EFFECT ON FLEXURAL STRENGTH OF JOIST DUE TO EXTERNAL SIDE REINFORCEMENT

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ABSTRACT

Reinforced concrete (RC) joists is a concrete structural components that exist in buildings in different forms with different strength and durability. Understanding the response of these joists components towards working load is necessary to the development of a safe and efficient structure. Various difficulties and problems we face through in daily life makes us think further and creatively to solve that certain problems with the specific solution. Therefore, there are few things that become enquiries based on the application of joists in upper floor construction is firstly the ability of designed joist with fixed dimension and geometry to act as permanent and temporary support to upper floor construction. This research primary scope is about the external reinforcement to be placed on the side of the joist. Therefore something to be focused on here is the effect towards flexural strength of joist due to different location of external side reinforcement. Does the side reinforcement will help in strengthen the joist or vice versa. These were things to be answered at the end of the study. There are two main objectives in this study. First is to measure the ultimate flexural capacity of designed RC joist to resist loading subjected from slab. The second objective is to observe any effects of side reinforcement towards the flexural strength of RC joist. These two aim is to be completed by laboratory testing. The four point flexural test will be conducted in specification of standard required based on previous research findings. Structural lab of Faculty of Civil Engineering, UMP will be used to proceed the testing. Thus at the end of this study, perhaps all the objectives can be achieved and the problems stated above is solve.

ABSTRAK

Rasuk bertetulang (RC) adalah komponen didalam struktur konkrit yang dimana ia wujud dalam pelbagai bentuk yang berbeza mgikut daya ketahanan dan kakuatan bersesuaian dengan sesuatu bangunan yang bakal dibina. Pemahaman terhadap reaksi rasuk tersebut terhadap daya yang dikenakan adalah amat penting dalam membina satu struktur yg efisen dan selamat. Sesuatu kajian dibuat berdasarkan apa yang kita telah, sedang dan mungkin bakal dialami dalam kehidupan seharian melalui pelbagai kesukaran dan masalah. Masalah-masalah tersebut membuatkan kita berfikir jauh dan lebih kretif bagi mnyelesaikannya melalui penyelesaian yg terperinci dan spesifik. Beberapa perkara yang mungkin boleh menjadi persoalan berdasarkan implikasi rasuk dalam pembinaan aras atas yang pertama adalah keupayaan rasuk yang direka dengan dimensi dan geometri yang ditetapkan untuk bertindak sebagai sokongan tetap dan sementara untuk pembinaan lantai aras atas. Skop utama kajian ini adalah mengenai kayu tepi yang dilekatkan di sebelah rasuk. Oleh itu topik yg perlu diberi perhatian di sini adalah berkenaan kesan kayu tepi terhadap kekuatan lenturan rasuk kerana lokasinya yang berbeza. Adakah kayu tepi akan membantu dalam mengukuhkan rasuk atau sebaliknya. Ini adalah perkara-perkara yang perlu dijawab di akhir kajian. Terdapat dua objektif utama dalam kajian ini. Pertama adalah untuk mengukur keupayaan lenturan maksima rasuk yang direka untuk menahan daya yang dikenakan aras atas kepadanya. Objektif kedua adalah untuk melihat apa-apa kesan kayu tepi terhadap kekuatan lenturan rasuk bertetulang. Kedua-dua matlamat ini bakal dipastikan melalui ujian makmal. Empat titik ujian lenturan akan dijalankan berdasarkan spesifikasi standard yang diperlukan berdasarkan hasil penyelidikan sebelum ini. Makmal Struktur Fakulti Kejuruteraan Awam, UMP akan digunakan untuk meneruskan ujian. Oleh itu pada akhir kajian ini, diharap kesemua objektif boleh dicapai dan masalah yang dinyatakan di atas dapat diselesaikan.

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CHAPTER 1

INTRODUCTION

1.0 Background of Study

Reinforced concrete (RC) beams is a concrete structural components that exist in buildings in different forms with different strength and durability. Understanding the response of these beam components towards working load is necessary to the development of a safe and efficient structure. In order to analyze their response toward applied loading, different methods and research have been conducted. Experimental based testing of behavior and ultimate failure mechanisms of RC beams is an effective approach to conduct the research and the effects to concrete durability under loading. Even though this method sure generate more cost compared to computer software models but it help to better understand their in-situ response in RC structure. Thus a more realistic designs can be assigned.

The application of RC beam in building construction is widely used eventhough there are hundreds of structure collapse in 10 years back due to beam fail to resist the external loading applied to it. Understanding on the structural design works of RC beam is an important study in viewing the behavior of construction material when subjected to load. Such studies allow the maximum capacity of flexural force can be resisted by a normal RC beam and further improvements, especially in terms of structure's safety can be determined by certain test that will be discussed as this paper goes through.

In this study, a series of joists is arranged in transverse to interlocking block in order to restrain directly from slab and eventually replace the usage of scaffolding in construction site. Scaffolding is defined as any structure, framework or a suspended scaffolding of a temporary nature, used for the support or protection of workers engaged in or in connection with construction work, for the purpose of carrying out that work or for the support of materials used in connection with any such work; and includes any scaffolding constructed as such and not dismantled, whether or not it is being used as scaffolding; and also includes any plank, coupling, fastening, fitting or device used in connection with the construction, erection, or use of scaffolding (J. M. Chetwin, 1995).

Additional information for readers, in this paper and research I will be using the term 'joist' instead of beam whenever and whichever related to my experiment and approach. While term 'beam' is used as regarded to other researches such contains in literature review. Joist is an element of beam which is properly defined by Definition.net as a number of small parallel beams laid horizontally to which the planks of the floor or the laths or furring strips of a ceiling.

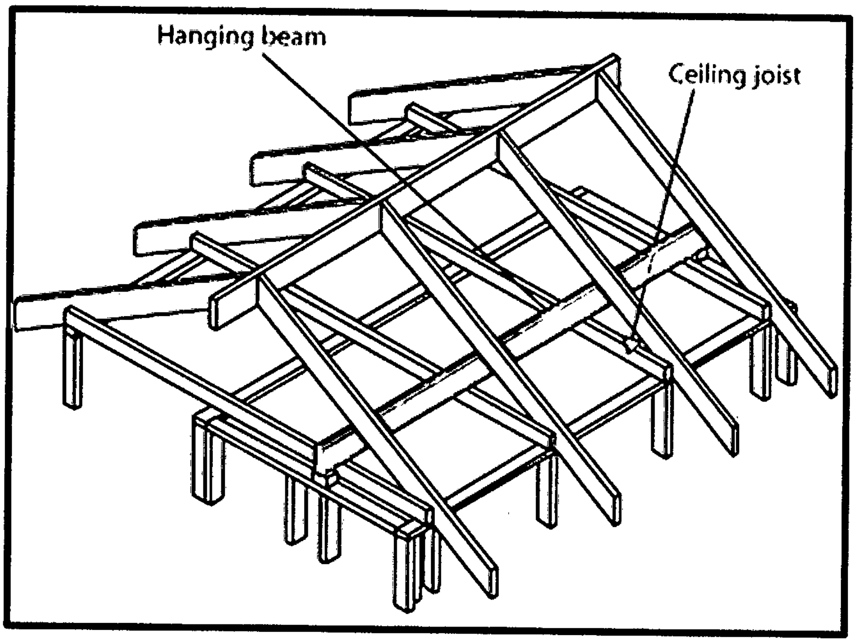

Figure 1.1: Illustration between joist and beam

1.1 Statement of Problem

A study is made based on what we had learned in our daily life through various difficulties and problems. Few things that might become questionable based on the application of joists in upper floor construction is firstly the ability of designed joist with fixed dimension and geometry to act as permanent and temporary support to upper floor construction. This research is primary about the side reinforcement to be placed on the side of the joist. Therefore something to be declare here is the effect towards flexural strength of joist due to different location of external side reinforcement. Does the side reinforcement will help in strengthen the joist or vice versa. These were things to be answered at the end of the study.

1.2 Objectives

i. To determine the flexural capacity of designed RC joist to resist loading from slab using the four-point flexural test.
ii. To observe any effects of side reinforcement towards the flexural strength of RC joist.
iii. To study the crack pattern appears on joist.

1.3 Expected Outcomes

Presently, the main markets for application of Integrated Building Systems (IBS) in construction world has very high demand. Basically this study is still fresh and none of researchers had done further deep research through this matter. So hopefully this study able to act as a basic requirements and control specimens for the next related researches which is collaborated with the interlocking block. Furthermore, all the objectives is expected to successfully achieve at the end of the study. The data obtained will help engineers to determine the suitability of proposed size and design of joist to maintain as permanent support to slab without being restrained at any point.

1.4 Scope of Study

In this study, I need to understand the ASTM C78 / C78M standard test method for flexural strength of concrete (using simple beam with third-point loading) for reinforced concrete (RC) joist designed and also to highlight the importance of proposed dimension and specification of the joist. With the placing of side reinforcement onto the joist, does it will affect the flexural strength or not is going to be observed and analyzed. Furthermore, the advantages of using set arrangement of small joists in replacing the usage of scaffolding in upper floor construction will be discuss.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

B. Singh and M. Gupta, 2005 taken from his journal *Structural Design for Natural Fiber Composites for Building Applications* once said that when a beam with a straight axis loaded by lateral forces, the axis which mean the beam will deformed into a curve called the deflection curve of a beam. Hence, the displacement of beam in the direction of y – axis at any point along a straight line is called a deflection. The measurement of deflection plays a crucial assist in construction of buildings and structures. Thus this literature review will briefly enlighten us a few basic things about beam such as the characteristic that includes definition bending and deflection on words and calculation. Further review will brings us to the knowledge related to the four-point loading flexural test which explained through calculation to obtain the flexural strength, how it is being setup. This will bring few matter from different definition of test setup to be compared of.

2.1 Characteristics of RC Beam

Behavior of an RC beam can be predicted within the elastic boundary is available by the Hook's Law, expressed by stress graph as a linear function of strain and modulus elasticity. This is because RC beam loaded close to its ultimate strength capacity during high tension pressure applied such as from nature phenomenon; earthquake hence calculation for the beam behavior is crucial and important.

2.1.1 Bending and Deflection of Beam

When a beam with a straight longitudinal axis loaded by lateral forces, the axis is deformed into a curve, called the deflection curve of a beam. (B. Singh, M. Gupta, 2005). From what I have understand, deflection of beam is a displacement of that a point of loading at certain point from its original position measured in y direction. The induced deflection forces can be described by how beam were supported. The ability of support to restrict lateral, rotational movements as well as to provide stability can limit the deformations to a certain allowance. For example, a simply-supported beam loaded at its third-points will deform into the exaggerated bent shape shown in Figure 2.1.

A beam supported by pins, rollers, or smooth surfaces at the ends is called a simple beam (R. Burgueno et al, 2004). The simple bending theory for beams relates the internal strains in beams due to bending deformations or curvatures to the moment action that causes these deformations (R. C. Hibbeler 2005). There are three type of loading for a simply supported beam, single point loading, two equidistant loads and uniform distributed loading. In next final report am going to focus about two equidistant loading which is the theory to be applied in laboratory testing.

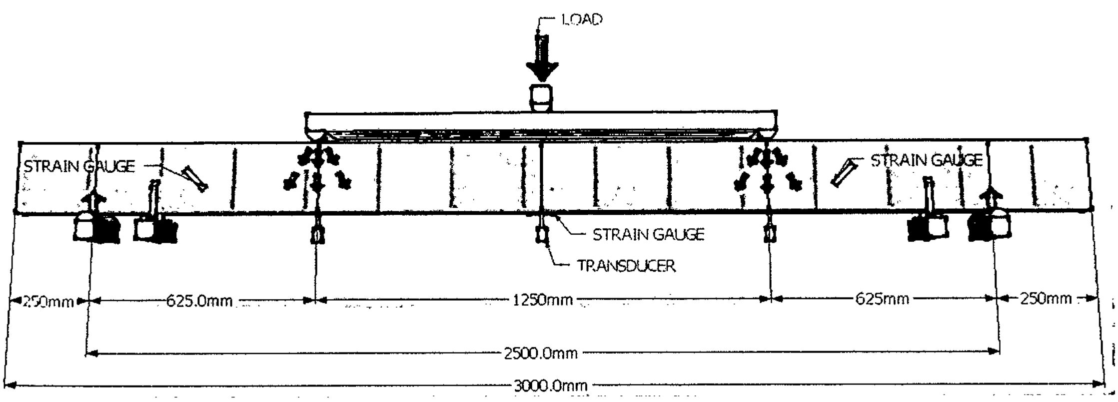

Figure 2.1: Examples of a beam (4 point loading)

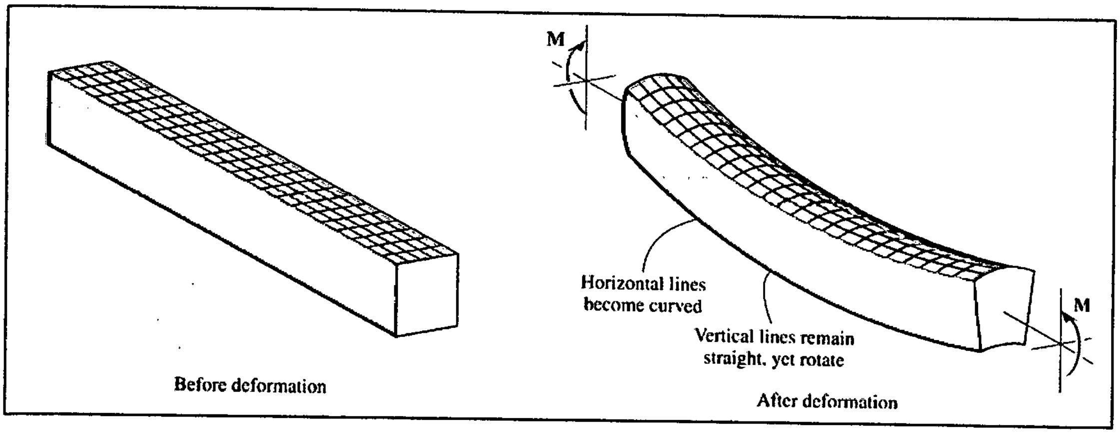

Figure 2.2: Initially straight beam and the deformed bent beam

Figure 2.2 shows an initially straight beam deformed into a bent beam. The vertical lines will remains straight on its axis and plain but do rotated due to the distortion. According to the stress and strain theory from R. C. Hibbeler, 2005, the beam is analyzed using the Euler-Bernoulli beam equation as shown below

$$\sigma = \frac{My}{I_x} \qquad \textbf{eq 2.1}$$

Where
σ is the bending stress
M is the bending moment at neutral axis
y is the perpendicular distance to the neutral axis
I_x is the second moment of inertia about the neutral x axis

Equation above is valid only when the stress at the portion of the beam furthest from the neutral axis is below the yield stress of the beam material. At higher loadings the stress distribution becomes non-linear and ductile materials will eventually enter a plastics state where the magnitude of the stress is equal to the yield stress at any point on the beam (Shi, 2008). If there is continuity at the neutral axis, the stress chances from tensile to compressive. This plastics state is used as limit state in the design of structures.

2.2 Four Point Loading Flexural Test - ASTM C78 / C78M

This test method is used to determine the flexural strength of specimens prepared and cured in accordance with Test Methods C42/C42M or Practices C31/C31M or C192/C192M. Results are calculated and reported as the modulus of rupture. The strength determined will vary where there are differences in specimen size, preparation, moisture condition, curing, or where the beam has been molded or sawed to size.

2.2.1 Flexural Strength Calculation

This test method covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading. The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard (ASTM C78 / C78M - 10, 1996). It is used in testing concrete for the construction of slabs and pavements. Beam flexure represents one of the three most common loading categories for mechanical systems. Four points loading flexural test is to prescribe the flexural strength of specimens of hardened concrete by means of a constant moment in the center zone. The flexural strength of concrete is given by the expression:

$$fct = \frac{3F}{d^2}\left(\frac{N}{mm^2}\right) \qquad \text{eq 2.2}$$

Where
F is the maximum load in Newton
d is the length of the side of specimen in mm

2.2.2 Test Setup

There sure are a lot of previous research related to using four-point loading test to measure the ultimate flexural strength or to observe the behavior of samples according to cracks pattern and amount of deflection due to continuous loading. There are lots of varieties in information collected but unfortunately only few of them is able to state clearly the reasons for using the specified distance although figures and dimension is given. Therefore it is quite difficult for me to verify the true values and sources that will give the best result for this research paper. I am going to review and compare a few theory and previous research on apparatus setup that includes the position shear distance α, effective span, Le versus the actual joist length, L. Consideration toward most suitable setup is noted and will be used in my laboratory testing

2.2.2.1 Review 1

S.C. Chin, N. Shafiq and M.F. Nuruddin (2010) is an associate from Universiti Teknologi PETRONAS were doing research on structural performance of reinforced concrete beam containing used engine oil based on the flexural strength test of the beam. They provide few beam samples with 120 mm x 260 mm cross section and 1800 mm clear span were simply supported and then the sample is loaded in a four point arrangement with a constant moment region of 600 mm. The reinforcement of the beams is shown in Figure 1. Steel stirrups of 6 mm diameter were used at 150 mm spacing along the beam length for all beams. The top and bottom steel reinforcements were 12 mm diameter size. The test setup is shown in Figure 2.

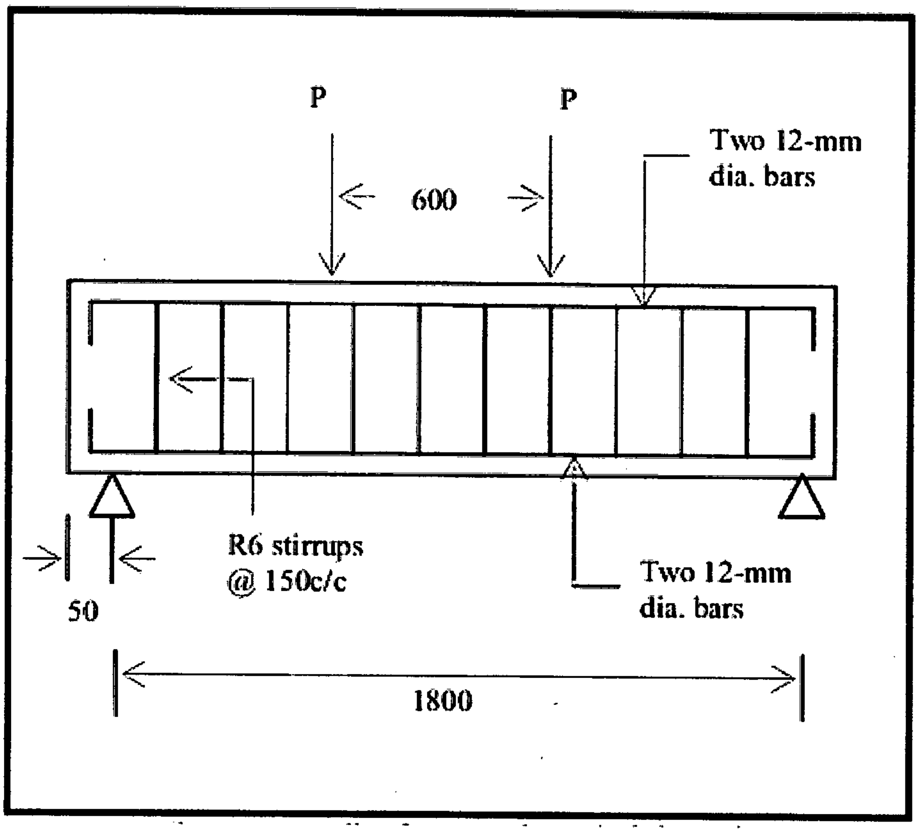

Figure 2.3: Reinforcement arrangement diagram (unit in mm)

Thus some information gathered from above research is stated below:

- Shear distance, α = L/3 = 600mm from support
- Actual span, L = 1900mm
- Effective span, Le = 1800mm

2.2.2.2 Review 2

Second review is on research written by J M Hodgkinson (2000) about mechanical testing of advance fibre composite. To make it clear J M Hodgkinson was explained about two possible testing method to be use in testing the flexural strength of a fibre concrete sample. I can find his research was compromising when come to part 7.3.1 Specimen dimensions and testing arrangement where he manage to explain every reason and source of data obtained to conduct the test he made.

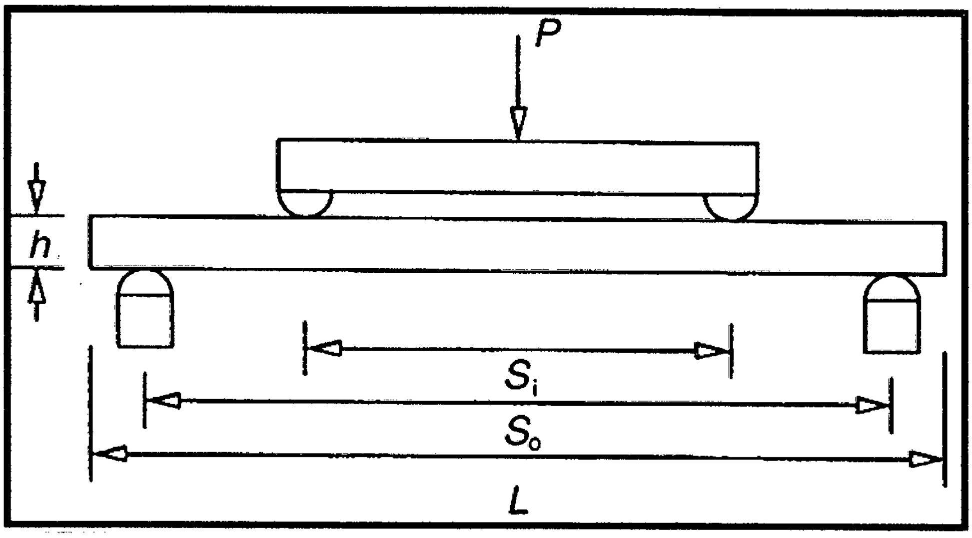

Figure 2.4: four-point flexure diagram by J M Hodgkinson

Above figure show the general unit for test setup for four-point flexural test where h is the thickness, L is the actual span and S_0 is the effective span of the specimen. The data was referred from ASTM specifications which allow a wide freedom of choice in terms of specimen dimensions, as long as the cross-section is rectangular and specific span-to-thickness (L/h) ratios are adhered to. The ASTM specification allows a series of different L/h ratios (16: 1, 32: 1, 40: 1 and 60: 1) in four-point bending test. ASTM offers two arrangements for four-point loading, with the loading points set at either 1/3 or 1/4 of the support span or effective span, Le. The ASTM specification includes a series of tables which indicate the appropriate specimen width, length, support spans (and loading span for four-point testing) and rate of crosshead motion (based on the strain rate of 0.01 mm mm^{-1}) for the full range of specimen thicknesses and span-to-thickness ratios allowed as showed in figure 2.5. This is all very well but, given the range of possibilities, it is not clear under which set of conditions a particular type of material should be tested in order to obtain meaningful results.

Table 2.1: Possibilities for support and loading nose radii, span-to thickness ratios and loading rate in several specifications.

Specification	Support nose radius (mm)	Loading nose radius (mm)	Span-to-thickness ratio	Strain rate ($mm\,mm^{-1}$) or failure time
ASTM D790M	3–1.5*h*	3–4*h*	16, 32, 40, 60:1	0.01 and 0.1
BSI 2782	2	5	16:1	0.01
CRAG	3, 5	5, 12.5	16, 20, 25, 40:1	Failure time 30–180 s

Thus some information gathered from above research is stated below:

- Shear distance, α = Le/3 or Le/4 from support
- Actual span, L obtained from L/h ratios (16: 1, 32: 1, 40: 1 and 60: 1) where h is the span thickness

2.2.2.3 Review 3

Next review is a journal written by Chithra Rethnasamy, Thenmozhi Rajagopal and Hareesh Muthuraj (2011) a partner from Tamilnadu, India with the title of Bending behavior, deformability and strength analysis of Prefabricated Cage Reinforced Composite beams. Eighteen PCRC beam specimens and three equivalent RCC beam specimens were considered in this study. All the beams had the same dimensions 150x200x2500 mm and were simply supported with an effective span of 2080 mm c/c. Figure 2.6 is an illustration on experimental setup of the research.

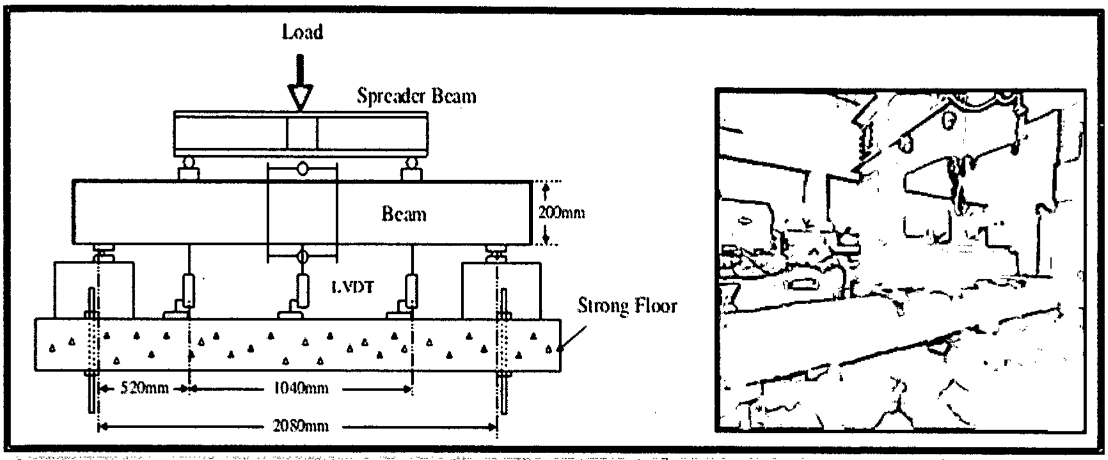

Figure 2.5: Test setup over strong floor

As we can see above the shear distance, α equal to 520mm over the length of 2080mm and this mean the shear distance taken one-fourth of the effective distance. This also can be an evidence to theory 2 above where α can be taken 1/4Le. There were few assumption be made in the analytical study that might be useful:

1. Plane sections remain plane even after bending.
2. The stress–strain curve for cold formed sheet is the same both in tension and compression.
3. Tensile strength of concrete is neglected.
4. Compressive stress distribution is represented by a rectangular stress block.
5. The steel in the compression zone is neglected in the calculation of moment of resistance.
6. The stress strain relationships for steel and concrete are elastic perfectly plastic. The plastic strength of the steel is equal to f_y (f_y is the yield strength of the steel). The plastic compressive strength of the concrete, f_c is equal to the characteristic compressive design strength of the concrete material, f_{ck}).
7. The enhancement in concrete strength due to partial confinement provided by prefabricated cage is taken as the partial safety factor for materials.

2.3 Case Summary

Decision had been made to select the most suitable setup from three theories above and these results will be used to specify the apparatus setup for this research. Further explanation on figures and procedure used will be discussed in the next chapter. Table 3 below show the details.

Table 2.2: Apparatus setup details

Effective span, Le	Shear Distance, α	Actual distance, L
Varied	Le/4	L/h ratios 16: 1, 32: 1, 40: 1 and 60: 1

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

There are two main objectives in this study. First is to measure the ultimate flexural capacity of designed RC joist to resist loading subjected from slab. The second objective is to observe any effects of side reinforcement towards the flexural strength of RC joist. These two aim is to be completed by laboratory testing. The four point flexural test will be conducted in specification of standard required based on previous research findings. Structural lab of Faculty of Civil Engineering, UMP will be used to proceed the testing. Figure 3.1 show the methodology flow chart of my study.