thickness of profile steel sheeting (PSS), type of Dry Board, and spacing connector (Wan Hamidon, et.al, 2010)

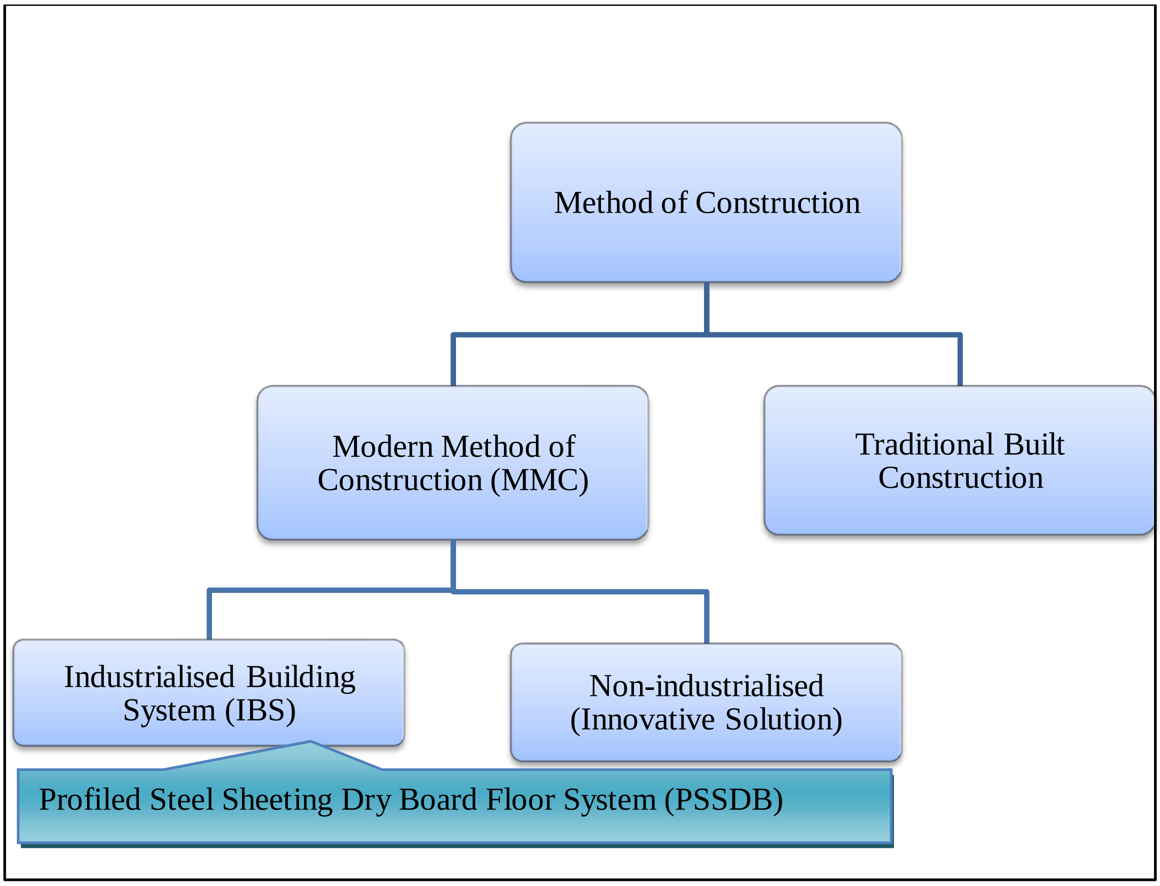

Figure 1.1: Profiled Steel Sheeting Dry Board in Method of Construction

Development of the composite slab structure gives many new ideas to the researcher to improve the method of structural system to be more efficient and significant for the user. In Malaysia, slab structures commonly used in construction project are Composite Ferro-cement Masonry Slab (CFMS), (Yavuz Yardim, 2010) and Precast Composite Slab with Steel Fibre Reinforced Concrete Topping (Nurul Nadia and Izni Syahrizal, 2013). Development of the composite slab structure gives many new ideas to the researcher to improve the method of structural system to be more efficient and significant for the user. The Profile Steel Sheeting Dry Board without infill caused vibration, low strength and decreased the stiffness of the system when used it. Further research is needed to identify the effect of differences screw spacing when foam concrete used as infill in Profile Steel Sheeting Dry Board floor panel in order to increase the stiffness of the system.

1.2 Objectives

The objectives of the Profile Steel Sheeting Dry Board (PSSDB) research are:

1. To identify the stiffness of the PSSDB structure with the foamed concrete infill.
2. To identify the suitability of foamed concrete as infill.

1.3 Scope of Study

The main purpose to conduct this research and experiment is to identify the stiffness for the PSSDB slab system and applied it as a structural element in the construction site. This experiment is using bending moment test based on British standard 8110 code (BS 8110).

For this experiment, the thickness of the Profile Steel Sheeting (PSS) used is 0.8 mm and the size is 1.2 m x 2.0 m. The lightweight concrete made up from combinations of the Styrofoam, cements, sand and water. The concrete will filled in the PSSDB structure before attaching the dry board to it.

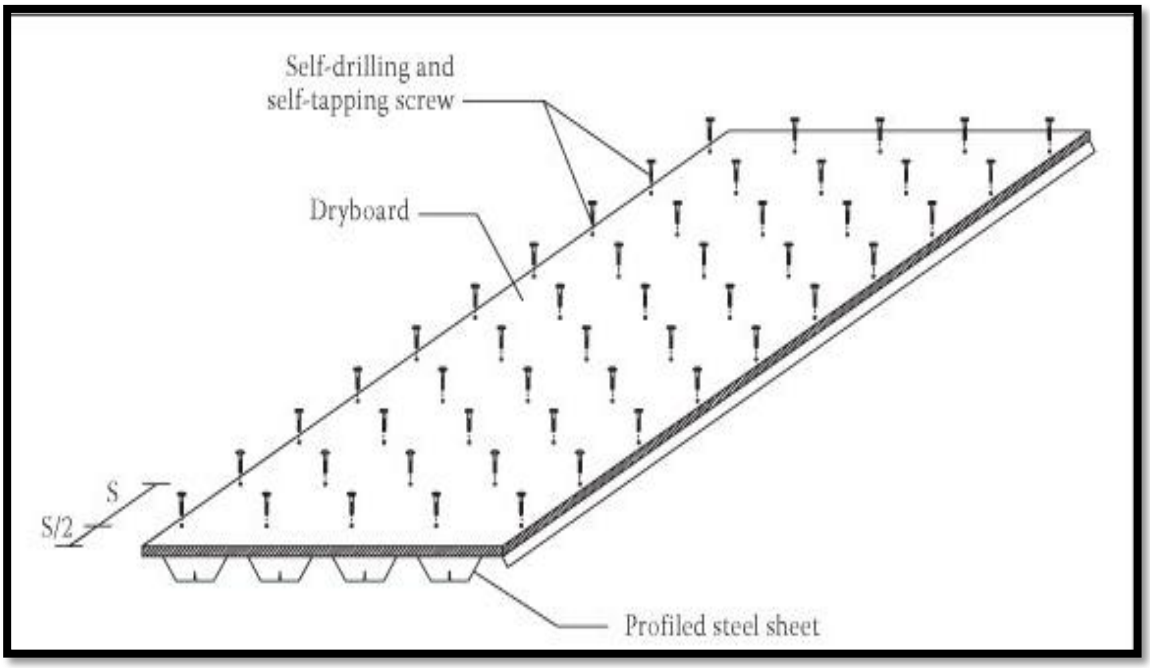

Figure 1.2: Profiled Steel Sheeting Dry Board System

1.4 Conclusion

This chapter discuss the background of the study, objectives of research, problem statement and scope of study related to Profiled Steel Sheeting Dry Board (PSSDB) Panel System. There have two objectives that should be decide which related to PSSDB panel system. In the next chapter will discuss about the review of the previous research paper related to this study. It based on the scope of study and objectives of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In Malaysia, the concept of construction usually uses reinforcement concrete, timber building, precast or prefabricated concrete. The research about the newer concept introduced a new element that can be use such as steel building system, composite slab system and others (Wan Hamidun, 2003). Profile Steel Sheeting Dry Board (PSSDB) panels commonly constructed as a single membrane member. These floors have safety function to support all the vertical loads. It also able to transfer all the loads to the foundations through members supporting the floor (Wan Hamidun, 2002)

2.2 Profiled Steel Sheeting Dry Board (PSSDB) System

PSSDB is a lightweight composite system that made up from profile steel sheeting and dry board and connected by using mechanical connector. The function of the floor is to safely support all possible vertical loads, and transfer them to the foundation via members supporting floor. PSSDB flooring system carries the out of plane bending and shear (Ehsan Ahmed and Ghazali Ahmad, 2006). This system had been introduced by Wright and Evans (1986).

From the early research (Wright and Evans 1986, and Wright et al.1989) it focused on development of PSSDB system as slab panel in the construction of building to replace the timber formwork in United Kingdom. Besides, there was other experimental that had purpose to investigate the fire resistance performance of Profiled Steel Sheeting Dry Board with infill normal concrete, polystyrene block, polystyrene cement mortar. (W.H. Wan Badaruzzaman , 2003)

2.3 Elements / Components of PSSDB Floor System.

This section shows the components that had been choose in order to use in the research or experiment of PSSDB as a slab panel in construction of building. In the PSSDB system there have three (3) main elements that are profile steel sheet, dry board and mechanical connector. For this experiment, all the materials use artificial locally.

2.3.1 Profiled Steel Sheeting (PSS)

Profiled steel sheeting is produced from flat steel strips that had been folded into continuous ridged profiles. Profile steel sheeting normally used as non load bearing roof in Malaysia. It also been used as wall claddings in the construction of building. Other than that, Profile steel sheeting commonly been used as conventional cast in-situ concrete composite slab in developed country and also available in Malaysia (Wan Hamidon et.al, 2002)

In the BCCFP system, nearby available structural profiled steel sheeting identified as Bondek II. It can produce by BHP Steel Building Products, it was adopted with some alteration. Bondek II is a re-entrant type profiled steel sheeting, rolled formed from high strength steel strip in bare metal thicknesses of 0.6, 0.75, 0.9 or 1 mm. (Grade G550 of Australian Standard AS 1397: 1993). Due to re-entrant shape, various infill materials can suitably be filled in the troughs to improve the fire resistance and sound proofing properties of the panels. In terms of yield strength per unit cost, high strength steel is significantly cheaper than the other varieties.

The profiled steel sheeting made from high strength steel has the advantage that they can sustain the form firmly. They show high resistance to chance buckling, denting or harm in handling during transportation, production or service. Therefore, for a BCCFP floor, where soft infill are commonly used, high strength steel is particularly beneficial for their firm shape, in contrast to the composite concrete floor, where the hardened concrete restrains the profile from changing shape.

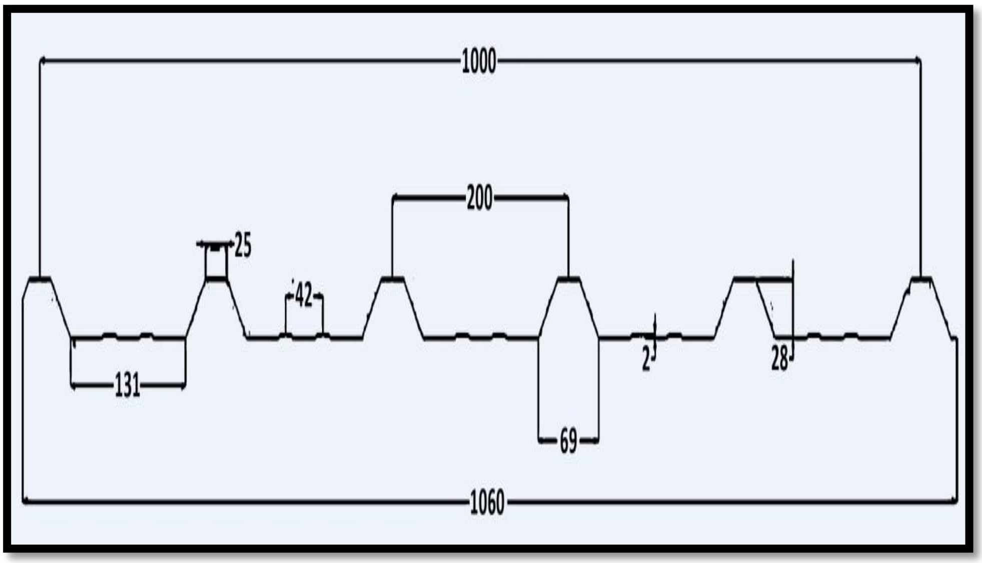

Figure 2.1: Dimension for Profiled Steel Sheeting (PSS)

2.3.2 Dry Board

There are many types of board that can be obtained in the market to use as structural element in the construction field. Types of board available in Malaysia market are plywood, chipboard, dry board and cement bonded mineral board. All these types of board widely use and available in Malaysia market. There are two (2) types of board called plywood and chipboard that had been purpose because of it suitability use in the PSSDB system (Wright et.al, 1986).

However, more detailed studies at the Building Research Establishment (BRE), Watford, England on various types of dry boards indicate some distinct advantages of cement bonded boards. Cement-bonded board was found have high resistant toward both fungal and insect attack. This is because highly alkaline nature of the material and the cement structure of wood particles (Wan Hamidon et.al, 2002).

On the aspect of reaction to water, the extent of swelling for cement-bonded boards is much lower than in other wood-based panel. Whilst on the aspect of fire resistance, cement-bonded boards are classified as highly fire-resistant in relevant German and British standards. Cement boards can also be finished with a wide range of finishes commonly used with concrete floors, such as tiles, laminates, foils, etc., that are popular to modern users. Because of the special qualities mentioned above and easy availability in local market, Cemboard, a type of cement board produced by Hume Cemboard Berhad Malaysia, becomes the most preferred choice in the BCCFP system. (Wan Hamidon et.al, 2002).

However, other boards are also studied for comparison purposes. Comparison of the material properties of the three chosen types of dry boards based on tests carried out at Universiti Kebangsaan Malaysia (UKM) follow the British Standard BS 5669.

Figure 2.2: Dryboard (plywood)

2.3.3 Connector (screw)

Simple mechanical connectors, such as self-drilling, self-tapping screws, in small grids of usually 100–300 mm, have been used to connect the dry board to the steel sheeting to form the composite unit

Screwed connections are responsible for transferring the horizontal shear between the dry board and the profiled steel sheeting. Like other similar composite structures, such as composite beam, the performance of these connections determines the degree of composite action achieved and hence the stiffness of the structure as a composite unit. The capacity of a screw connection is expressed by its shear modulus, which is the amount of shear force transferred per unit length of shear displacement. Shear modulus and total shear capacity of the screw connections determined by push out tests (Wan Hamidon, 2003).

2.3.4 Foamed concrete

From previous experiment by Brady et.al (2001), foamed concrete also known as cellular concrete because it has similar materials such as air entrained concrete. Foamed concrete also defined as a cementations material having a minimum of 20 percent (by volume) of mechanically entrained foam in the plastic mortar. This differentiates foamed concrete from (a) gas or aerated concrete, where the bubbles are chemically formed through the reaction of aluminium powder with calcium hydroxide and other alkalis released by cement hydration, and (b) air entrained concrete, which has a much lower volume of entrained air (Van Deijk, 1991).

Foamed concrete requires no compaction because it can flow readily from a pump outlet to fill restricted and irregular cavities. It can pump successfully over significant heights and distances. The range of the compressive strength of 28-days foamed concrete from 1 to 10 N/mm^2 and the dry density from 400 to 1600 kg/m^3. Commonly, the specific strength is 4 N/mm^2. The plastic density of the material is about 150 to 200 kg/m^3 higher than its dry density.

Based on this research, the current usage of the foamed concrete in United Kingdom (UK) for bulk filling, trench reinstatements and variety of other applications such as:

i. Bulk filling, using relatively low strength materials, for redundant sewerage pipes, wells, disused cellars and basements, storage tanks and subways etc.
ii. Highway trench reinstatement (by ready-mixed concrete producers)
iii. Infill to the spandrel walls of arch bridges.
iv. Backfill to retaining walls and bridge abutments
v. Stabilising soils, for example in construction of embankment slopes.
vi. Various industrial application and for domestic housing, including as insulation to foundation and roof tiles, blinding layers, cast in-situ piles, fire protection and high frequency sound insulation.
vii. Sandwich fill for precast units
viii. Grouting for tunnel works.

2.4 Used of PSSDB

Load Bearing Wall Panel

From the previous research (Abdelghani and Wan Hamidon, 2003) recommended a semi-empirical equation taking effective width and local buckling into consideration in order to gain the ultimate load bearing capacity of PSSDB wall.
The mode of failure due to overall buckling of PSSDB wall panel, the Euler equation has been organized to calculate the elastic buckling load (P_{cr}).

2.5 Previous Experiments

From the previous experiment, the PSSDB had been tested in many characteristics and properties to get and show the result related to the strength by using different type of test.

2.5.1 Effect of thickness of board

Thickness of the board will effected flexural stiffness or variation of the deflection for the composite structures or panels. The difference of the deflection can be seen by using Cemboard that have different thickness. Based on tests that had been conducted by W.H Wan, shows the result of the test for different thickness of board. For the thickness Cemboard used was 12 mm, the flexural stiffness/load deflection found was 138 kNm^2/m whereas for Cemboard thickness was 16 mm and 24 mm, the flexural stiffness/load deflection was 142 kNm^2/m and 157 kNm^2/m respectively. The result shows that using the different thickness of board will gives different values of flexural stiffness each. As expected, the use of a thicker board will increase the stiffness of the panel (Wan Hamidon, 2003).

2.5.2 Effect of spacing connector

The effect of varying spacing of connectors on flexural stiffness for three different types of boards can be evaluated in terms of percentage composite interaction. Stiffness is the computed value of the stiffness assuming complete interaction between the component layers. It can be seen that closer spacing of connectors clearly improves the stiffness and performance of the composite panel (Wan Hamidon, 2003).

2.5.3 Effect of types of board

The flexural performance (load-deflection relationship) of the panel system use difference types of boards gives the different result. When plywood had been used the performance is better than chipboard and Cemboard. This is because plywood has larger elastic modulus and bending strength. For Cemboard, it not provided in 18mm thick. It only provided 16mm thick of Cemboard but it can perform better than 18mm thick chipboard. Between Cemboard and plywood, there only have very small difference in stiffness. Thus, both of these types of board can be used and perform well in the PSSDB system (Wan Hamidon, 2003).

2.5.4 Moment capacity of PSSDB panels

The moment capacity of Bondek II steel sheeting alone when using the elastic section properties were approximates 8.2 kNm/m. As expected, the experimental ultimate moment capacity of the composite panel is greater than the steel sheeting alone. The composite action between the boarding and steel sheeting will increase the buckling stress of the test panels, which contribute to the higher moment capacity. From all the experiments, different result had been collected related to the strength of the PSSDB structure and had been applied in the construction industries nowadays.

2.6 Advantages of PSSDB System

From research result by Wan Hamidon (2003), a newer concept included steel building system, composite slab system and various modular systems in construction industry. The advantages of using PSSDB system are:

- Shorter construction time/duration
- Decrease the use if heavy equipment
- Decrease the specialised trades
- Fasten the completion time
- Excellent thermal and sound barrier
- Environmentally intelligent
- Increase the quality of buildings
- Reduce labours time and costs
- Make the construction process simpler
- Increase the durability
- Do not need any formwork in the construction.

2.7 Conclusion

This chapter has discusses about the review of the previous studies that related to this research. The review was related to Profile steel Sheeting, dry board, connector, foamed concrete and also advantages and disadvantages of this system based on previous research. It helped to understanding about Profiled Steel Sheeting Dry Board system. In Chapter 3, it will discuss about the methodology of laboratory test that will be conduct and the procedure from preparing materials process until experimental process.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This research is to determine the strength of the PSSDB slab structure by using bending test. Uniformly distribution loads bending moment test will be applied in order to get the result of the stiffness of the structure and the crack pattern will be observed and recorded.

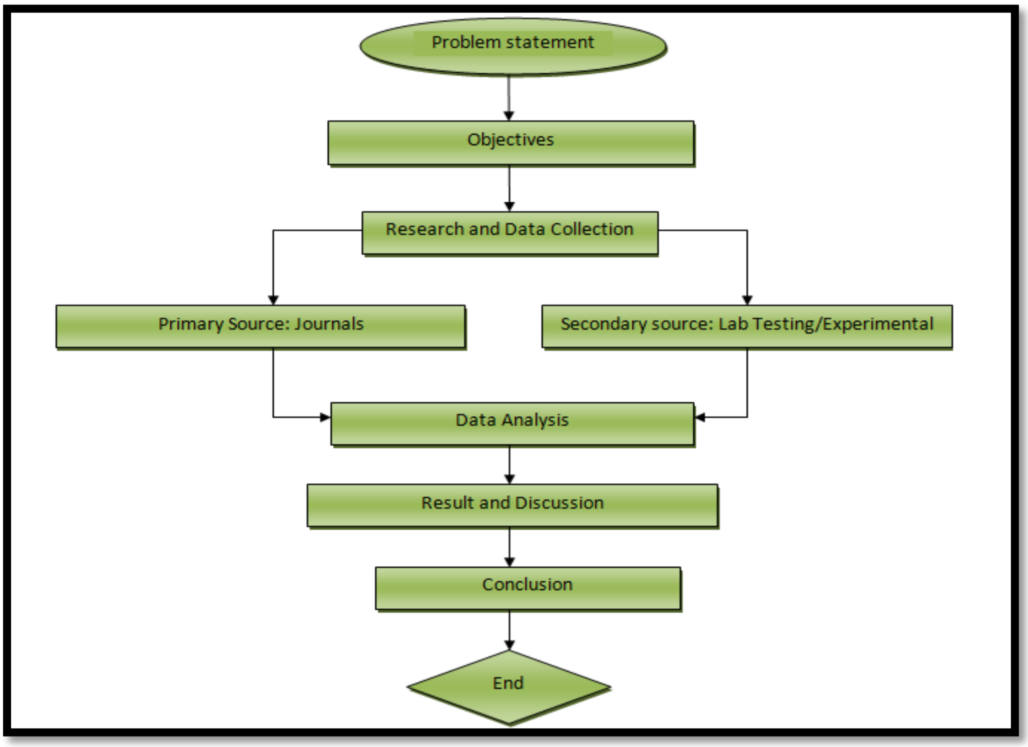

Figure 3.1: Methodology for the Research

3.2 Materials

Research materials and equipments are the main body in the methodology chapter. The materials involves in the production of foamed concrete are Ordinary Portland Cement (OPC), silica sand as fine aggregate, foaming agent and water.

3.2.1 Ordinary Portland Cements

Ordinary Portland cement used in order to produce the lightweight concrete. This is because the kind of cement is widely used and it is assumed to be applied in most construction. In addition, ordinary Portland cement is easily to get in market and readily available in laboratory. Cement is cohesive upon mixing with water.

3.2.2 Fine Aggregate

The fine aggregate comprises the portion of the aggregate, which has a small particle size. Fine aggregate as used in concrete normally is sand. It is filter materials is a sample of concrete mix to fill up all possible voids which appear in mixture. For this experiment, silica sand has used because silica sand already filtered and the size of the particles too small and suitable for foamed concrete mix.

3.2.3 Water

In concrete, water is very important materials to initiate the cohesive properties of the binder Portland cement through hydration process. In the presences of excessive water, the hardened concrete will lose their strength. The water should be clean from any impurities such as water from pipe.

3.2.4 Foaming Agent

Foaming agent is the material to produce foam. The purpose of foam is to control the density of lightweight foamed concrete as the bubble inside the foam will create voids to decrease the density of concrete. For this experiment, the forming agent-water ratio used is 1:25 by volume.

3.3 Equipments

The equipments use for this research and experiment are:

i. Bending test with 30 tonnes apparatus (Whiffle-Tree Method)
ii. Screw driller
iii. Foamed concrete mixer

Magnus frame and Apparatus 30 Tonne is the equipment use to test the bending moment, deflection, and stiffness of the structure. The method for this apparatus is "Whiffle-Tree System". "Whiffle-Tree System" is a system where the hollow steel should be placed at specific distances and arrangement for each test. The load will be applied on the panel until it gave the result of maximum loading. The Transducers will be attach at the apparatus to get the reading of the deflection occur on the panel during the test. Besides, another apparatus use in this experiment is screw driller. It used to connect the plywood with the Profiled Steel Sheeting infill with foam concrete. Another apparatus needed are formed generator and concrete mixer.

Figure 3.2: Screw Driller