THE FLEXURAL STRENGTH OF POLYSTYRENE SANDWICH BEAM

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ABSTRACT

During construction, the formwork for beam is widely used. This contributes to the increase in cost and time for the project. A precast beam is an alternative solution to do away with the formwork. One such beam which is gaining around is the polystyrene sandwich beam. A sandwich beam is a special form of laminated composite fabricated by attaching two thin but stiff skins to the lightweight but thick core. The benefits of using the sandwich concept in structural components are its high bending and high strength to weight ratios. This research aims to investigate the flexural strength of the polystyrene sandwich beam and also the crack pattern of the beam. It is achieved by using the Four Point Flexural Bending Test, (FPB). There are three types of sample. For sample 1 and 2, the beam consists of polystyrene wrapped with wire mesh and covered with concrete. Sample 3 is the same with sample 1 and 2 but has the reinforcement bars at the bottom of the beam. The highest load for this research is 21.6kN of sample 3 and the value for the its flexural strength is 15 kPa. The shear crack pattern can only be obtained from the sample 3 but none from sample 1 and 2. This research has produced a new sandwich beam design using polystyrene, which is also a form of precast beam under the Industrial Building Service (IBS).

ABTRAK

Semasa pembinaan, acuan untuk rasuk digunakan secara meluas. Ini menyumbang kepada peningkatan dalam kos dan masa untuk projek ini. Satu rasuk adalah penyelesaian alternatif untuk menghapuskan acuan. Satu rasuk seperti yang semakin popular adalah rasuk sandwic polisterin. Rasuk sandwich adalah satu bentuk khas komposit berlapis direka dengan melampirkan dua kulit nipis tetapi tebal dan ringan. Faedah menggunakan konsep sandwich dalam komponen struktur adalah kekuatan lentur dan tinggi yang tinggi kepada nisbah berat badan. Kajian ini bertujuan untuk mengkaji kekuatan lenturan rasuk sandwich polisterin dan juga corak retak rasuk. Ia dicapai dengan menggunakan Four Point Lenturan Ujian Lenturan, (FPB). Terdapat tiga jenis sampel. Bagi sampel 1 dan 2, rasuk terdiri daripada polisterin dibalut dengan dawai dan ditutup dengan konkrit. Contohnya sampel 3 adalah sama dengan sampel 1 dan 2 tetapi mempunyai bar tetulang di bahagian bawah rasuk. Beban tertinggi bagi penyelidikan ini adalah 21.6kN bagi sampel 3 dan nilai untuk kekuatan lenturan adalah 15 kPa. Corak retak ricih hanya boleh diperolehi daripada sampel 3 tetapi tidak di dapati daripada sampel 1 dan 2. Kajian ini telah menghasilkan reka bentuk rasuk sandwich baru menggunakan polisterin, yang juga merupakan satu bentuk rasuk bawah Perkhidmatan Bangunan Industri (IBS).

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CHAPTER 1

INTRODUCTION

1.1 Background of study

A structural sandwich is a special form of a laminated composite fabricated by attaching two thin but stiff skins to the lightweight but thick core. The benefit of using the sandwich concept in structural components is its high bending and high strength to weight ratios (Belouettar, S, *et al*, 2008).

The polystyrene sandwich beam is a new technology which is gaining around. There are some advantages to this type of beam that makes it a popular choice in the industry. Polystyrene is used in many aspects of building work including large structures such as public buildings or even small family residences. Polystyrene can be used to produce a beam element in order to be IBS compliant in construction. This pre-cast technology is manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works is important to reduce the time and cost exist, at the same time increase the quality.

This project will propose a beam design that is economical and practical. In this study, the primary focus will be on the flexural strength behavior and the crack pattern. The flexural strength test measures the behavior of materials subjected to simple beam loading.

1.2 Problem statement

Structural sandwich construction is used in many air and space vehicles, residential and also walling components. Connection of the sandwich construction component to a framework or substructure is a critical issue in the detail design for sandwich construction. Sandwich construction is one of the most functional forms of composite structures developed by the composite industry. It has attained broad acceptance in aerospace and many other industries and it is widely employed in residential construction. Sandwich construction provides several key benefits over conventional structures, such as very high bending stiffness, low weight, cost effectiveness and durability. The major advantage of this structural type is a very high stiffness-to-weight ratio and high bending strength.

A typical sandwich beam or panel usually consists of a honeycomb, foam or low-density wood cores sandwiched between isotropic or laminated facings. Sandwich construction has many advantages over the conventional structural constructions. Nowadays, the use of sandwich construction is further enhanced by the introduction of the Polystyrene Sandwich beam . Therefore, it is desirable to have further studies about the Polystyrene Sandwich Beam.

1.3 Objective

The objective of this research are as follows:

1. To determine the flexural strength of polystyrene sandwich beam.

2. To study the crack pattern on polystyrene sandwich beam.

1.4 Scope of study

This project concentrates more on designing polystyrene sandwich beam or expanded polystyrene beam for moment and shear using British Standard 8110 code. This project is only covers simply supported beam.

In this design, the beam size is chosen to be 3000mm X 200mm X 90mm, concrete grade is 25N/mm^2, concrete cover is 20mm, strength of reinforcement is 460N/mm^2, and the reinforcement bar is 6mm in diameter. Three types of polystyrene sandwich beam samples are being proposed. Two beams use different diameter of wire mesh and the other one uses wire mesh with reinforcement bar.

The research has been carried out using British Standard 8110. Figure 1.1 below show the arrangement of polystyrene sandwich beam. Figure 1.2 show the cross section of beam for sample 1 and sample 2. Figure 1.3 is the arrangement of the polystyrene sandwich beam for sample 3.

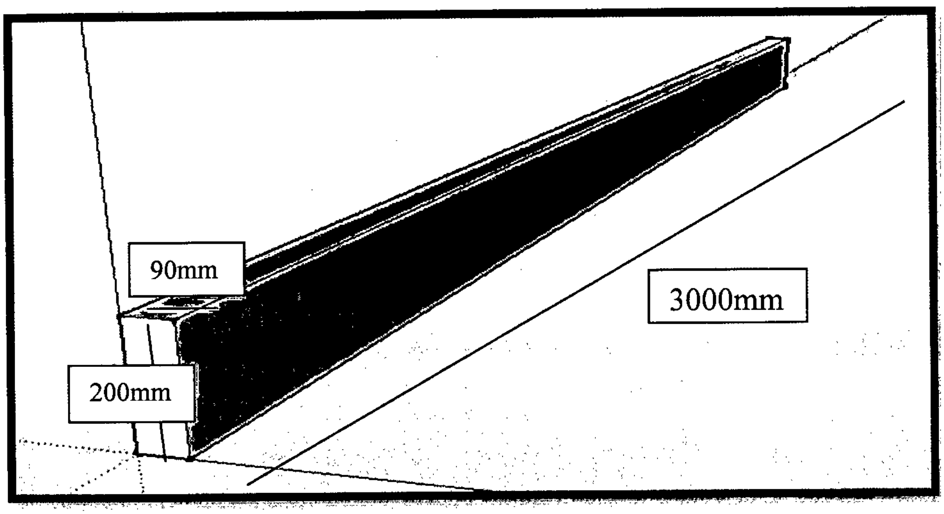


Figure 1.1: The arrangement of Polystyrene Sandwich Beam.

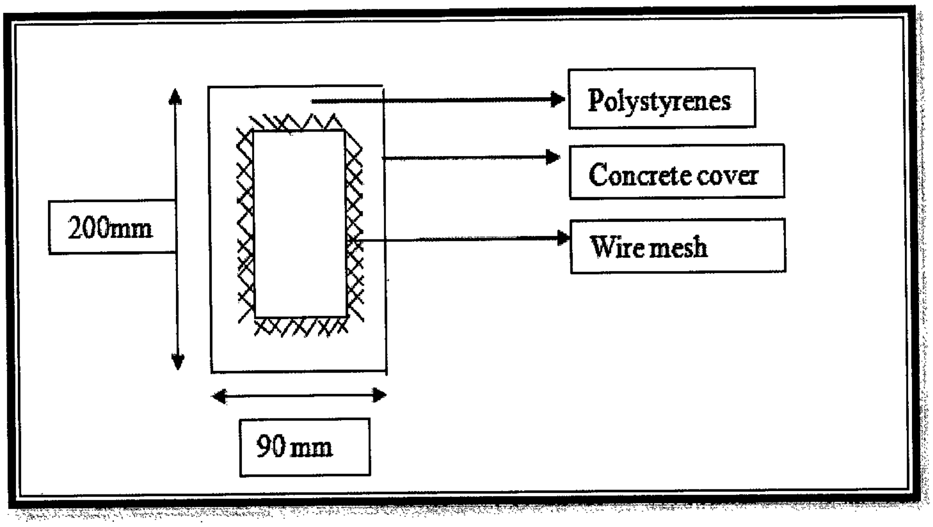


Figure 1.2: The cross section of Polystyrene Sandwich Beam using wire mesh only for sample 1 and 2.

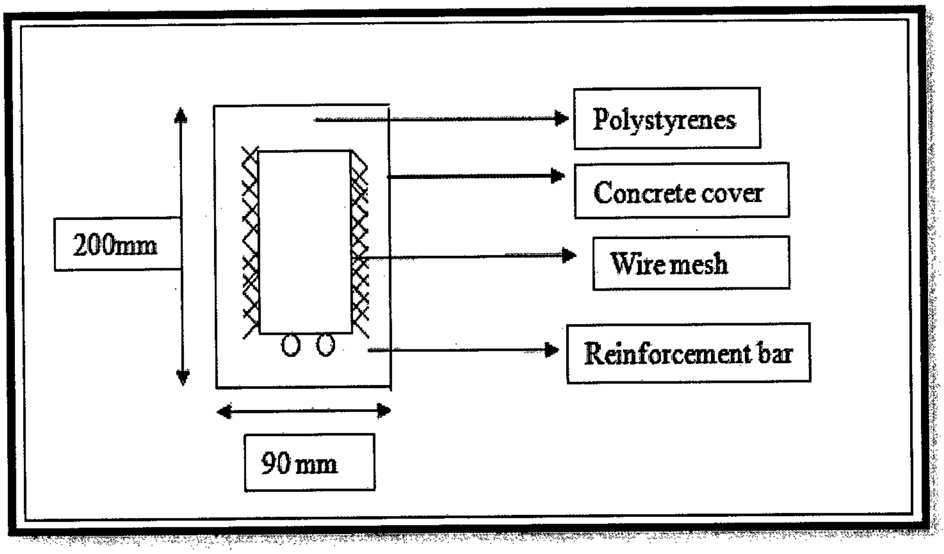


Figure 1.3: The arrangement of the Polystyrene Sandwich Beam using wire mesh and reinforcement bar for sample 3.

1.5 Expected outcome

This research will require producing a new sandwich beam design using polystyrene. Besides that, it also produces precast beam that complies with Industrial Buildings service (IBS).

The polystyrene sandwich beam will be tested using Four Point Flexural Bending Test to get the flexural strength and crack pattern on the beam.

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

The purpose of a literature review is to analyse and convey to the reader the knowledge and ideas that have been established in the published literature related to polystyrene sandwich beam and its strength. Other than that, the purpose of a literature review is also to identify data sources that other researchers have used, and to discover how a research project is related to the work of others. In this chapter, related literature review are from the primary resources of published materials such as books, journal articles, research papers and thesis.

2.2 Sandwich structure

Amongst all possible design concepts in composite structures the idea of sandwich construction has become increasingly popular because of the development of man made cellular materials as core materials. Sandwich structures consist of a pair of thin stiff, strong skins (covers) and a thick lightweight core to separate the skin and carry loads from one skin to the other (Petras, 1998). An example of the structure of a sandwich beam is show in Figure 2.1.

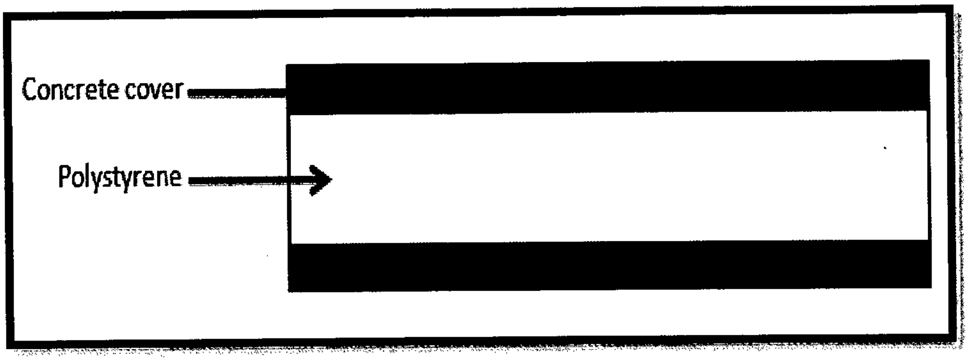
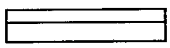
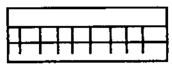
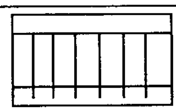


Figure 2.1: The structure of sandwich beam.

Table 2.1 below shows the flexural stiffness and strength advantage of sandwich panels compared to solid panels using typical beam theory with typical values for skin and core density. A stiffer beam has a high modulus of elasticity and high second moment of area that produces less deflection (Asnie.M, 2010).

Table 2.1: Show an example of structural efficiency of sandwich beams in terms of weight and the stiffness.

			
Relative Bending Stiffness	1	7.0	37
Relative Bending Strength	1	3.5	9.2
Relative Weight	1	1.03	1.06

2.3 Four point flexural test.

The four point bending has the advantage that subjects a beam to a constant bending moment and zero shear force between the center rollers (Harte, Fleck, & Ashby, 2001). The flexural test measures the forces that required bending a plastic beam under four point loading system. The difference between three point loading and four point loading flexural tests is the location of the bending moment. The four point bending method allows for uniform distribution between the two loading noses, while the three point bending method stress is located under the loading nose or at the middle of the beam. Figure 2.2 below show the Four Point Flexural Bending Test.

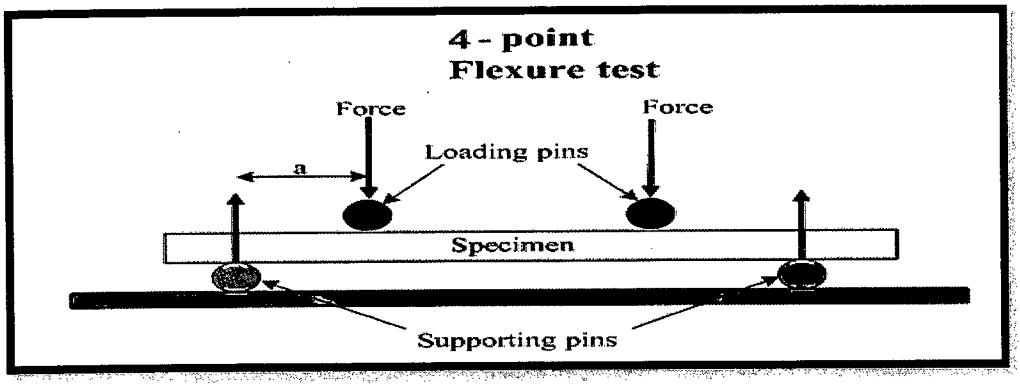


Figure 2.2: The four point flexural bending test.

The formula to calculate the flexural strength is:

- For a rectangular sample under a load in a four point bending. Where the loading span is one third of the support span:

$$\sigma = \frac{FL}{bd^2}$$

F = The load (force) at the fracture point
L = The length of the support (outer) span
B = Width
D = Thickness

- For the four point bending setup, if the loading span is half of the support span:

$$\sigma = \frac{3FL}{4bd^2}$$

- If the loading span is neither 1/3 or 1/2 the support span for the four point bending setup:

$$\sigma = \frac{3F(L - L_t)}{2bd^2}$$

L_t is the length of the loading at the middle span.

2.4 Beam structure

Beam is a member subjected to loads applied transversely to the long dimension and it will cause the member to bend. Beam are primarily designed to resist bending moment, however if they are short and carry large loads, the internal shear force may become quite large and this force may govern their design (R.C.Hibbler, 2009). Beams are classified on the basis of supports or reactions. A simply supported beam is supported by pin, rollers and smooth surfaces at the ends (R.C.Hibbeler, 2005).

By using highly deformable material such as rubber, it can physically illustrate what happens when a straight prismatic member is subjected to a bending moment. Figure 2.3A below is the undeformed bar which has a square cross section and is marked with longitudinal and transverse grid lines. When bending moment is applied, it tends to distort these lines into a pattern like Figure 2.3B. Here it can be seen that the longitudinal lines become curved and the vertical transverse lines remain straight and yet undergo a rotation (R.C.Hibbeler, 2008).

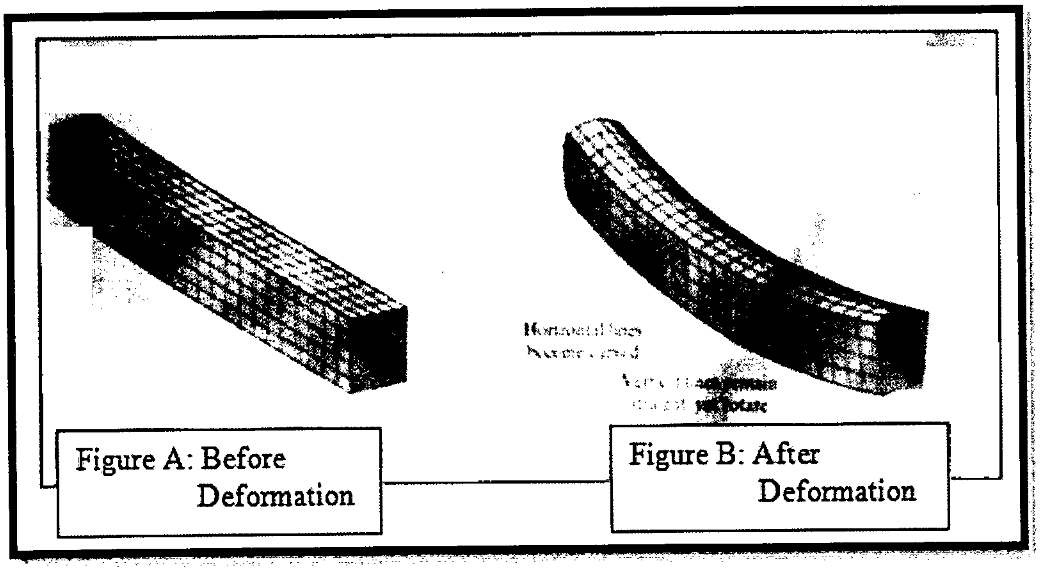


Figure 2.3: The bending deformation of a straight member in beam.

2.5 Sandwich beam

Sandwich beams are used in applications requiring high bending and strength combined with low weight (Steeves,C. & Fleck,N, 2004). The sandwich constructions have excellent characteristics, such as mass saving, high specific stiffness (bending stiffness with respect to the mass), good fatigue properties, sound damping properties, fire resistance and good thermal and insulation properties. Nowadays, the polystyrene is used for floor, wall foundation, slab and roofing insulation Polystyrene is to be installed in accordance with local building codes and engineering specifications. Insulation for use in high strength applications (soils and civil engineering) to either prevent heat from leaving the ground or, in the case of permafrost applications, to prevent heat from entering the ground (Runways et al., n.d.). When compressive loads are applied to the insulation layer, such as under a concrete slab the stress limits provide a factor of safety and means to limit long-term compressive creep in the insulation layer. Besides that, the allowable stress limits are defined based on a percentage of minimum insulation compressive resistance. The Figure 2.4 below show the structure of polystyrene used for the slab.

Figure 2.4: The polystyrene used in the slab structure.

Celfort 300 & Foamular Insulation Boards proved the polysterene can used for foundation wall to reduce the heat flow through the floor slab and prevent frost penetration. Insulation that is installed on the inside of the foundation wall will increase the temperature of the floor slab. Insulation may be installed on the outside of the foundation as well but must be protected above the ground level. The thickness and location of insulation in a shallow foundation are dependent on whether the building is heated or unheated, the type of soil and building location. The Figure 2.5 below, shows the polystyrene on the foundation wall.

Figure 2.5: The polystyrene used on the foundation wall.

Hanson Heldelberg Cement Group, also used the polystyrene for the jetfloor. Since its introduction in 1982, Jetfloor has been the market leading solution for thermally insulated, structural ground floors. The benefits of using jetfloor are that it is easy and quick to construct with no special skill workers required. The Figure 2.6 below shows the construction of jetfloor by using the polystyrene.

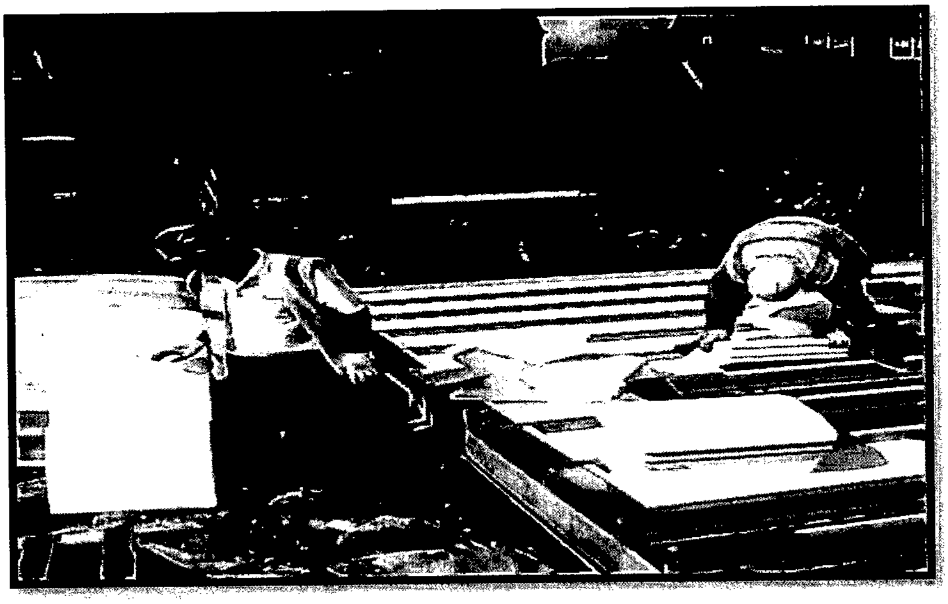


Figure 2.6: The polystyrene uesd for the floor.

2.6 High stength polystyrene

Polystyrene is a term for polystyrene and styrene copolymers that expand into a variety of useful products. Polystyrene is supplied to moulder in the form of a polystyrene bead, polystyrene beads are loaded with a blowing agent, usually pentane, and other chemical agents and additives that give the beads expansion vibrancy and allow them to be processed and moulded into low-density foam articles, polystyrene is comprised of 90 percent air. The shock absorbing properties and other qualities of polystyrene combined with its low-cost, high insulating properties, custom mol ability and ease of processing make it a popular packaging material (Technical Buletin, 2000).

2.6.1 Characteristic of polystyrene

Tensile Strength ranges of polystyrene are between 20 to 400kPa, depending on the type and the thickness. Polystyrene is combustible as defined in BS 476:Part 4. During burning, polystyrene behaves like other hydrocarbons such as wood and paper (British Standard 476, Part 4. The density of polystyrene is between 10 to 35kg/m^3 which is light and safe for the construction. It also has low thermal conductivity due to its closed air-filled cell structure that inhibits the passage of heat or cold, a high capacity for thermal insulation is achieved. The material is flexible that no allowance need be made for thermal expansion in the method of insulation (Properties, 2000).

2.7 Crack pattern on beam

The control of cracking in concrete structures is a desirable matter to satisfy durability. In the previous studies, many investigations are focused on tensile and flexural cracks for Reinforced Concrete (RC) members. The aim of this section is to show the main differences between shear cracking mechanism and flexural cracking mechanism in RC members. Shear crack opening displacements in RC members are usually accompanied by shear crack sliding displacements along shear cracks which create shear transferred by aggregate interlock. Besides that, shear sliding displacement which is related to shear opening displacement is a main factor for fracturing of shear reinforcement, especially under cyclic loading. The region of constant bending moment only tensile and flexural crack width occur without sliding along the crack.

In a previous study, the diagonal crack spacing is not significantly affected by the type of shear reinforcement bars (Hassan et al, 1991). A shear crack generally crosses shear and tension reinforcement diagonally, while the flexural crack intersects perpendicular main longitudinal reinforcement.

From the previous study it is found that the diagonal crack spacing can be related to the crack control characteristics of both the longitudinal and transverse reinforcement, which can be represented by vertical and horizontal crack spacing as illustrated in Figure 2.7. The vertical and horizontal crack spacing are the spacing which would occur under the tension in the direction perpendicular to the longitudinal and transverse reinforcement (Collins and Mitchell, 1991).

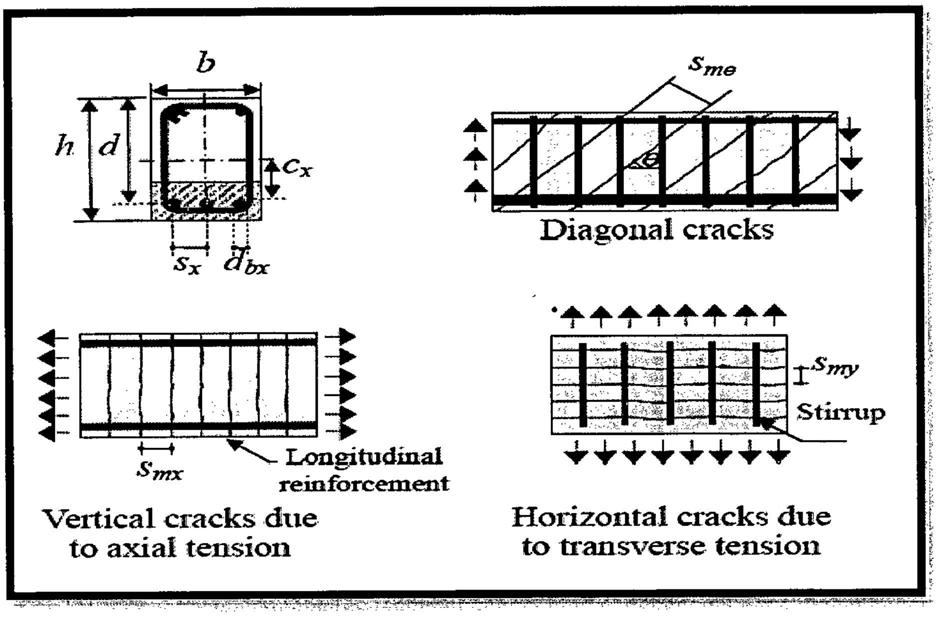


Figure 2.7: Characteristics of diagonal crack spacing (Collins and Mitchell 1991).

2.8 The advantage of sandwich beam

2.8.1 Weight reduction

The polystyrene sandwich beam can reduce the use of raw materials such as cement. It is because the polystyrene sandwich beam uses other composite at the middle of the beam. The material used in the middle is usually light and from recycled substances. This can reduce waste and increase material economy.

2.8.2 Easy in application

The low weight of Polystyrene makes it easy to handle and to transport to site. Polystyrene can be cut into the shape or size required by the construction project.

As a conclusion, the previous study show that the polystyrene has a lot of benefits in the construction. Mostly polystyrene is used in slab, flooring, roofing and also foundation wall. It is because polystyrene is easy to shape, and lightweight. The high strength polystyrene also can reduce the use of raw material like cement and aggregate. Futhermore, it also can reduce the pollution to the environment. Polystyrene can also be used in the construction of a precast beam. It also saves construction time due to its easy accessibility. Sandwich beam is a new technology and complies to the IBS in construction. By using the polystyrene, the versatility of the precast beam will be increased. This research is to know the flexural strength for the polystyrene sandwich beam.