DRY MASONRY BRICK HOUSE SYSTEM-TENSILE STRENGTH ANALYSIS FOR VERTICAL REINFORCEMENT MEMBER

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CERTIFICATION OF APPROVAL

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By

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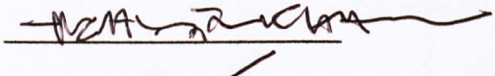

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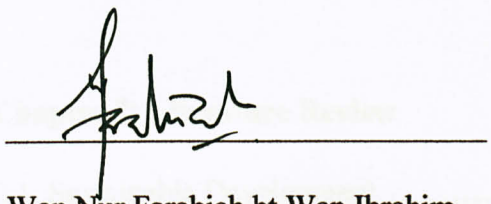
UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



Wan Nur Farahiah bt.Wan Ibrahim

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Year by year, the production of municipal solid waste become increase caused by increasing number of population especially at urban areas like Kuala Lumpur,Shah Alam and others. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing. The increasing rate of municipal solid waste generation must be taken as a big problem because it can cause negative impact to our environment if municipal solid waste does not manage efficiently. Municipal solid wastes are come from many sources like residential areas, factories, restaurants, and more.

Municipal solid waste can be divided into 4 broad categories which are biodegradable waste, recyclable material, construction and demolition waste(C&D), and hazardous waste. Based on prediction statistic, from year 1995 to 2025, in Malaysia, the production of municipal solid waste will increase 4 times with increasing 72% of generation rate. If this statistic is accurate, one day, our generation will live in the country with full of waste. The ideas to reduce and minimize the production of municipal solid waste are very important to sustain our country and also our world.

As a effort to reduce municipal solid waste generation, one new structural building system called Dry-masonry Brick House System or DBHS being constructed by a group of researchers lead by Prof.Yasunori Matsufuji of Khusyu University. DBHS is utilized by a construction method called "Steel Reinforced Brick based on Distribution Unbonded Prestress Theory"(SRB-DUP). In this system, mortar is not required but in order to tie these layers of brick together, steel nut, round and spring washer are used

Through DBHS, the production of municipal solid waste from construction and demolition waste (C&D) can be reduced. This because DBHS is a sustainable housing model that promotes 3R: Reduce-Reuse and Recycle. The DBHS structure can be

dismantled easily and from dismantle process 98.32% of bricks can be reused and 1.66% can be recycled. For other parts like steel bolts, nuts and plates can be 100% recycled.

1.2. PROBLEM STATEMENT

Dry-masonry brick house system or DBHS is one of new type of structural building system that already applied in construction of housing units in Japan. This structural building system is constructed by group of researchers from Japan, so this system strictly comply Japanese Standard and specification.

As we known, Malaysia and Japan are totally different especially based on climatic condition where Malaysia is hot and humid condition while Japan has 4 seasons a year. Besides that, Malaysia also free form earthquake. From that situation, Malaysia cannot adopt DBHS strictly without do any modification because it can cause over design to DBHS of Malaysia version.

1.3. OBJECTIVE

The objective of this paper

- To analyze the appropriate size (diameter and length) of bolts which is one of vertical reinforcement members of Dry masonry Brick House System (DBHS) as required by British Standard 4190 (commonly adopted by Malaysian standard and specification) through tensile strength analysis.

- To redesign/modify wall form fastening composition of DBHS to comply structural modification based on the new verified dimension of vertical reinforcement.

1.4. SCOPE OF STUDY

In order to find the appropriate size of bolt to be used as vertical reinforcement member in Dry masonry Brick House System (DBHS) of Malaysia version, the different size of bolts which are different diameter and length will be tested through tensile strength analysis by Universal Testing Machine (UTM).

CHAPTER 2: LITERATURE REVIEW

2.1 Sustainable Development

Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.Based on Dharmija(2006),sustainable development was development that was required to be economically affordable, socially acceptable and environmental effective.

In achieving sustainable, it requires people to live within the limits of the earth's capacity to provide the materials for activities and to absorb the waste and pollution that generate from people activities. The construction, fit-out, operation and ultimate demolition of buildings is a huge factor in human impact on the environment both directly and indirectly. The built environment also has crucial impact on the physical and economic health and well being of individuals, communities and organizations.

According to Halliday.S, 2008, to meet the challenge we have to enhance quality of life for all by designing healthy buildings and environment fit for individuals and communities both now and in the future. There are:-

- Enhance biodiversity-not use materials from threatened species of environments and improve natural habits where possible through appropriate planting and water use.
- Support communities – identify and meet the real needs, requirements and aspirations of communities and stakeholders and involve them in key decisions.
- Use resources effectively – not consume a disproportionate amount resources
- Minimize pollution – create minimum dependence on polluting products and materials,management practices,energy,power and forms of transport.
- Create healthy environments – enhance living ,leisure and work environment

- Manage the process - require to identify appropriate targets, tools and benchmarks and manage delivery

2.2 Masonry

Masonry commonly used for the walls of buildings, retaining walls and monuments According McKenzie (2004), masonry can be regarded as an assemblage of structural units, which are bonded together in a particular pattern by mortar or grout. Hendry (2001) state that, the masonry walls may be external or internal and may be load bearing, providing the structure, or non loadbearing, sub-dividing space or acting as the cladding of the building.In construction, masonry has own advantages and disadvantages. The advantages of masonry are:-

i. Low cost - maintenance costs minimal compare with other material. Besides that, brick typically are not requiring for painting and it can provide a structure with reduced life-cycle costs.

ii. Excellent durability

iii. Easy and faster to build compare with others materials

iv. Good thermal insulation-can provide good fire protection

v. Sound insulation-less noise transmitted through it.

vi. Easy to combine with other materials

The disadvantages of masonry are:-

i. Easy to damage caused by extreme weather-if type of brick is not choose correctly based on local weather.

ii. Heavy-must builds upon a strong foundation to avoid potential settling and cracking.

Based on W.G Curtain (1997) state that, masonry has strong compressive strength (vertical load) but weak in tensile strength (twisting or stretching).According J.K Beck (1988), bending tensile strength of masonry is often 5% of their compressive strength. On the other hand, they can be reinforced to carry the tensile stress or prestressed to eliminate them.

In construction, two common types of masonry are being used such as dry masonry and wet masonry. In wet masonry, mortar generally used while for dry masonry, lack or no mortar are used. In this literature review, dry masonry will be discussed more detail because this is type of masonry had been used in this new structural building system.

2.2.1 Dry masonry brick house system

Dry masonry brick house system or DBHS is a new type of brick house system that already apply at most construction at Japan.DBHS is utilized from a construction method called "Steel Reinforced Brick based on Distribution Unbonded Prestress Theory" (SRB-DUP).This system suggests that "materials of different kinds shall not be bonded". According Yamaguchi et al (2007),it would be easier to reuse materials if the different materials were not bonded together and design for deconstruction(reverse of construction process)

Dry masonry means mortarless or mortar is not required. In order to tie these layers of bricks together, steel nut, round and spring washer are used (refer to figure 2.2.1.a). Based on Yamaguchi (2007) state that,SRB-DUP is a new type of dry masonry structure where solid elements such as bricks and horizontal reinforcing elements such as steel plate are laid alternately and fixed at each level with vertical reinforcing elements, such bolts, and utilizing a friction resistant stress transfer mechanism.Unbonded type in this system means that the structure is characterized by the fact that prestress is applied at each connection point of each vertical reinforcing elements in a distributed manner (refer to figure 2.2.1.b).

Based on Khamidi et al (2004), the main goal of DBHS is to be sustainable housing system to achieve high Life Cycle Assessment (LCA) and low Life Cycle Cost (LCC) performance.DBHS is one of structural building system that introduced as a new housing system to the housing market as green cycle with the ability to reduce, reuse and recycle. DBHS can be dismantled easily and from dismantle process 98.34% of bricks can be reuse and 1.66% can be recycled. For other parts like steel bolts, nuts and plates can 100% be recycled.

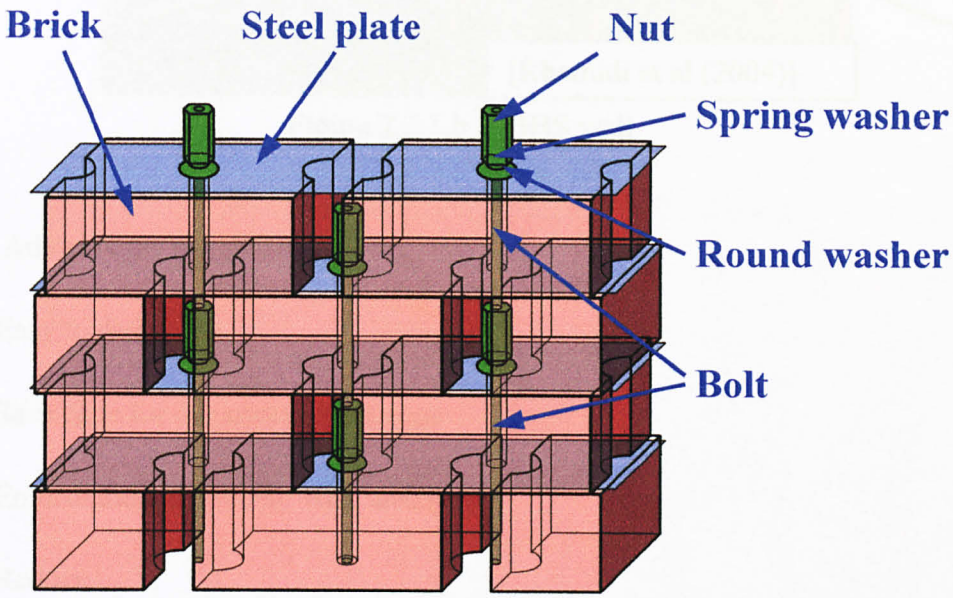


Figure 2.2.1.a. Structural Composition of DBHS Wall with SRB-DUP Method

[Khamidi et al (2004)]

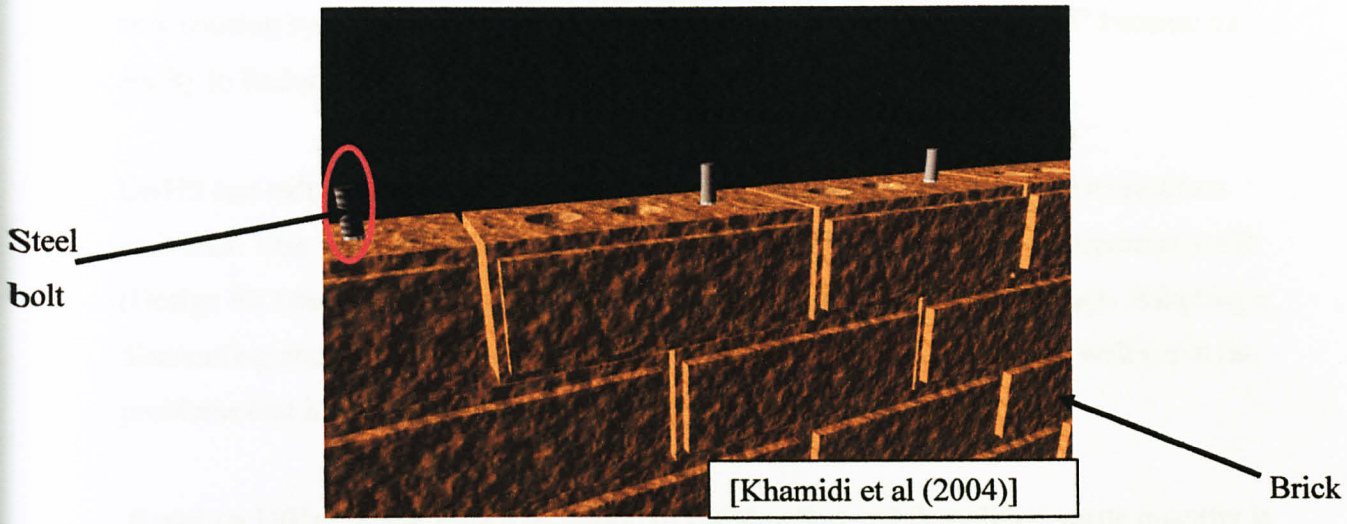


Figure 2.2.1.b. DBHS wall

2.2.1.1. Advantages of DBHS

- Easy to dismantle
- Save time for construction process
- Environmental friendly with ability to

Reduce
Reuse
Recycle
} **3R**

2.2.1.2. Construction and Demolition waste (C&DW) minimization

According to Khamidi et.al (2004), Dry masonry Brick House System aims to be a sustainable housing system that will able to achieve high Life Cycle Assessment (LCA) and low Life Cycle Cost (LCC) performance. It is aimed that with DBHS,an environmental-friendly cycle that encompass of "3R" scheme may be introduced as a

new housing system to the housing market. We can call it as "Green Cycle" because its ability to Reduce-Reuse-Recycle.

DBHS can reduce or minimize the waste generation from construction and demolition activities. This because DBHS is a dismantleable building system that incorporates DFD (Design for Dismantling) and DFR (Design for Recycling) in its design stage. Adapting a dismantling and recycling friendly building methods is a remedy that may well solve the problems that have been plaguing the constructions industry for years.

Based on DBHS, a significant reduction of construction and demolition waste quantity is achievable in a sense that 98.34% of bricks used in the construction is reusable with the balance 1.66% can be recyclable. Others parts used in DBHS like steel bolts, nuts, and plates can 100% are recycled after demolition since these components can be easily recovered and separated.

2.2.2. Types of masonry walls

Masonry walls can be divided into three types, there are

i. Prestressed masonry walls

ii. Reinforced masonry walls

iii. Unreinforced masonry walls

2.2.2.1. Prestressed/reinforced masonry

Prestressing or reinforcing of masonry is defined as the application of compressive stresses to masonry members.According M.M Lwin (2001),prestressed masonry and reinforced masonry are differs from two aspects, there are the type of reinforcing steel used and the way the reinforcing steel is stressed.

The advantages of prestressing and reinforcing are:-

i. Minimize the effect of cracks

ii. Improve bending resistance

iii. Improve shear and tensile stress

iv. Increase ductility and stiffness

For the prestress,there are two methods of prestress,there are :-

i. Pre-tension

ii. Post tension

M.M Lwin et al (2001) state that, for pretensioning,the tendons are tensioned with anchors outside the concrete/masonry members before concrete/masonry cast in form while for postensioning,the tendons are tensioned with anchors outside the concrete/masonry members after the concrete/masonry has attain required initial strength.

Generally, for prestressed masonry, postensioning methods always used because most successful and simplest method.

2.2.2.2. Unreinforced masonry

Unreinforced masonry wall is opposite with reinforced masonry wall where for unreinforced masonry walls, reinforcing steel not placed in walls. It only uses mortar in order to tie each brick together.

"For unreinforced masonry walls, the lateral and vertical loads lead to tension and shear combined with compression within the masonry walls. Fracture and failure of masonry wall under shear compression is intricate because of the complex interaction of shear failure along the mortar joints and compression failure often at the toe of the wall"[Chaimoon et al (2006)]

2.3. Brick

"A brick is a walling unit not exceeding 337.5mm in length,225mm in width and 337.5mm in height.The form may be generally defined as a rectangular prism of a size that can be handled conveniently with one hand"[Lynch]

In construction, bricks give many benefits to users, such as:-

i. Lack or avoid noise pollution from busy streets
ii. Provides a property boundary wall
iii. Increases security against burglars or intruders
iv. Modish privacy wall

The good qualities of bricks can be known from their characteristics such as:-

i. Shape-consistent in size and conform to the standard BS 3921
ii. Well burnt- fired throughout its thickness and show uniform texture internally when cut across
iii. Sound-emits a clear ringing sound when struck with another brick.
iv. Water absorption – varies considerably according to its type. A soft rubbing bricks will naturally absorb much more than a dense vitrified engineering brick.
v. Compressive strength – Clay bricks vary in strength from about 7N/mm^2 to well over 100N/mm^2.Usually bricks are used well below their load bearing capacity.
vi. Materials – clays for bricks must be composed of well blended materials.
vii. Colour – brick should be of uniform colour

2.3.1. Types of bricks

There are three types of bricks that always used in construction.There are:-

- Clay bricks

  "clay bricks are produced in variety of colours depending on the mineral content and firing temperature,most commonly in shades of red but facing bricks in

yellow,buff and brown and with roughened surface texture are frequently selected".[Hendry,(2000)]

Hendry (2000) also state, the density of clay bricks is 2t/m^3 but the weight of units is more importance in construction depends on their size, shape and type. Certain clay bricks which absorb between 4.5% and 7% can be used as damp proof course material.However,the highly absorptive clay bricks may remove water from the mortar avoiding complete hydration of the cement.

- Concrete bricks

There are three categories of concrete bricks are available:-

(1) Facing bricks of 20N/mm^2 strength-provide attractive appearance for use in all forms of construction, internal or external. They are available in a wide range of colours including multi-colours and in smooth, rustic, split, pitched or weathered finishes.

(2) Engineering bricks of 40N/mm^2 strength- particularly aggressive conditions where sulphate resistance and low water absorption are paramount.

(3) Common bricks – manufactured in wide range of strengths, densities and cementations content to satisfy the structural and durability requirement of BS 5628:part3.

- Calcium silicate bricks

This type of bricks is designed by BS 187:1978 according to their compressive strength and appearance into the classes. The advantages of calcium silicate bricks are:-

(1) Consistent structure – no soluble salts or sulphates within them.

(2) Sizes-the regularity of dimensions in size and shape of the bricks gives enhanced consistency of laying.

(3) The light-reflective qualities added to dimensional accuracy, give appeal for decorative internal brickworks.

(4) The inherent properties give global attributes for use in hot and cold climates.

(5) A comprehensive range colors is available which can be adjusted in tone to match any colour shade the client request.

2.4. Walls

"Walls are the vertical constructions of building that enclose, separate, and protect its interior spaces. They maybe load bearing structures of homogeneous or composite construction designed to support imposed loads from floors and roof, or consists of a framework of columns and beams with nonstructural panels attached to of filling in them".[Ching et al(2000)]

Ching et al (2000) also state that, exterior wall constructions must be able to withstand horizontal wind loading to support vertical loads and if rigid enough, they can serve as shear wall and transfer lateral wind and seismic forces to the ground foundation.

2.4.1.Types of wall systems

2.4.1.1. Structural frames

Structural frames are a structure can support and accept varieties of nonbearing or curtain wall system. Structural frames for wall systems consist of:-

i. Concrete frames (rigid frames) – can be characterize as noncombustible (fire-resistive construction)

ii. Noncombustible steel frames – may utilize moment connections and necessitate fireproofing to characterize as fire-resistive construction.

iii. Timber frames – diagonal bracing or shear planes are required for lateral stability and can characterize as heavy timber construction if used with noncombustible, fire-resistive exterior walls and if the members meet the members meet the minimum size requirements specified in the building code.

iv. Steel and concrete frames- able to span greater distance and carry heavier loads than timber structures.

2.4.1.2. Concrete and masonry bearing walls

- Concrete and masonry walls are strong in compression and require for reinforcing to handle tensile stresses .Its can be characterized as noncombustible construction and based on their load-carrying capability. The critical factors in wall design and construction are height to width ratio, provisions for lateral stability and proper placement of expansion joint.

2.4.1.3. Metal and wood stud walls.

- According Ching et al (2000) state that

i. Studs carry vertical loads while sheathing or diagonal bracing stiffness the plane of the wall.

ii. Cavities in the wall frame can accommodate thermal insulation, vapor retarders and mechanical distribution and outlets of mechanical and electrical services.

iii. Studs framing can accept variety of interior and exterior wall finishes.

iv. Studs walls are flexible in form due to the workability of relatively small pieces and the various means of fastening available.

2.5. Municipal solid waste

According volume 40 of the U.S Code of federation Regulations (40 CFR 240.101) defines a solid waste as:

"*Garbage, refuse, sludge and other discarded solid materials resulting from industrial, commercial operations and from community activities. It does not include solid or dissolved material in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial wastewater effluents, dissolved materials in irrigation return flows or other common water pollutants.*"

Municipal Solid Waste or MSW and sometimes also known as domestic waste is generated within a community from several sources, and not simply by the individual consumer or a household.MSW originates from residential, commercial, institutional and municipal sources.

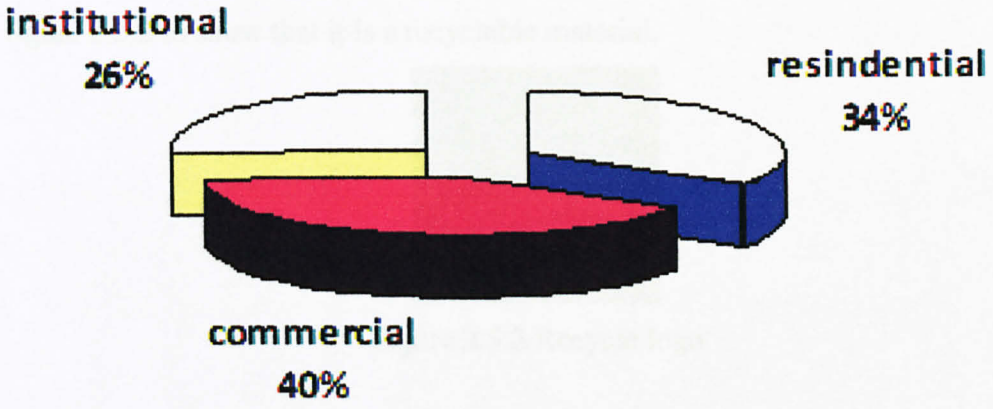


Chart 2.5.Waste composition in KL, 2002

[Local Government Department Ministry of Housing & Local Government]

Municipal solid waste can be divided into 4 major categories which are:-

- Biodegradable waste
- Recyclable material
- Construction and demolition waste
- Hazardous waste

2.5.1 Biodegradable waste

Biodegradable waste is a originating from plants and animals and can be broken down by other living organisms. Biodegradable waste can be commonly found in municipal solid waste as green waste, food waste, paper waste, and biodegradable plastics. Other biodegradable wastes include human waste, manure, sewage, slaughterhouse waste.

2.5.2 Recyclable materials

Recyclable materials are materials can be processed into new products. There include many kinds of glass, paper, metal, plastic, textiles, and electronics. Nowadays, usually for recyclable materials, it will have recycle logo as shown in figure 2.5.2 to show that it is a recyclable material.

Figure 2.5.2.Recycle logo

2.5.3 Construction and demolition waste

Construction and demolition (C&D) waste material produced during construction, renovation, or demolition of structures. Structure includes residential and nonresidential buildings as well as roads and bridges. Components of C&D include concrete, asphalt, wood, metals, gypsum wallboard and roofing. Land-

clearing debris such as tree stumps, rocks and soil are also included on C&D waste.

2.5.4 Hazardous waste

According to the Resource Conservation and Recovery Act (RCRA), hazardous waste mentioned as

"*any waste or combination of wastes which pose a substantial present or potential hazard to human health or living organisms because such wastes are non-degradable or persistent in nature or because they can be biologically magnified, or because they can be lethal,or because they may otherwise cause or tend to cause detrimental effects.*"

The characteristic of hazardous waste are:-

- Ignitability
- Corrosivity
- Reactivity
- Toxity

Examples of hazardous waste are residues from solvent manufacture, electroplating, metal treating, wood preserving, and petroleum refining.

2.6. Stress strain diagram

According Beer et al, (2006) state that, stress-strain diagram representing the relation between stress and strains in a given material are an important characteristic of the material. To obtain the stress strain diagram of a material, a tensile test usually be conducted.

"Stress-strain diagrams of various materials vary widely and different tensile tests conducted on the same material may yield different results, depending upon the temperature of the specimen and the speed of loading" [Beer et al (2006)]

Based on Beer 2006,

Stress,σ= P/A where P is tension load while A is tension area.But,if the resulting σ= P/A does not exceed the propotional limit of the material,we may apply Hooke's Law and write

$$\sigma = \epsilon E$$

Where E=modulus elasticity, and ϵ= strain

$$\text{Strain, } \epsilon = \delta / L$$

Where δ= elongation of material and L = total length of material

There are various group of materials but there can be divided into two broad categories based on their characteristics, ductile materials and brittle materials.

Ductile materials are characterized by their ability to yield at normal temperatures. Ductile materials inclusive of structural steel as well as many alloys of other materials.In tensile test, this material will neck where necking is a local phenomenon for ductile materials before rupture. Different types of materials will have different yield characteristics although having similar catagories depends on gage length and cross sectional area of the specimen, ductile materials as showing in appendices, figure 2.6.a.

Brittle materials which comprise cast iron, glass and stone are characterized by the fact the rupture occurs without any noticeable (at appendices, refer to figure 2.6.b) prior change in the rate of elongation. Thus for brittle materials, there is no difference between ultimate strength and the breaking strength. Also, the strain at the time of rupture is much smaller for brittle than for ductile material.

Table 2.6. Distinguishing characteristics of brittle versus ductile behavior depending on the scale of observation.

Scale of observation	Brittle	Ductile
Structural engineer	Applied stress at failure is less than the yield stress	Applied stress at failure is greater than a yield stress
By eye (1x)	No necking,shiny facets,crystalline,granular	Necked,fibrous,woody
Macroscale (<50x)	"Low"RA or ductility	Medium to high reduction area
Microscale,scanning electron microscopy (100 – 10,000x)	Brittle microprocess,cleavage,intergranular	Ductile microprocess,microvoid coalescence
Transmission electron microscopy (>10,000x)	May have a large level of local plasticity	High amount of plasticity globally

[ASTM E8]

For this research project,only ductile materials (steel bolts) will be tested for tensile strength analysis.

2.6.1. Tensile strength

Tensile strength or Ultimate Tensile Strength (UTS) measures the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. The Ultimate tensile strength happens before the object failure (at appendices, refer to figure

2.5.1).Tensile strength is important for design characteristic because it will be used for quality control in production, for ranking performance of structural materials, for evaluation of newly developed alloys and for dealing with the statistic requirements of design.

2.6.2. Tensile strength test

Tensile test is commonly used to determine the maximum load of tensile strength that a material or product can withstand. To determine ultimate tensile strength for steel bolts, direct tension test can be done.

Besides that, through tensile strength test,its also can determine others mechanical properties inclusive of :-

- Elastic deformation properties,such as the modulus of elasticity (Young's Modulus) and Poisson's ratio.
- Yield strength
- Ductility properties,such as elongation and reduction in area
- Strain hardening characteristics

[ASTM E8]

In this tensile test, the test specimen will be placed in testing machine (refer to appendices, figure 2.6.2.a) which is used to apply centric load P.For ductile materials, after a critical value σ_y of the stress had been reached, the specimen undergoes a large deformation with a relatively small increase in the applied load. After a certain maximum value of the load has been reached the diameter of a portion of the specimen begins to decrease because of local instability (necking).After necking, somewhat load are sufficient to keep the specimen elongating further until it's finally ruptures (refer to appendices, figure 2.6.2.b)

During a tensile strength test, the force applied to the test piece and the amount of elongation of the test piece is measured simultaneously by test machine. Using the data generated from a tensile test, stress-strain curve can be plotted.

2.7. Steel structures

Steel structures are composed of elements which are rolled to a basic cross-section in a mill, and worked to the desired size. According Dunggal, 2000, state that, for building a steel structure, the designer is normally compelled to use standard rolled sections.Fortunately, the variety of steel sections available is so great that any desired structural effect can be achieved in steel.

The advantages of steel as a structural material are:-

i. Have high strength per unit weight

ii. Light – can be conveniently handled and transported

iii. Have a long life

iv. The properties mostly do not change with time

v. Ductile material – do not fail suddenly

vi. Additions and alterations can be made easily

vii. Can be erected at a faster rate

viii. Have the highest scrap value amongst all buildings materials

However, steel also have their own disadvantages as a structural material, there are:-

i. Corrosion – when placed in exposed conditions and require frequent painting.

ii. Need fire proof treatment – increase cost

2.7.1. Steel bolts

According Dunggal, 2000, state that, a bolt may be defined as a metal pin with a head at one end and a shank threaded at the end to receive a nut. Steel washer provided under the bolt as well as under the nut to distribute the clamping pressure on the bolted member and to prevent the threaded portion of the bolt bearing on the connecting piece.

For this project, the type of bolts are been used is stud bolt. Stud bolt is a round metal bar screwed at both ends or fully screwed.

Even though bolts commonly used to connect the structural elements, there also have objections to the use of bolts. There are:-

i. High cost

ii. Tensile strength of the bolt is reduced because of area reduction.

iii. When subjected to vibrations or shocks bolts may get lost.

For this project, stud bolt are been chosen as a vertical reinforcement member for Dry-Masonry Brick House System because stud bolt can improved stress concentration factors, reduces local material variations, lower cost especially for high duty applications, less clearance required on holes allowing more accurate assemble, and studs with two nuts can be tightened from either side of joint.

In other hand, stud bolts also have their own disadvantages such as more items can loosen and the nuts are normally considered the weak link in a join.

2.7.2. Bolt connections

Bolts is one of vertical reinforcement members in Dry-masonry brick house System (DBHS).Bolts usually attached together with nuts and washer. The bolting connection can be dividing into two

3 Non-preloaded

4 Preloaded

Based on Dunggal, 2000, the advantages of bolted connections are:-

- The erection of the structure can be speeded up
- Less skilled person are required

CHAPTER 3: METHODOLOGY

In the methodology, there have 7 processes in one flow must be followed in order to finish this Final Year Project as schedule. Below is the flowchart of research methodology for Dry-masonry brick house system for tensile strength analysis of vertical reinforcement member.

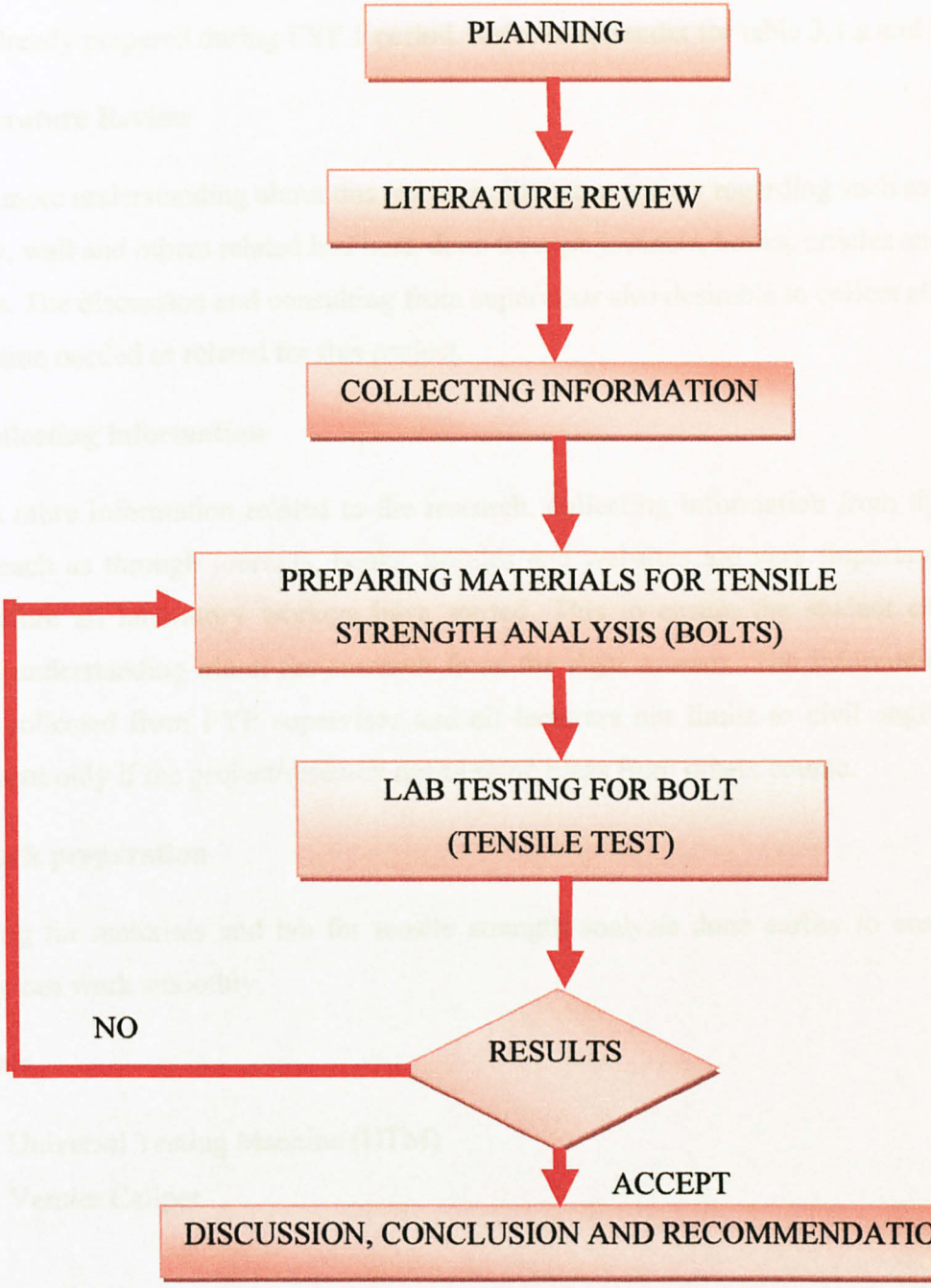


Figure3.0. Flowchart of research methodology

3.1. Project Plan

Planning is very important in desired to achieve the objectives stated. Excellent planning will drive this project smoothly. At early stage before, much attention will goes to literature review as it gives information and basic understanding for this project. Literature review is then followed by laboratory works. In order to ensure this research can be done smoothly and always on the right track without any problems, milestone for FYP 2 already prepared during FYP 1 period. Refer to appendix for table 3.1.a and 3.1.b.

3.2. Literature Review

To gain more understanding about this research, literature review regarding such as brick, masonry, wall and others related had been done through journals, books, articles and websites. The discussion and consulting from supervisor also desirable to collect all the information needed or related for this project.

3.3. Collecting information

To gain more information related to the research, collecting information from the right source such as through journals, books, articles and websites are very important to be done before all laboratory workers have started. This to ensure the student can gain deepest understanding about the research from the right sources. The information also can be collected from FYP supervisor and all lecturers not limits to civil engineering department only if the project/research needs some ideas from others course.

3.4. Work preparation

Preparing for materials and lab for tensile strength analysis done earlier to ensure the analysis can work smoothly.

Materials

- Universal Testing Machine (UTM)
- Vernier Caliper

- Steel Bolts with different length and diameter.

Table3.4. Variations of steel bolts for tensile strength analysis

Bolt diameter	Length (cm)
M10	16.2
	32.4
	48.6
M12	16.2
	32.4
	48.6

3.5. Lab testing

For tensile test of steel bolts, the experiment can be performed using computer control or manual control. Normally, for tensile test, computer control is recommended because it is automatic and can records more data during test.

➢ Procedure for tensile test using computer control as below:-

1) Measure the midsection of steel bolt diameter using vernier caliper for three times and take the average of all the measurement.
2) Connect the extensometer to the HSC strain conditioner. The extensometer is interfaced with strain conditioner which is interfaced with the UTM.
3) Turn on the UTM console first and then HSC strain conditioner.
4) Adjust both the load display and extension display to zero.
5) Fix the steel bolt in the grippers and re-zero the load and extension display to zero.

6) Double click UTM for windows on the computer desktop and type in test information.
7) Zero the extensometer by adjusting the zero knobs and attach the extensometer to the test specimen such that it firmly holds on to the sample.
8) Select the desired strain range (1:1).Zero the strain display on HSC strain conditioner.
9) Open test set-up and now click "START TEST".
10) Type in the measured diameter of the specimen in the space provided for diameter and type preload in the space provided.
11) A graph would be drawn on the monitor showing load and strain relationship. Watch the load and steel bolt carefully where before the steel bolt start necking, remove the extensometer and put it in a stable area near the tester. Zero the extensometer and HSC strain conditioner.
12) Watch carefully at the specimen and the graph where at the some point the steel bolt will break and click on "ACCEPT" at the end.
13) Use the UTM panel control to move the crosshead up to create enough space for steel bolt removal.
14) Remove the steel bolt that already broke from the test set up and measure the smallest diameter at the specimen necking area.

3.6. Results

The result of tensile test can be determined during the tensile test by watching the load shown on the display of the testing machine. The tensile strength result will be compared with BS standard. If the results accepted, the result will used for discussion, conclusion and recommendation. This means, the research successfully done. However, if the results rejected, tensile test will be repeated until get the satisfy value.

3.7. Hazard analysis

Hazard analysis is defined to be the identification of hazards and their causes. The term hazard analysis is useful because it encapsulates, in a less ambiguous manner, the two distinct, but complementary activities described in the ISO/IEC 14971 hazard identification process. A hazard is a condition or combination of condition that, if left uncorrected, may lead to an accident, illness or property damage. All these hazards will cause deaf, irritation and more disease.

Hazard might come in several ways for instance through physical, chemical and biological. During tensile test for steel bolt at mechanical lab, the probability of hazard to happen is high. This will happen if:-

i. Have not complete procedures to guard the equipment.
ii. Wear improper personal protective equipment (PPE)
iii. Poor housekeeping
iv. Not follow the rules provided by the laboratory.

In order to avoid the accident and illnesses from happen during tensile strength test conducted at mechanical laboratory, some action must be taken. There are:-

i. Wear appropriate personal protective equipment (PPE)
ii. Always follow all the rules provided by the laboratory
iii. Follow the procedures provided during conduct the experiment
iv. Have a guard from lab technician before start the experiment.
v. Practice good housekeeping.

CHAPTER 4: RESULTS AND DISCUSSION

Dry-masonry brick house system is a new structural housing system from Japan that promotes 3R; Reduce-Reuse-Recycle. As mention earlier, to adopt this system to Malaysia, it must follow local building standard and specification such as Act 133 Street, Drainage and Building 1974 and Uniform Building By-Law (UBBL) 1984.

The vertical reinforcement members such bolt, nuts and washer are posses' high resistance against earthquake and wind force. However, as we known, Malaysia is totally different with Japan where no earth quake exists in Malaysia. Besides that, different of climatic condition also require DBHS to make some design modifications to ensure it's comply with local standard and specification. For example, reduction in size of structural components likes bolts.

In DBHS,bolt is one of main component after bricks that posses the structural design and standard. In order to make design modifications, the suitable characteristic of bolts to be used in DBHS of Malaysian version must be considered before do any design modifications to other parts of DBHS. This because bolt is a one of vertical reinforcement members which function like a back-born to ensure the stabilization of the DBHS structure.

Tensile strength analysis is one important analysis for design characteristic because it will be used for quality control in production, for ranking performance of structural materials, for evaluation of newly developed alloys and for dealing with the statistic requirements of design.

In this Final Year Project, analysis of tensile strength for steel bolts will be done using 2 different diameters (M10 and M12) and each diameter will have three different length of bolt. Different length of bolts will use for different numbers of brick layers. This because, in current practice at Japan, nuts used are fastened at every layer to tie brick and bolt together. However for DBHS with lesser length, this can be done at every 2^{nd} and 3^{rd} layer of brick wall. This modification can reduce the cost and construction time.

Table 4.0.Numbers of brick layers can be fastened based on bolts' length

Length (mm)	Numbers of brick layers to be fastened
162	Fasten at every layer (original length)
324	Fasten at every 2nd layers
486	Fasten at every 3rd layers

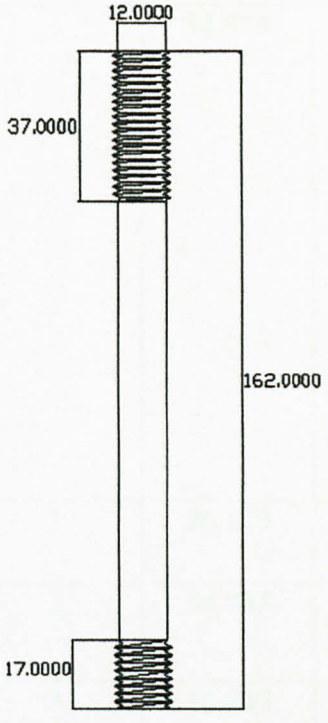


Figure 4.0.original size of steel bolt currently used in Japan

4.1. Results

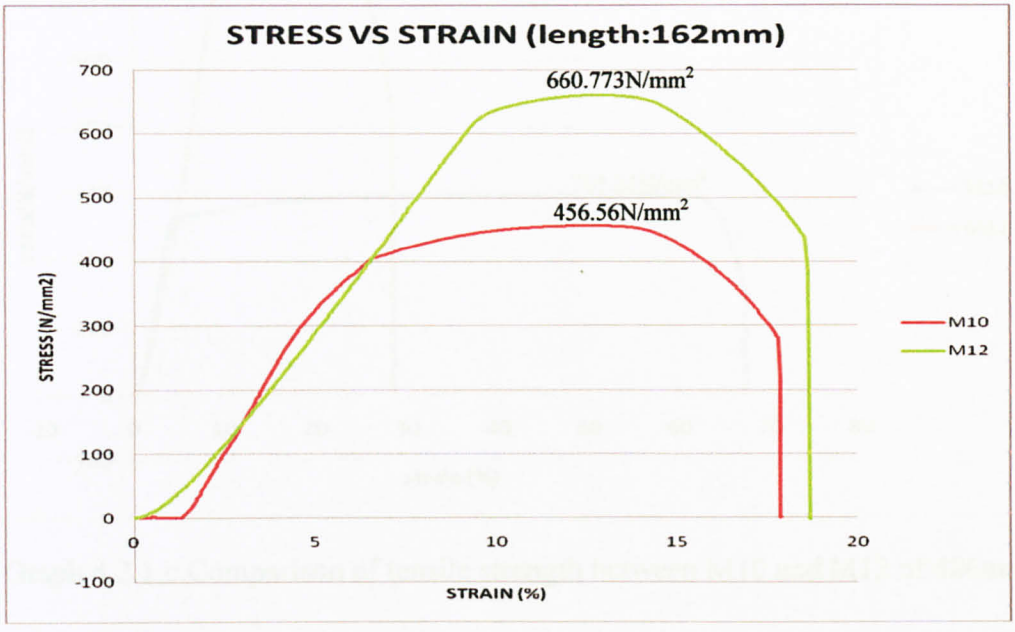
Table 4.1. a. Result of tensile strength analysis

Diameter (mm)	Length (mm)	Sample	Maximum load (kN)	Tensile strength (N/mm^2)	Average Tensile strength (N/mm^2)
10	162	1	**35.901**	**457.11**	456.56
		2	**35.815**	**456.01**	
		3	**34.545**	**439.84** **This value is rejected because very low compare with other two.**	
	324	1	**36.179**	**460.65**	454.15
		2	**34.985**	**445.44**	
		3	**35.842**	**456.35**	
	486	1	**24.053**	**306.25**	301.21
		2	**23.488**	**299.06**	
		3	**23.43**	**298.31**	

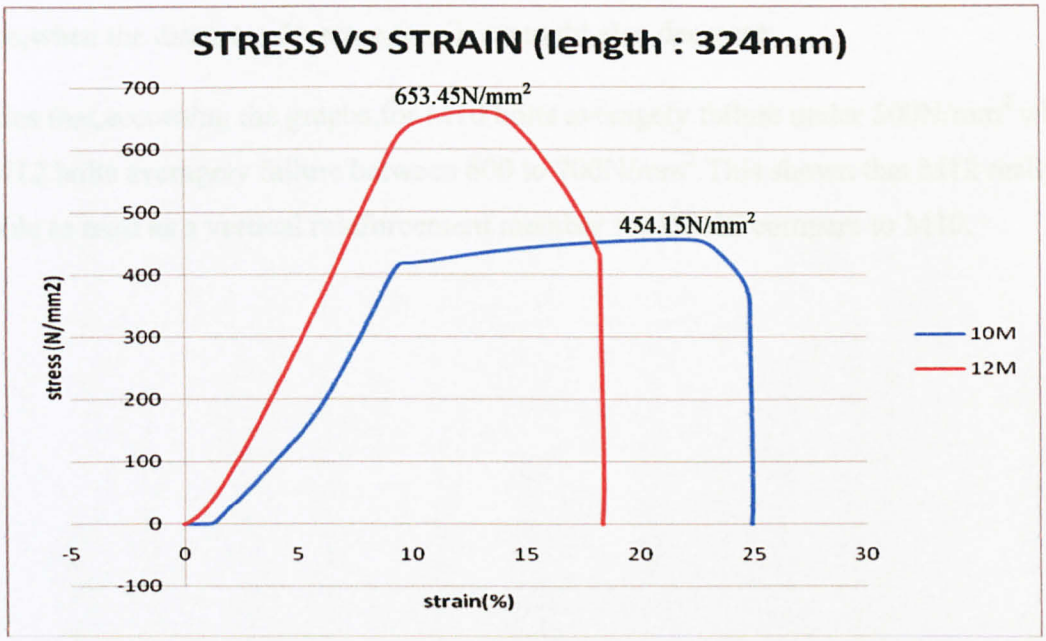
12	162	1	**74.616**	**659.75**	660.773
		2	**74.776**	**661.17**	
		3	**74.803**	**661.4**	
	324	1	**73.695**	**651.61**	653.45
		2	**74.246**	**656.48**	
		3	**73.768**	**652.26**	
	486	1	**72.133**	**637.79**	646.02
		2	**73.396**	**648.96**	
		3	**73.662**	**651.32**	

4.2. Discussion

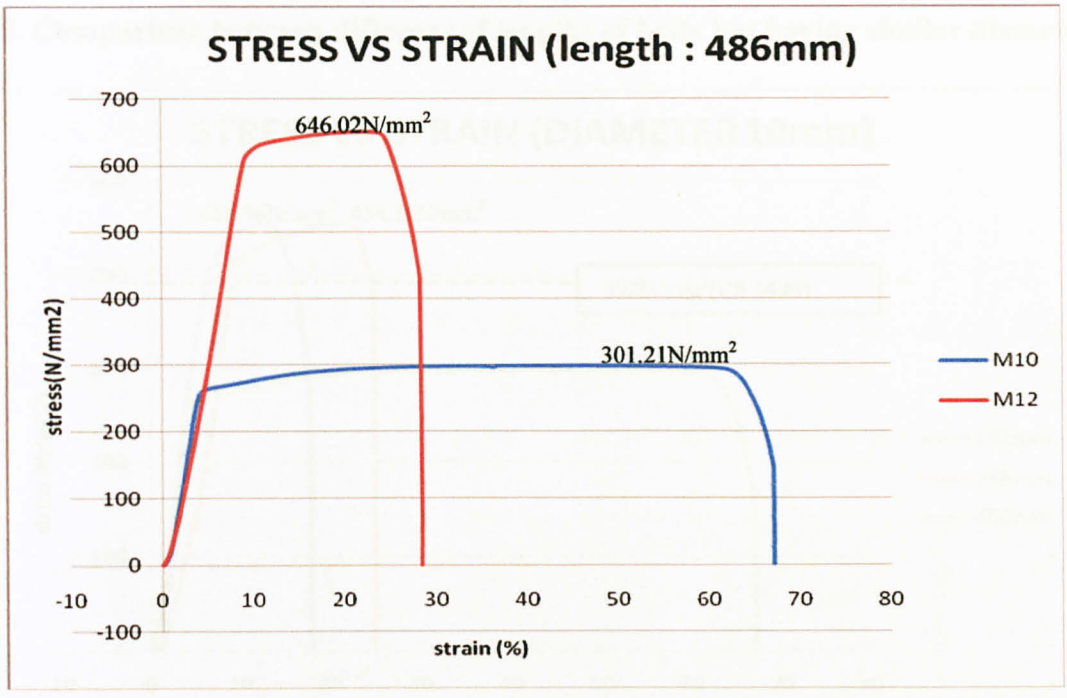
4.2.1. Comparison between different diameters of bolts but having similar length.



Graph 4.2.1.a.Comparison of tensile strength between M10 and M12 of 162mm bolts



Graph 4.2.1.b.Comparison of tensile strength between M10 and M12 of 324mm bolts

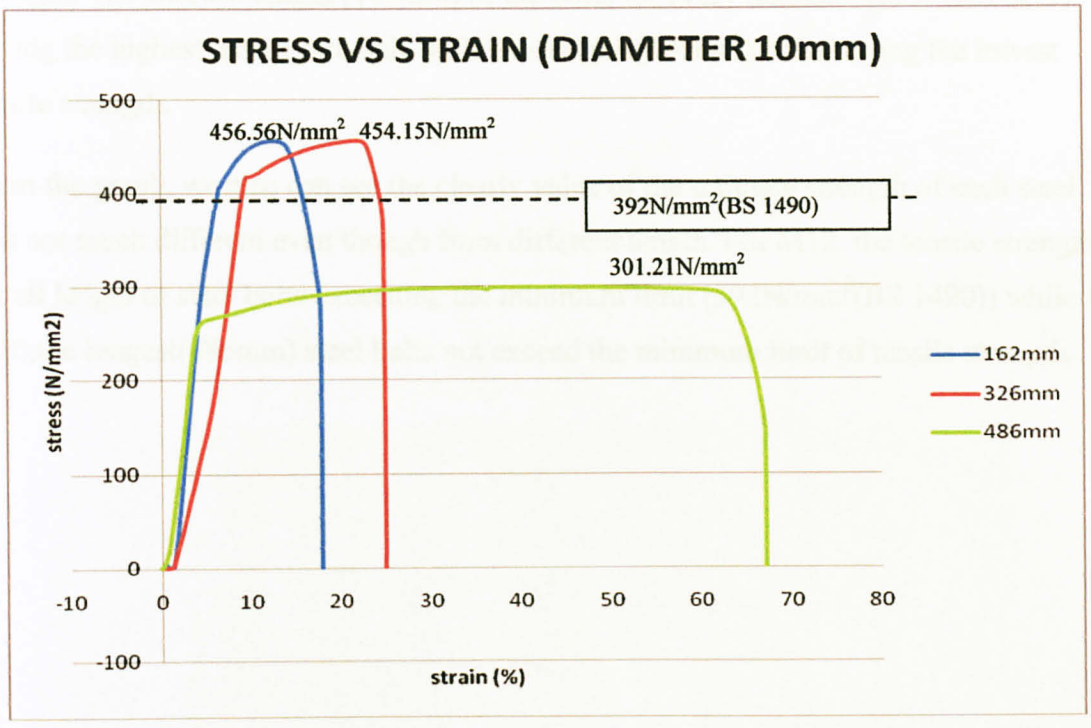


Graph 4.2.1.c.Comparison of tensile strength between M10 and M12 of 486mm bolts

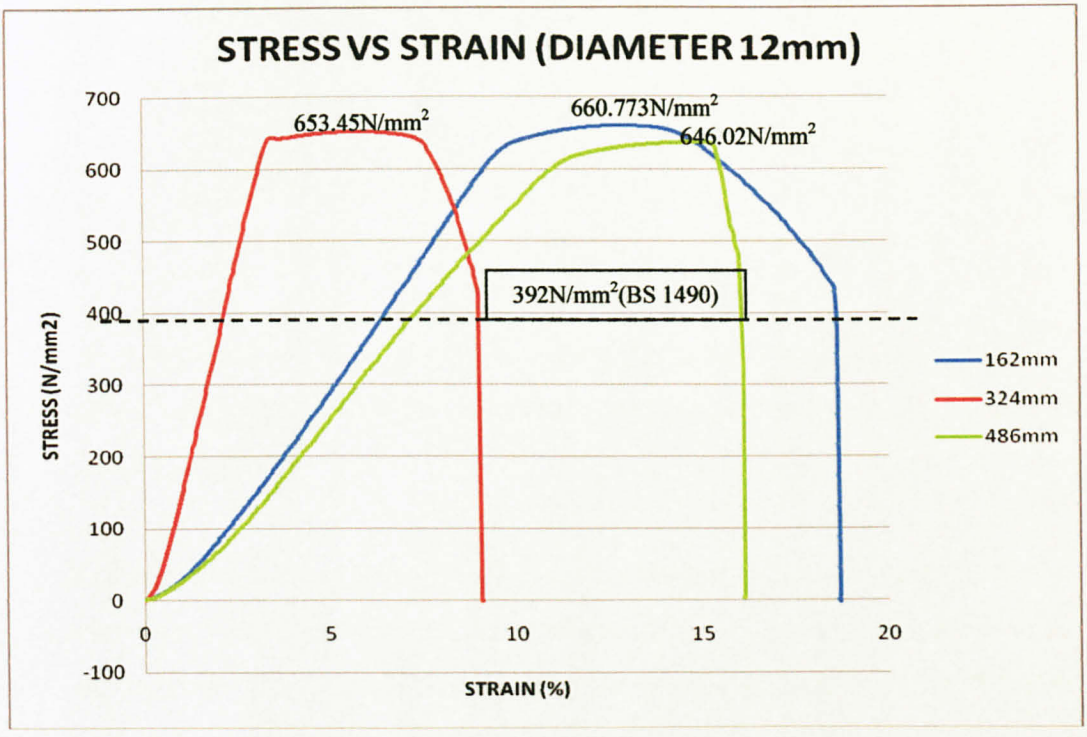
Based on graphs above,clearly we can see the tensile strength for M12 are higher than M10 in all length even though there are from similar length and steel grade.This means,when the diameter decrease,tensile strenght also decrease.

Besides that,according the graphs,for M10 bolts averagely failure under 500N/mm^2 while for M12 bolts averagely failure between 600 to 700N/mm^2.This shown that M12 really suitable to used as a vertical reinforcement member for DBHS compare to M10.

4.2.2. Comparison between different of lengths of bolts but having similar diameter..



Graph 4.2.2.a.Comparison of tensile strength for different length of M10 bolts.



Graph 4.2.2.b.Comparison of tensile strength for different length of M12 bolts. 35

Both graphs shown, the increasing length of bolts cause the decreasing value of tensile strength. The shortest length (162mm) of the bolts for every diameter (M10 and M12) having the highest tensile strength while the longest(486mm) bolts having the lowest tensile strength.

From the graph, we also can see the clearly value of the ultimate strength of each steel bolt not much different even though from different length. For M12, the tensile strength for all length of steel bolts exceeding the minimum limit (392N/mm^2(BS 1490)) while for M10,the longest(486mm) steel bolts not exceed the minimum limit of tensile strength.

4.2.3. Errors during conducting laboratory work

One of result from sample M10 with length 162mm was rejected because this value very low compares other two. This happen because error occurs during tensile strength test without realized by the author. The error maybe occurs are:-

1. Parallax error is a common error that always occurs during taking any measurement/reading. For the tensile strength analysis, the parallax error maybe occur during the author taking measurement of the smallest diameter of steel bolt after necking happen using vernier caliper.

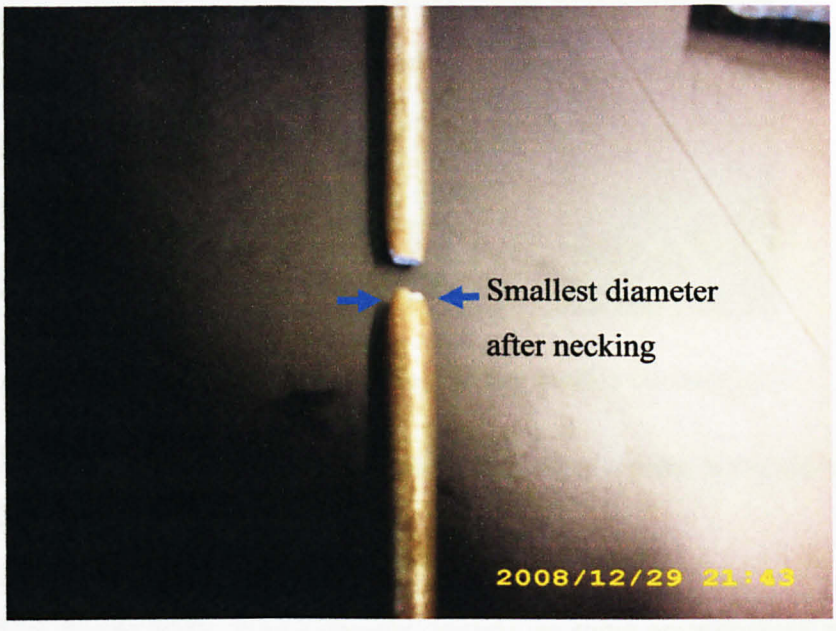


Figure 4.2.a.show the smallest diameter after necking

Parallax error can be avoided with taking the measurement repeat at least 3 times and take the average. With this way, the percentage of the parallax error can be reducing.

2. Gripping method also can affect the result. This because, as we known, the necking usually will happen at the weakness point. Weakness point for the stud bolt is at the thread area. If the steel bolt not grip well, the stud bolt will fail at

thread area. This can be avoided with grip the steel bolt more than thread area. With this method, the weakness point will move to area at the middle of the stud bolt.

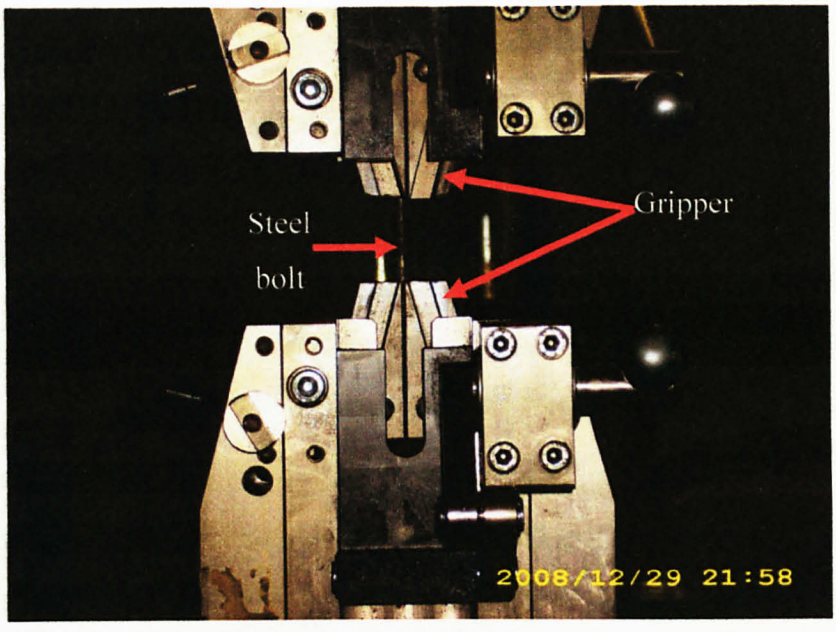


Figure 4.2.b.The position of specimen during tensile strength test

3. Besides that, the error also happen because the steel bolts were not gripped well and caused slippery during test.

Tensile strength test 95% using computer control, so some error such as zero error can be avoided.5% of this test still using manual control such as taking the measurement or reading of the specimen cannot avoid the error from happen.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Based on the result, M12 is the most suitable steel bolt to be used as vertical reinforcement member in Dry-masonry Brick House System. This because,

- M12 have higher tensile strength compare with M10
- The longest length (486mm) of M10 does not exceed the minimum limit, 392N/mm^2 (BS 4190).
- To achieve the objective of this project – M12 can go longest since its tensile strength still exceed the minimum limit while M10 fail to carry up this objective.

Since the result of tensile strength for longest length of M12 exceeding the minimum limit, the length of the steel bolt can go longer than 486mm. The objective and plan to redesign the DBHS by fastening the bricks at every two or three layers using 324mm and 486mm are applicable and might be can go longest.

The advantages by this redesign are:-

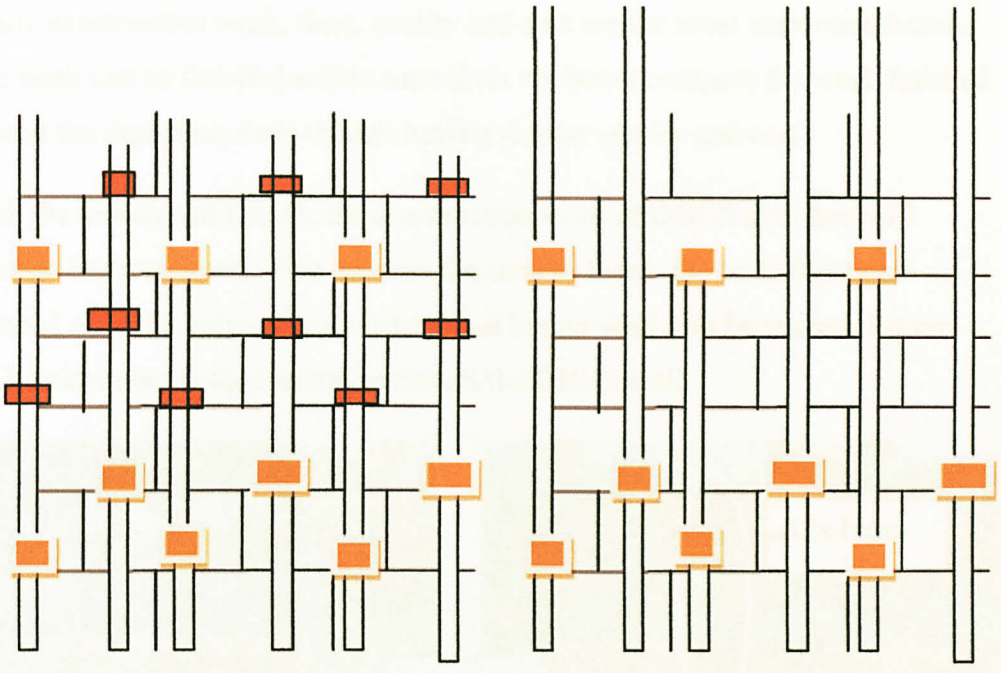
I. Reduce cost

Based on the cost, the cost for using longest(486mm) steel bolt are more saving compare with shortest(162mm) steel bolt. This can be proven by the price of M12 in the table below:-

Size	Quantity	Price	Cost of steel bolt for fastening the bricks at every two layers	Cost of steel bolt for fastening the bricks at every three layers
12 x 162 mm	1	RM 9.50	RM 19.00	RM 28.50
12 x 324 mm	1	RM 11.50	11.50	-
12 x 486 mm	1	RM 13.50	-	RM 13.50

Table 5.1.Price for M12 bolts

II. Reduce construction materials; e.g. less nuts be used



Before modification After modification

Figure 5.1.a.Interior view of the DBHS wall before and after modification

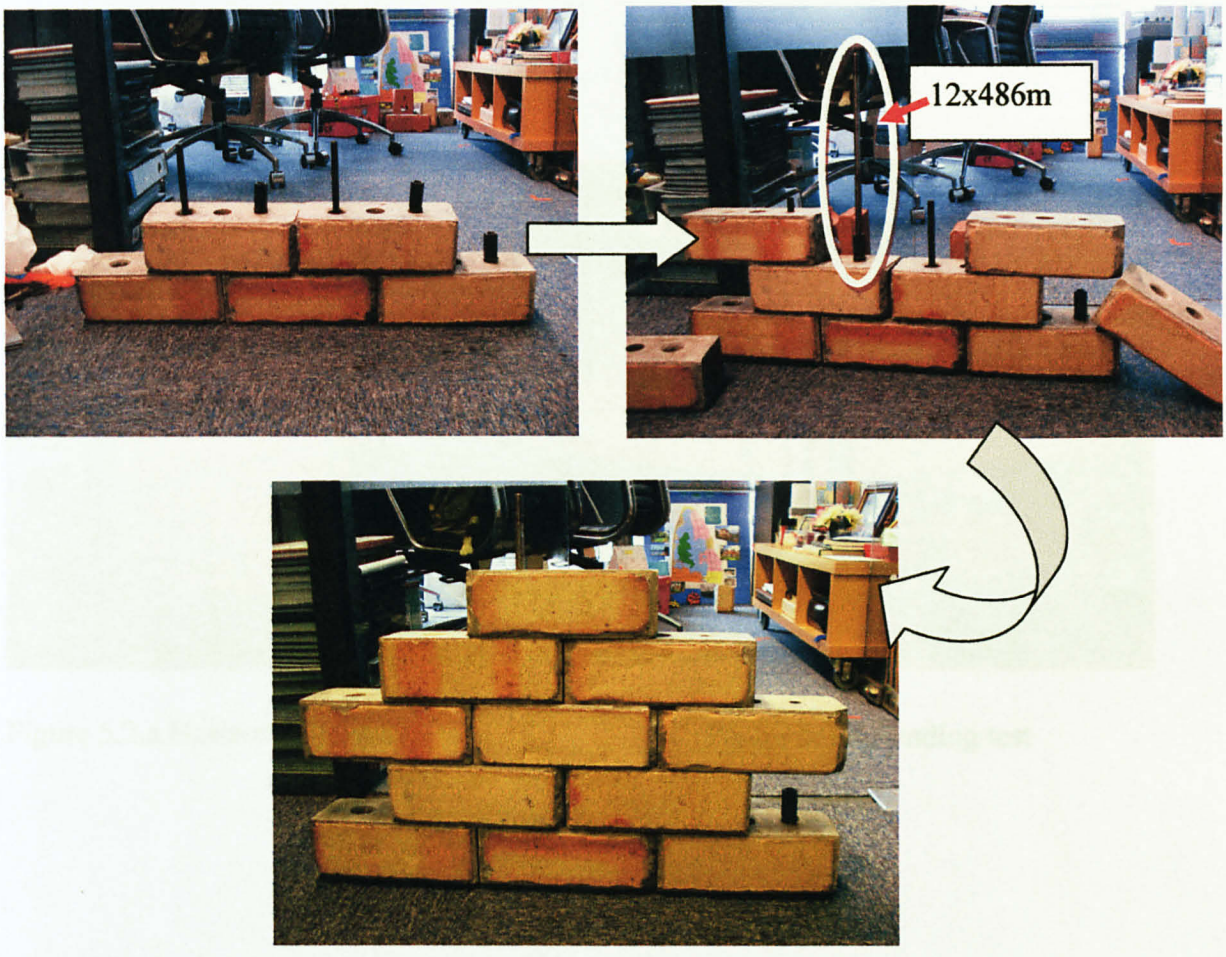
According the figure 5.1.a, the use of nuts in DBHS wall before and after modification is totally different. This because, before modification, the nuts are used to fasten the brick at every layers but after modification the nuts are used to fasten the brick at every three layers. This situation show that the numbers of nuts used are reduce 40 to 50%.

By the way, for the any modification of DBHS, for two first layers and two last layers of the brick must be fasten at every layer to ensure the stabilization of DBHS structure.

III. Construction work become faster

In any construction work, time, quality and cost are the most important factors. The work can be finished within time limit are better compare the work finished exceed the time limit even though having similar quality and cost.

With the redesigned DBHS, the construction work of DBHS structure will become faster as usual. This because the time to fasten the brick layers are reduced after the usage of nuts reduce and longer steel bolt been used. Figure 5.1.b below shown the method construct the DBHS wall.



Figures 5.1.b.Method construct the DBHS wall

5.2. Recommendation

Since the longest steel bolt of M12 still exceeding the minimum limits,so the length of steel bolt can go longer than 486mm.The further experiment using longer length of steel bolt maybe can be conducted for fastening the brick more than three layers. But this does not compulsory because fastening at every three layers already sufficient.

After finished the tensile strength analysis of vertical reinforcement member (steel bolt), others analysis of DBHS wall can be conducted by MBa student.There are horizontal loading test,compressive loading test and bending test.

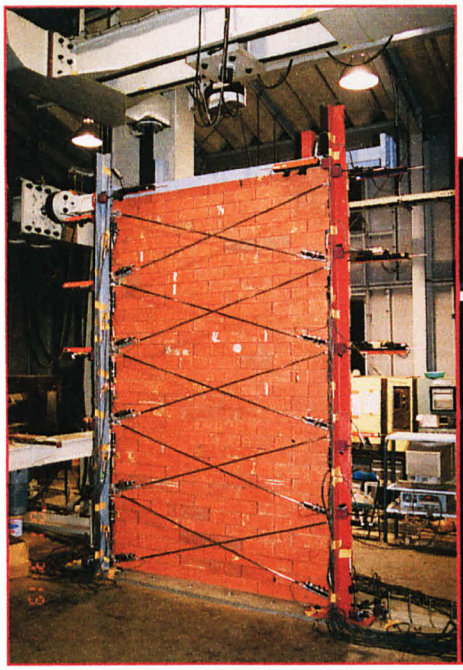


Figure 5.2.a.Horizontal bending test

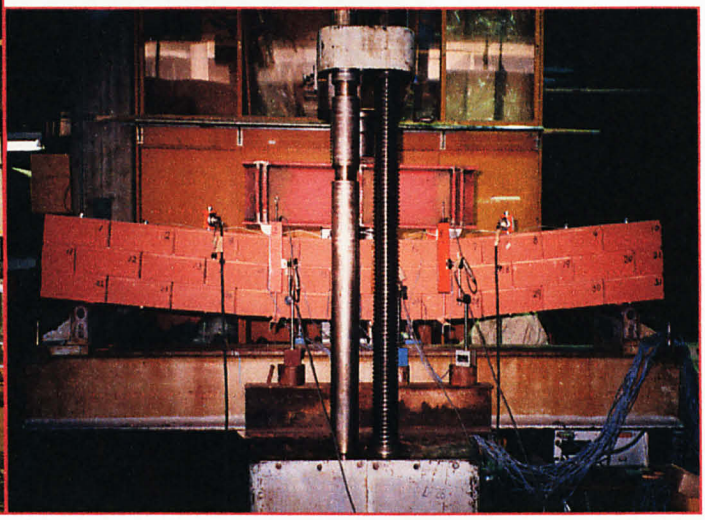


Figure 5.2.b.Bending test

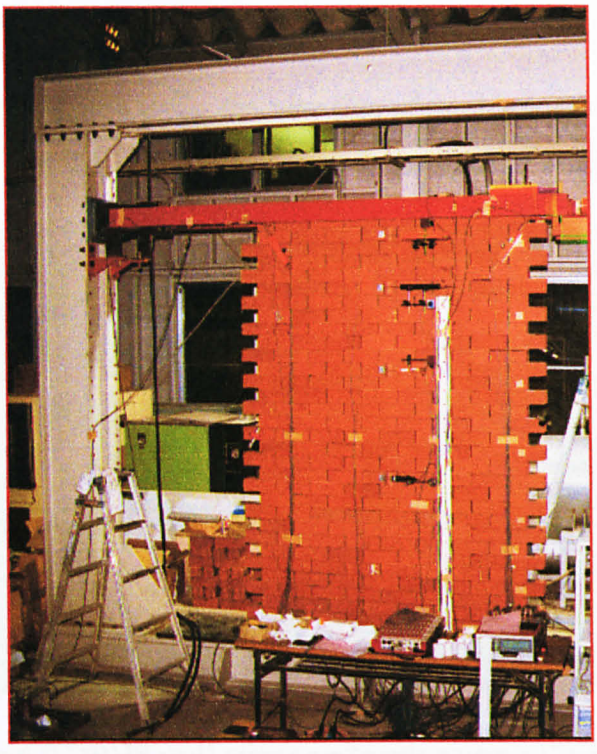


Figure 5.2.c.Compressive test

[Yamaguchi.K et.al,2007]

6.0. MODIFICATION

When construct the DBHS wall using the new size of steel bolt (M12), the author realize the length of the steel bolt too long. This can see at the figure 5.3 below.

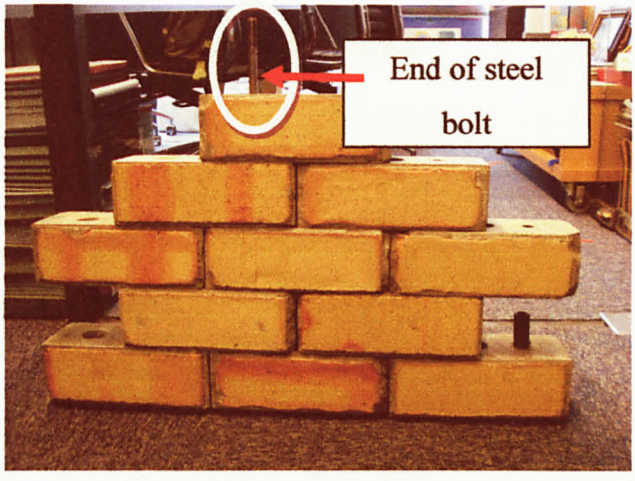


Figure 6.0.DBHS wall after constructing using 12x486mm

Here are the new lengths of the steel bolt after modification;

Table 6.0.New lengths of steel bolts

Length (mm)	Numbers of brick layers to be fastened
162	Fasten at every layer (original length)
270	Fasten at every 2nd layers
378	Fasten at every 3rd layers

APPENDICES

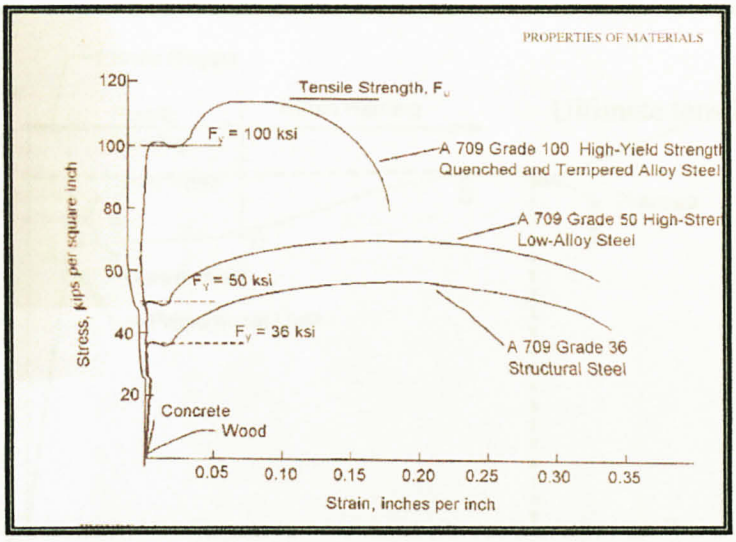


Figure 2.6.a.Graph stress vs. strain for ductile materials

[Lwin,(2001)]

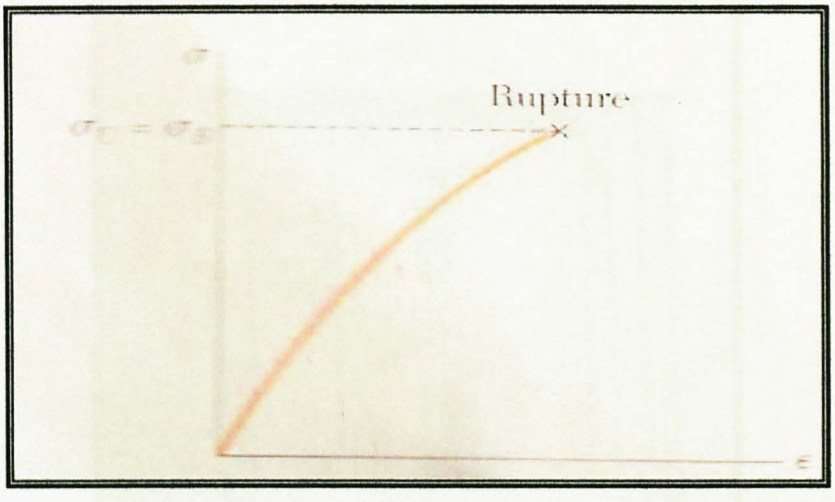


Figure 2.6.b. Graph stress vs. strain for brittle materials

[Beer,(2006)]

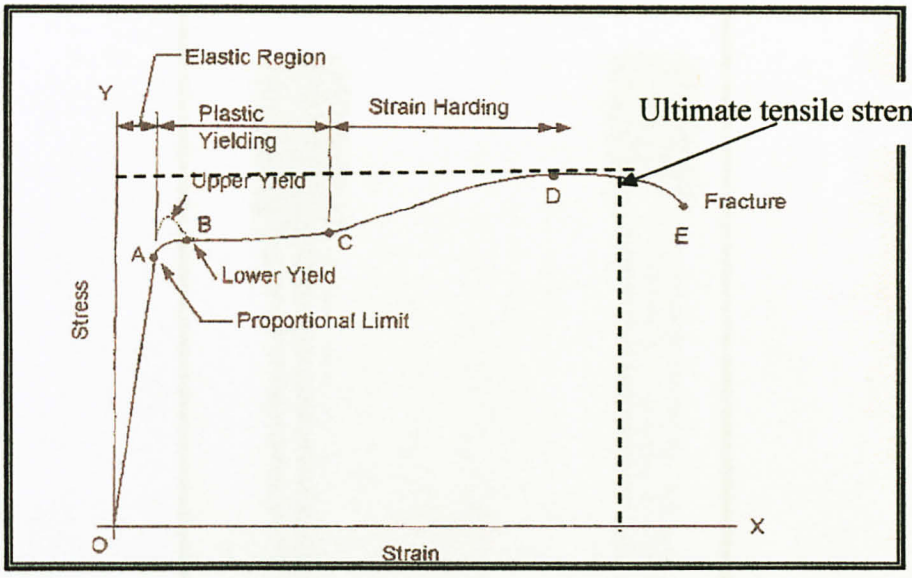


Figure 2.6.1.Graph stress vs. strain

[Lwin,(2001)]

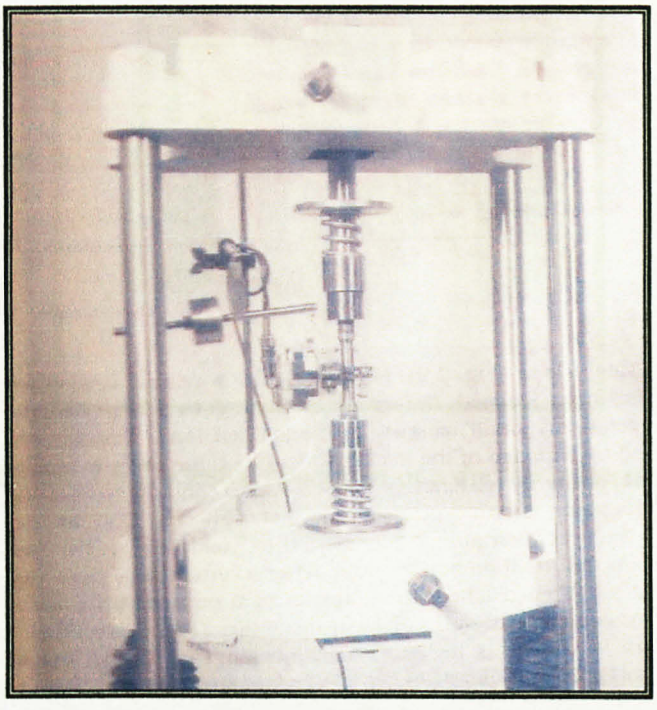


Figure 2.6.2.a.Tensile testing machine

[Beer,(2006)]

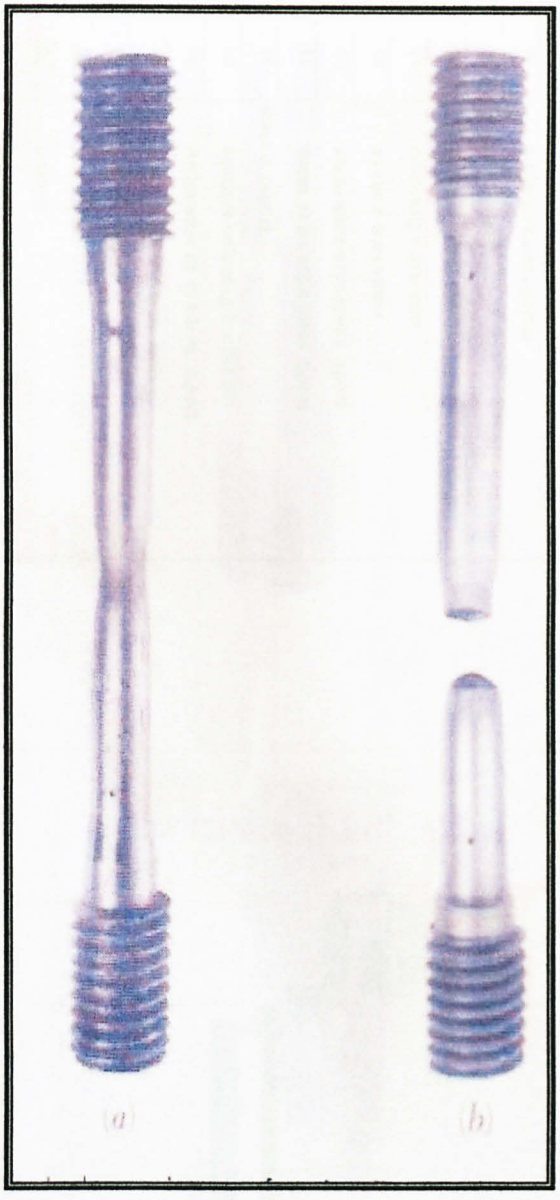


Figure 2.6.2.b.tested specimen of a ductile material.

[Beer,(2006)]

Table 3.1.a.Gantt chart for FYP 1

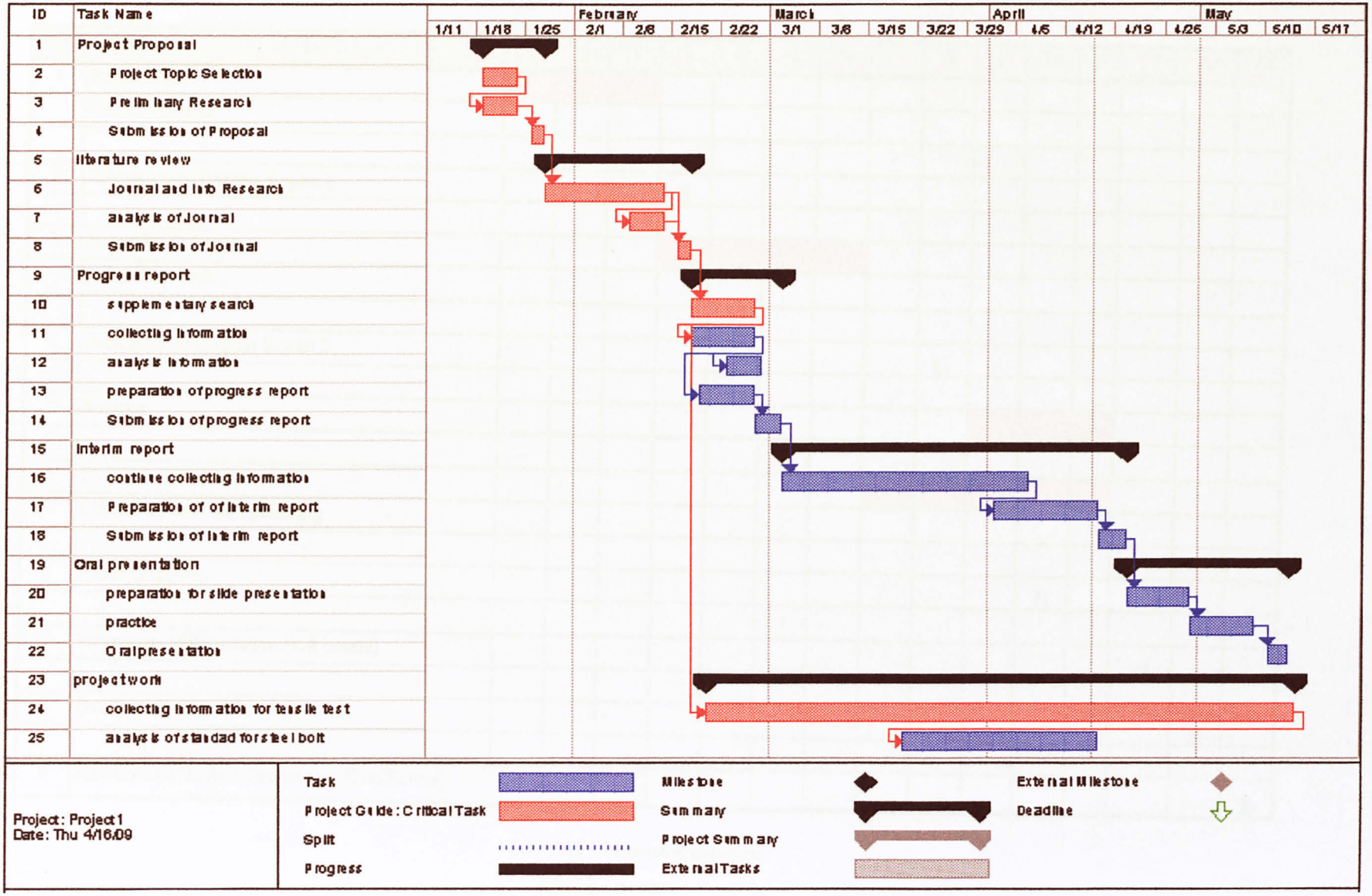


Table 3.1.b.Gantt chart for FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work															
	Laboratory work															
2	Submission of Progress Report 1				●											
3	Project Work Continue															
	Laboratory work															
4	Submission of Progress Report 2									●						
5	Seminar															
5	Project work continue															
	Laboratory work/data gathering															
6	Poster Exhibition											●				
7	Submission of Dissertation (soft bound)													●		
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard Bound)															●

● Suggested milestone

■ Process

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