CHAPTER 1

INTRODUCTION

1.1 GENERAL

Devotions upon emergent Occasions, the seventeenth century English metaphysical poet John Donne wrote "No man is an Island, entire of itself". Through this statement, Donne asserted that we all share a common humanity. In today's increasingly complex and interrelated world, not only is no man an island but, similarly, no building stands alone. Every building exists within an environmental context upon which it not only acts but which also has an impact upon the building. Due to today's increased complexity and inter-relatedness, no building can be considered as microcosm. The people in charge of every building project must consider the impact it will have on the environment into which it will be placed locally and globally.

Sustainability is a social concept in that it considers the need of the unborn. It is an environmental concept in that it addresses the effect of pollution and resource management. The term sustainability, once rare to find in dictionary, has in last few years begun to appear with more regularity. The term green has also become part of our working vocabulary. Simply stated, a green building is one that is located and constructed in sustainable manner and that is designed to allow its occupants to live, work in a sustainable manner.

1.2 SANDWICH STRUCTURAL ELEMENTS

Lightweight sandwich structural elements in building construction is a growing trend in construction all over the world due to its high strength-to-weight ratio, reduced weight and good thermal insulation characteristics. Sandwich construction element consists of encasement of high performance material and a thick lightweight and low strength material as core. Ferro cement is regarded as highly versatile thin material possessing superior properties.

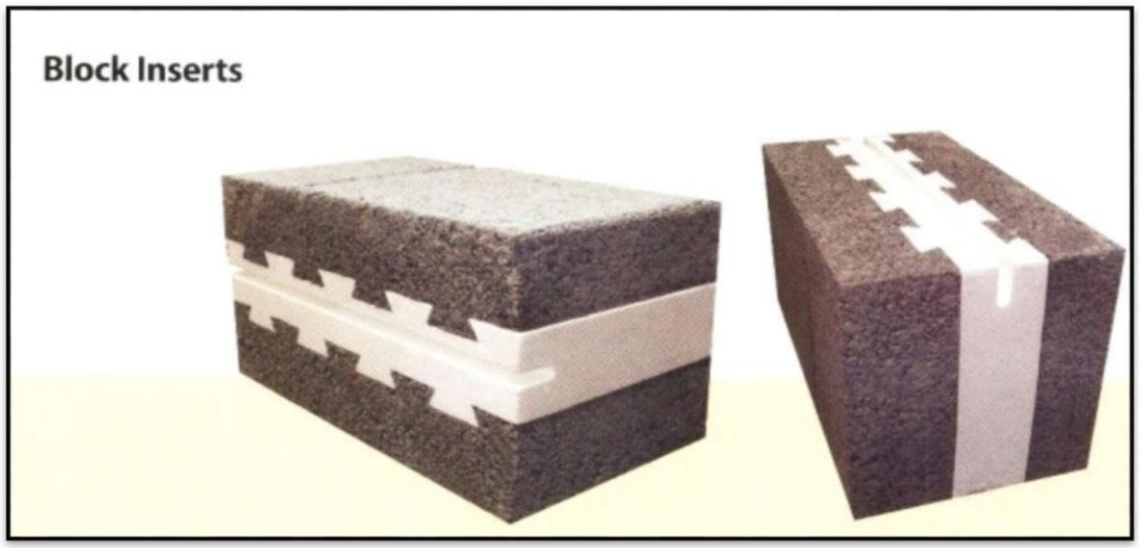

Figure 1.1: Polystyrene Sandwich Blocks

Sandwich composite structure possesses excellent flexural and shear properties. Their inherent lightweight characteristics make them ideal structural components where weight reduction is desirable. Thus structural sandwich blocks are becoming important elements in modern lightweight construction. In concrete construction, selfweight of structure it represents a very large proportion of the total load on the structures thus, reduction in the self-weight of the structures by adopting an appropriate approach results in the reduction of element cross-section, size of foundation and supporting elements there by reduced overall cost of the project.

The lightweight structural elements can be applied for construction of the buildings on soils with lower load-bearing capacity. Reduced self-weight of the structures using lightweight concrete reduces the risk of earthquake damages to the structures because the earth quake forces that will influence the civil engineering structures and buildings are proportional to the mass of the structures and building. Thus reducing the mass of the structure or building is of utmost importance to reduce their risk due to earthquake acceleration. Among the other advantages, its good thermal insulation due to the cellular thick core makes it an ideal external construction component. Some recent investigations suggest their excellent energy-absorbing characteristics under highvelocity impact loading conditions.

It been regarded as highly versatile construction material possessing unique properties of strength and serviceability. Its advantageous properties such as strength, toughness, water

tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material.

As an alternative construction material, Ferro cement has not gained widespread acceptance in both developed countries in general and developing countries in particular. Its acceptance is hindered mainly due to its small thickness and labor intensive method of production. In order to cope with the problem of thickness, one of the options currently suggested is to develop. Ferro cement is one of the relatively new cementations composite considered as a construction material. It is a type of thin walled reinforced concrete commonly consists of cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh. The closelyspaced and uniformly-distributed reinforcement in Ferro cement, transforms the otherwise brittle material into a superior ductile composite. Thus, ferro cement has been regarded as highly versatile construction material possessing unique properties of strength and serviceability. Its advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material. Ferro cement is the promising composite material for prefabrication and industrialization of the building industry. However, as an alternative construction material, ferrocement has not gained widespread acceptance in both; developed countries in general and developing countries in particular. Its acceptance is hindered mainly due to its small thickness and labor intensive method of production.

In order to cope with the problem of thickness, one of the options currently suggested is to develop ferrocement sandwich elements. This technique provides not only the thickness but makes the sandwich element lightweight and good heat insulating. Sandwich block is a three-layer element comprising of two thin, flat facing plates of relatively higher strength material and between which a thick core of relatively lower strength and density is encased or it could consist of thin skin box of relatively higher strength material in-filled with relatively weaker and lower density material known as core. These have been used in the aerospace industry for many years and more recently they are being used as load bearing members in naval structures. Presently, it has gained attention to be used as an effective structural form in the building and construction industries.

Sandwich is a three-layer element comprising of two thin, flat facing plates of relatively higher strength material and between which a thick core of relatively lower strength and density is encased or it could consists of thin skin box of relatively higher strength material in-filled with relatively weaker and lower density material known as core. These have been used in the

aerospace industry for many years and more recently they are being used as load bearing members in naval structures. Presently, it has gained attention to be used as an effective structural form in the building and construction industries. Sandwich construction form has distinct advantages over conventional structural sections, because it promises high stiffness and high strength to weight ratios. Hence, it is only natural that currently almost every field of industry resorts to the use of sandwich material in building and construction. The introduction of new materials such as laminated composites; ferrocement, for the face sheets/skin box and low density materials like aerated concrete, for the core presents new possibilities in the design of sandwich construction.

Aerated concrete refers to concrete having excessive amounts of air voids. These air bubbles are created to reduce the density of the concrete and to make it lightweight, which provides good thermo-acoustic insulation too. However, aerated concrete, which is a porous material and classified as cellular construction material exhibits low compressive strength and high rate of water absorption. It can be used as a potential material for core in sandwich composite because of its relatively more compressive strength compared to the traditional lightweight core materials like foam. Attention has not been paid in order to investigate its suitability as core material. Most recently, its application as core material in sandwich block has been reported so far. However, the literature is silent about its application as core in cement-based sandwich composite structural blocks.

Green building material can be classified in different ways. One of the ways is to classify them according to their use in the building.

1.3 FUNCTIONAL USES

Depending on their functional use in the building, they can be classified as follows:

- Structural/ Partition Materials
- Ventilation/ Thermal Insulation Materials

- Finishing Materials/ Paints
- Materials for Furniture.
- Miscellaneous Materials.

Figure 1.2: Building By Using Sandwich Blocks

CHAPTER 2

LITERATURE REVIEW

S. Ananda Selvan states r to make use of these building materials more efficiently and make people aware of its benefits, an organized technique is required to promote them. It is very important that people are aware of the benefits of using the substitutes for construction materials.

Salihuddin Radin Sumadi states has embarked and paved the way to adopt a novel and potential approach of ferrocement encasement of lightweight non-autoclaved aerated concrete to produce lightweight sandwich composite. The sandwich elements produced are high performance in compressive strength, flexural strength and ductility where as the water absorption and ISAT values were very low leading to the durability of the elements particularly in aggressive environment

Abang, discusses the efficient use of alternative building materials and technology, appropriate to the local needs of a country must be studied and developed in order to assist the country in sustaining its building activities. Ferrocement, as a relatively new construction material in Malaysia, is slowly gaining acceptance. Various applications of ferrocement as a low cost construction material in the country is discussed.

CHAPTER 3

METHODOLOGY

3.1 FERRO CEMENT

Ferro cement is a construction material composed of reinforced concrete and various layers of steel wire mesh were electro-welded, distributed uniformly around Thermocol. Normally a mortar rich of cement, sand and water is used. This material is thin (10–35 mm thick) and with high resistance and flexibility besides of being a low cost material. Ferro cement constructions present weight reduction compared to traditional building materials. The study is almost experimental in nature. The study consists of two-phase study scheme. First phase of the present research focuses on development of optimum, high workability and high performance mortar, which should be capable to be poured during the casting of ferrocement skin boxes over concrete, in single operation. The performance of the mortar was investigated in terms of compressive strength, strength development, water absorption, and unit weight. The specimens were cured in three curing regimes namely water, air, and natural weather in order to determine the appropriate curing regimes to be adopted for sandwich specimens.

Figure 3.1: Concrete Structure Using Ferrocement

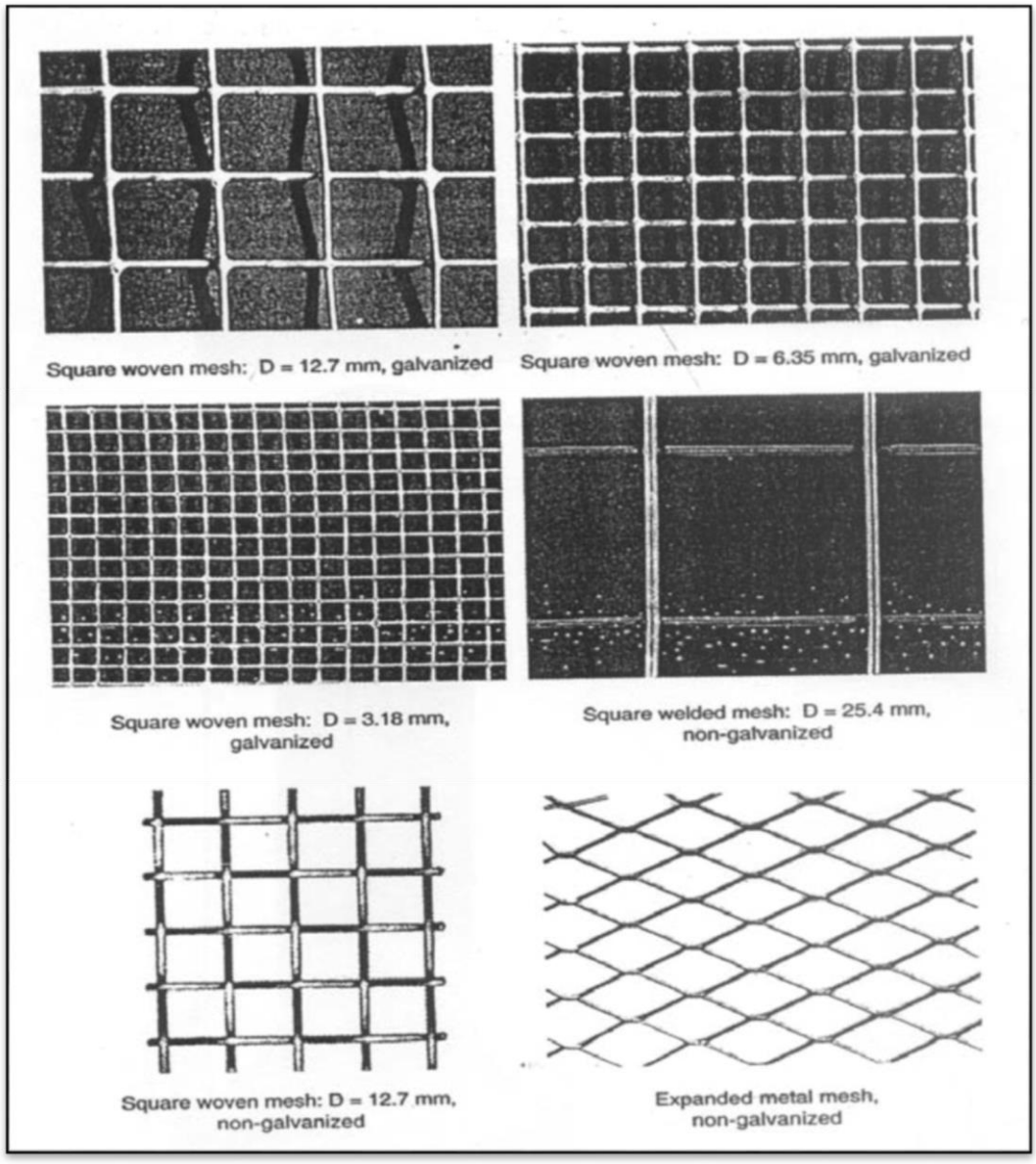

Figure 3.2: Types of Wire Mesh

During the second phase of the experimental program, behaviour of sandwich specimens; cubes, blocks prism beams and wall elements of relatively large size, were investigated under compression as major parameter and under bending as additional parameter. To achieve the main aim, a stepwise strategy was adopted by addressing a number of variables. Wire mesh namely square welded wire mesh, and were incorporated in ferrocement box by varying the number of layers; 0, 1, 2, 3 and 4. The performance of the sandwich specimens were studied in terms of ultimate compressive strength and flexural strength, unit weight load-axial deformation, and load-lateral deformation under compression along with load-deflection and

load-strain relationship under bending. The failure mode and composite action of sandwich elements under both the loading conditions were also studied. In addition, efforts were made that it should be low cost, lightweight, and water resistant. Aerated concrete previously developed and subsequently improvised were used as core during this study. Finally mathematical models were developed which were related to both the phases of this study. The mathematical models developed were applicable to predict compressive strength of high workability cement based mortar and ferrocement encased lightweight aerated concrete sandwich wall elements.

3.2 SANDWICH STRUCTURAL ELEMENTS/MEMBERS

3.2.1 General

A sandwich block is a three-layer element, comprising two thin, flat facing plates of high-strength material and between which a thick lightweight core of low average strength is attached. Figure 3.3 presents a few types of sandwich block elements. Such sandwich structures have gained widespread acceptance within the aerospace, naval/marine, automotive and general transportation industries as an excellent way to obtain extremely lightweight components and structures with very high bending stiffness and high strength.

Figure 3.3: Sandwich Block

3.2.2 Advantages of Sandwich

1. Sandwich construction form has distinct advantages over conventional structural sections because it promises high stiffness and high strength-toweight ratio as compared with a solid member.
2. Sandwich composite structure possesses excellent flexural and shear properties. Their inherent lightweight characteristics make them ideal structural components where weight reduction is desirable.
3. In concrete construction, self-weight of structure itself represents a very large proportion of the total load on the structures thus, reduction in the self-weight of the structures by adopting an appropriate approach results in the reduction of element cross-section, size of foundation and supporting elements thereby reduced overall cost of the project.
4. The lightweight structural elements can be applied for construction of the buildings on soils with lower load-bearing capacity.
5. Reduced self-weight of the structures using lightweight concrete reduces the risk of earthquake damages to the structures because the earth quake forces that will influence the civil engineering structures and buildings are proportional to the mass of the structures and building. Thus reducing the mass of the structure or building is of utmost importance to reduce their risk due to earthquake acceleration.
6. Good thermal insulation due to the cellular thick core makes it an ideal external construction component.
7. Some recent investigations suggest their excellent energy-absorbing characteristics under high-velocity impact loading conditions.
8. Sandwich structures have been considered as potential candidate to mitigate impulsive (short duration) loads.

3.2.3 Shear Connectors

Eight specimen blocks prepared and tested in this study and the Compressive strength measured and compared to different types of shear connectors given below

Table 3.1: Types of shear connectors

Sl.No	Specimen Details	Specimen Index
1	Single Core with Single Mesh	SM
2	Single Core Single Mesh With “M” Pin	SMM
3	Single Core Single Mesh With “V” Pin	SMV
4	Single Core Single Mesh With “U” Pin	SMU
5	Three Core with Single Mesh	WM
6	Three Core Single mesh With “M” Pin	WMM
7	Three Core Single mesh With “V” Pin	WMV
8	Three Core Single mesh With “U” Pin	WMU

Although the mesh thickness ranging between 15mm to 75 mm, however it is mentioned that the appropriate thickness of the mesh be decided as per the requirement of the structure. The structural behaviour of the block depends greatly on the strength and stiffness of the connectors, while the thermal resistance of the insulation layer governs the insulation value of the pane. The arrangement and spacing of shear connectors depending on several factors, such as desired composite action, applied load and type of shear connectors used. Various types of connectors used are shown in Figure 3.4 and 3.5.

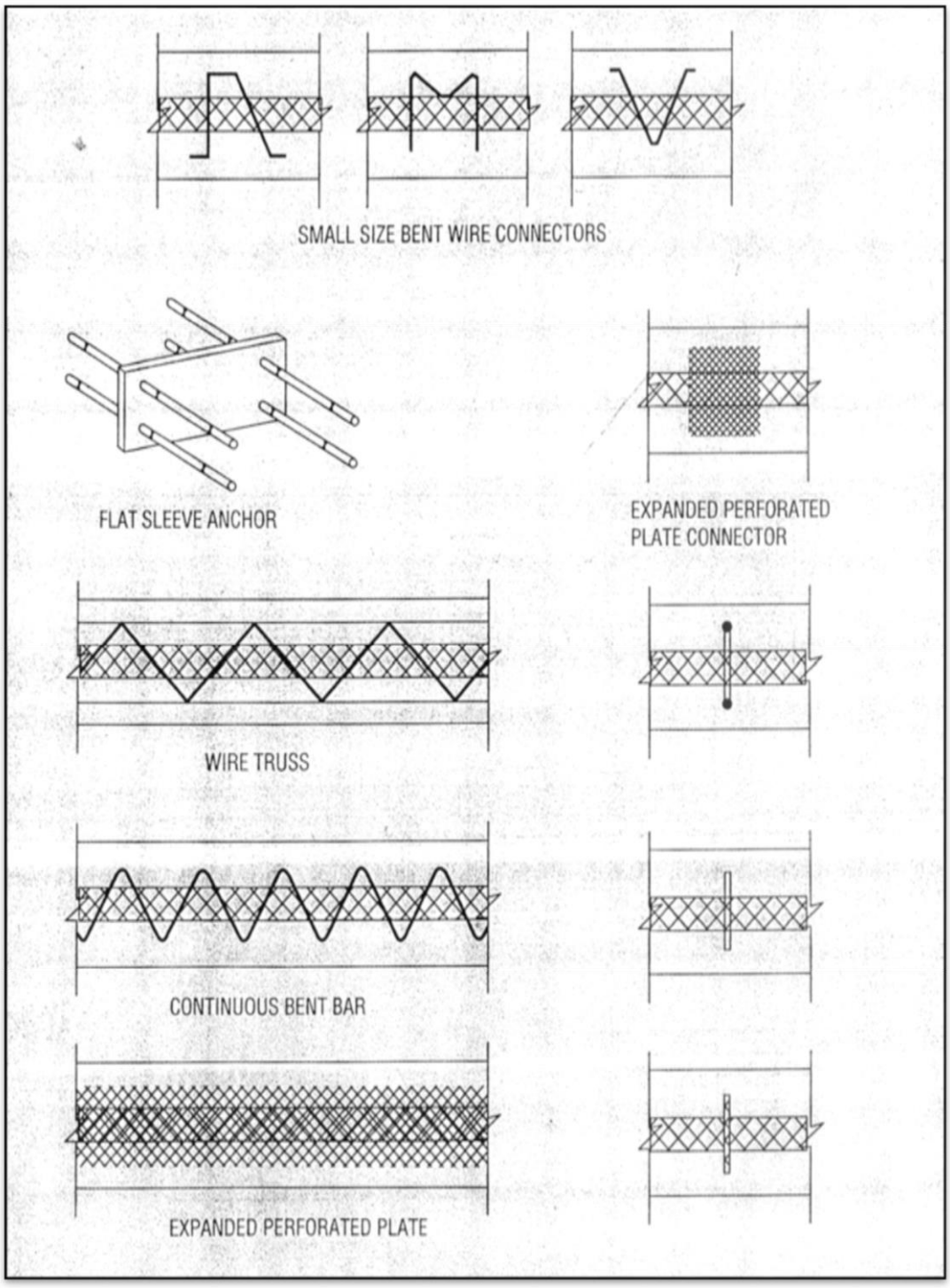

Figure 3.4: Shear Connectors

The insulation between the mesh may in some cases provide a shear resistance between the mesh. Rough faced dense insulation provides more shear transfer than slick faced insulation.

Shear resistance that may be available from bonded insulation is considered temporary. In semi-composite panels, the assumption is made that the insulation provides sufficient shear transfer to create composite action during handling and erection, but the shear transfer is not relied on to provide composite action for resisting service loads.

The structural integrity of any sandwich construction, to enjoy the full advantage of the strength of two meshes and to prevent individual mesh, depends on the strength of connection/bonding of the connectors/core with mesh. Commonly, the connection between the connectors and the two facing plates is achieved by the one-side spot welding, or self-taping screws/rivets. The fabrication of conventional sandwich block necessitates adequate contact area between the core and facing cement ensure proper connection between these elements.

In case of steel connectors, the cell walls provide a very small area for connection/bonding; inadequate to hold the two mesh connected until failure thereby causing the separation of two mesh and also may cause buckling of the diagonals. Also it is laborious and may face difficulties during production. Thus, difficulty in the production of such blocks affects the reliability of the connection between the elements resulting in uncertain role of connectors and interaction between various components. This is why; it continues to be a problem for investigators and fabricators alike. Moreover, the connectors pass from one concrete mesh to the other concrete mesh through the insulation layer. Thus, the placement of the connectors interrupts the continuous insulation layer.

Depending upon the material used to make the connectors in a block, the thermal performance of block may be decreased; in some cases as much as 40% by the large quantities of heat conducted through the shear connectors passing through the insulation On the other hand, the foam cores are bonded with the mesh by means of various types of bonding agents. Although the foam cores provide a large area in contact with the mesh, however it entirely depend upon the type, quality, an efficiency of bonding material along with the skills adopted during the bonding process. Flaws in the form of debone between the mesh and the cores are likely to prevail, and if the flaws propagate they may impart effect on the load-bearing capacity of the structure because of the loss of load transfer between the facings.

In addition, it has been demonstrated time and again that during flexural loading be controls the failure of the sandwich structures. Interfacial delaminating in a sandwich panel represents a severe defect that affects the overall integrity and safety of the structure. It typically begins

as a delamination crack at the core–skin interface near the loading point, advances towards the support along the sub-interface kinks into the core. Thus, in any event, it is clear that the delamination at the sub-interface region and the shear strength of the core in essence dictate the performance of the sandwich composites under flexure.

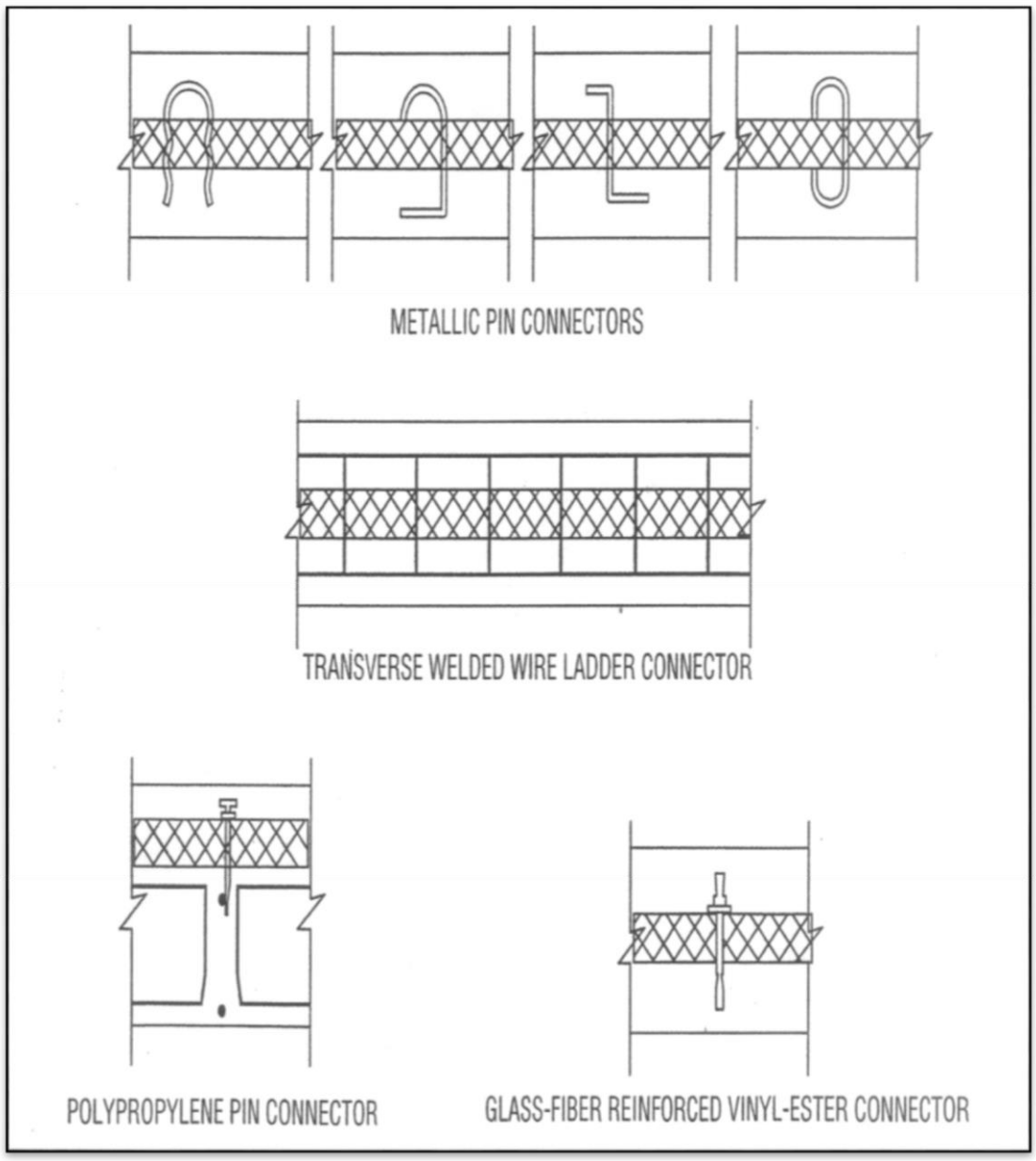

Figure 3.5: Types of Shear Connectors

3.3 SPECIMEN DETAILS

3.3.1 Steps in Methodology

1. Allocation of raw materials like cement, Sand, Mesh, Water proofing admixture (As per IS: 2645-1975) and Thermocol measuring as per requirements.
2. Cover 12mm.
3. Preparation of mortar is done with water cement ration of 0.45
4. The mould of size 400 x 200x 100 mm is made.
5. Thermocol is arranged for each type.
6. Casting of Blocks were done and kept for 1 day mould
7. Curing of blocks in water is done after removing from mould
8. Checking compressive strength for particular 28th day.

3.3.2 Formulation of Mix Design

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of required strength, quantity, durability and workability as economically as possible, is termed as concrete mix design. Since there are no standards for mix proportioning of foam concrete, this project is carried out with the formulation of the design procedure.

In normal concrete, water content in kg/m³ is used, which indirectly gives the values of cement content through use of graph. This method is not suitable for foam concrete, because such graphs do not exist for foam concrete. So a rational proportioning method based on solid volume calculation is adopted to determine the cement content.

Table 3.2: Mix Proportion of Mortar for Encasement (Ferro Cement)

Cement: Sand	1:2
PPC	100% of total binder by weight
Sand	Passing through sieve size 1.18mm
Water cement ratio	0.45
Waterproofing admixture	0.4

Table 3.3: Amount of Encasement Material Used In Each Block

Sl.No	Material	Quantities in Kg/m³	Proportion
1	Cement	350	1
2	Fine aggregate	700	2
3	Water-cement ratio	143.2	0.45

3.4 MANUFACTURING DETAILS

a) Preparing the reinforced wire meshes with the required block dimensions.

b) Preparing the steel mesh reinforcement for web

c) Arrange the shear connectors and attaching or fixing with the one side wire meshes.

d) The designed concrete is poured in the mold for the first layer. Placing the Thermocol or filler blocks material in place and above the first concrete layer.

e) The designed concrete is poured in the mold to full fill the mold and make the concrete cover with the required thickness.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

Compressive strength of Polystyrene Sandwich blocks with various types of connectors with is determined on the 28th day in the compressive strength testing machine of each sample. There were two samples for each test and the results would be taken as the average of these two.

Table 4.1: Compressive strength of sandwich blocks

S.NO	Details	Load(KN)	Compressive strength of concrete N/mm² 28 days
1	Single Core with Single Mesh(SM)	225	5.625
2	Single Core Single Mesh with “M” PIN (SMM)	267	6.675
3	Single Core Single Mesh with “V” PIN (SMV)	250	6.250
4	Single Core Single Mesh with “U” PIN (SMU)	255	6.375
5	Three Core w ith Single Mesh(SM)	290	7.250
6	Three Core Single Mesh with “M” Pin(WMM)	340	8.500

7	Three Core Single Mesh with "U" Pin(WMU)	300	7.500
8	Three Core Single Mesh with "V" Pin(WMV)	310	7.750

4.2 DISCUSSION

- The sandwich blocks are weight less and can used in construction purpose.
- The Single Core Single Mesh with "M" Pin is 1.19 times more compressive strength than Single Core with Single Mesh (SM).
- The Single Core Single Mesh with "V" Pin (SMV) is 1.11 times more compressive strength than Single Core with Single Mesh (SM).
- The Single Core Single Mesh with "U" Pin (SMU) is 1.13 times more compressive strength than Single Core with Single Mesh (SM).
- Three Core with Single Mesh (WM) is 1.29 times more compressive strength than Single Core with Single Mesh (SM).
- Three Core Single Mesh with "M" Pin (WMM) is 1.51 times more compressive strength than Single Core with Single Mesh (SM).
- Three Core Single Mesh with "V" Pin (WMV) is 1.33 times more compressive strength than Single Core with Single Mesh (SM).
- Three Core Single Mesh with "U" Pin (WMU) is 1.38 times more compressive strength than Single Core with Single Mesh (SM).

CHAPTER 5

CONCLUSION

In order to make use of these building materials more efficiently and make people aware of its benefits, an organized technique is required to promote them. It is very important that people are aware of the benefits of using the substitutes for construction materials.

According to various experts related to the real estate sector, the best environment friendly construction can be acquired through the usage of manufactured sand from stone quarries and brick substitutes. This will also avoid over-exploitation of natural resources like river sand and clay.

Sandwich Blocks these days are being used in incredible projects taken up by business tycoons and real estate builders. It is also necessary that the government should start promoting these environment friendly construction substitutes to boost market acceptance.

The government authorities have put a stop to the mining of sand due to environmental concerns but the manual operations in the sand mining have increased its prices. The sand prices have increased since the last few months and so are the brick prices due to climatic changes. Owing to all these reasons it is better that the usage of the Sandwich should be adopted.

REFERENCES

S. Ananda Selvan [2016]. "Experimental study on lightweight sandwich blocks for replacement on bricks". The blocks give long span and earthquake resistance. Carmichael, J (1986)." Pumice Concrete Blocks". Concrete, International. 8(11): 31– 32

Salihuddin Radin Sumadi et al., [2008]. "Development of Lightweight Ferro cement Sandwich Blocks for Modular Housing and Industrialized Building System". Research Vote No: 73311 University Technology Malaysia.

. Abang, A.A.A. (1995). "Application of Ferro cement as a Low Cost Construction Material in Malaysia". Journal of Ferrocement. 25(2):123-128. In modern construction, ferrocemcent is widely using and it is low cost material. In this the application of ferrocemcent is pointing.