# LIGHTWEIGHT FOAM CONCRETE

**PHASE-I PROJECT REPORT**

***Submitted by***


**ANVER SHERIF.A (080104201005)**

**KARTHIKEYAN.S (080104201019)**

**PRAVEEN PRASATH.S (080104201035)**


***in partial fulfillment for the award of the degree***

***of***

**BACHELOR OF ENGINEERING**

**in**

**CIVIL ENGINEERING**


**JAYAM COLLEGE OF ENGINEERING AND TECHNOLOGY,**

**DHARMAPURI-636813**

**ANNA UNIVERSITY OF TECHNOLOGY,**

**COIMBATORE 641047.**


NOV-2011

# ANNA UNIVERSITY OF TECHNOLOGY

# COIMBATORE - 641047

## BONAFIDE CERTIFICATE

Certified that this project report **"LIGHTWEIGHT FOAM CONCRETE"** is the bonafide work of

| | |
|---|---|
| **ANVER SHERIF.A** | **(080104201005)** |
| **KARTHIKEYAN.S** | **(080104201019)** |
| **PRAVEEN PRASATH.S** | **(080104201035)** |

who carried out the project work under my supervision.

| | |
|---|---|
| **SIGNATURE** | **SIGNATURE** |
| **Mr. C.MURUGANANDHAM, M.E.,** | **Prof. M.P.SENTHILKUMAR, M.E, Ph.D.,** |
| **SUPERVISOR** | **HEAD OF THE DEPARTMENT** |
| **Lecturer,** Dept. of Civil Engineering,<br>Jayam College of Engg. & Technology<br>Dharmapuri - 636 813 | Dept. of Civil Engineering,<br>Jayam College of Engg. & Technology<br>Dharmapuri - 636 813 |

Submitted for the Project Viva-Voce examination held on ______________.

**INTERNAL EXAMINER** **EXTERNAL EXAMINER**

## ACKNOWLEDGEMENT

We thank the Almighty for providing us with enough strength, courage and ideas for successful completion of the Project.

Our grateful thanks to our beloved Chairman, **Shri**. **M.RAMESH**, Our Trustee, **Smt.PARVATHI RAMESH,** Our Chief Executive Officer **Shri.A.R.SUGUMARAN,** Our Director **Shri. R.GOPINATH,** for providing us all the facilities during the course of the study and for giving us the opportunity to undertake this project work.

Our hearty thanks in deep sense of gratitude to our Principal **Dr.G.THOLKAPPIA ARASU B.E., M.S., Ph.D., PGDMIT.** who has been a source of encouragement and inspiration throughout.

We render our sincere gratitude to our Head of the Department **Prof.M.P.SENTHIL KUMAR, M.E., Ph.D.,** for favoring us with the needful during our project period.

It is a great pleasure to express our sincere and whole hearted gratitude to thoughts, our project internal guide **Lecturer.C.MURUGANANDHAM, M.E,** for his valuable guidance and care for us.

Also our sincere thanks to all the Staff Members of the Department of Civil Engineering for providing us creative ideas and knowledge in the field of our Project. We acknowledge with sense of gratitude, the help given to us by the Technicians in our Department.

Last but not least our sincere thanks to Family Members for their constant prayers, co-operation and encouragement during this period. Also we extend our thanks to all friends and well-wishers for their timely help and support while doing the Project Work.

# DECLARATION

I affirm that the project titled **"LIGHTWEIGHT FOAM CONCRETE"** being submitted in partial fulfillment for the award of Bachelor of Engineering degree is the original work carried out by us. It has not formed the part of any other project submitted for award of any degree or diploma, either in this or any other University.

(Signature of the Candidates)

ANVER SHERIF.A [080104201005]

KARTHIKEYAN.S [080104201019]

PRAVEEN PRASATH.S [080104201035]

I certify that the declaration made above by the candidates are true.

(Signature of the Internal Guide)

**Mr.C.MURUGANANDHAM** M.E.,

LECTURER/CIVIL ENGINEERING,

Jayam College of Engineering and Technology,

Dharmapuri- 636 813.

# CONTENTS

# ABSTRACT

# ABSTRACT

LFC is cementatious material integrated with mechanically entrained foam in the mortar slurry which can produce a variety of densities ranging from 400 to 1600 kg/m$^3$.The application of LFC has been primarily as a filler material in construction works. This research explores the potential of using LFC in building construction, as non-load bearing partitions of lightweight load-bearing structural members. Experimental and analytical studies will be undertaken to develop quantification models to obtain thermal and mechanical properties of LFC at ambient and elevated temperatures. In order to develop thermal property model, LFC is treated as a porous material and the effects of radiant heat transfer within the pores are included. The thermal conductivity model results are in very good agreement with the experimental results obtained from the guarded hot plate tests and with inverse analysis of LFC slabs heated from one side.

Extensive compression and bending tests at elevated temperatures were performed for LFC densities of 650 and 1000 kg/m3 to obtain the mechanical properties of unstressed LFC. The test results indicate that the porosity of LFC is mainly a function of density and changes little at different temperatures. The reduction in strength and stiffness of LFC at high temperatures can be predicted using the mechanical property models for normal weight concrete provided that the LFC is based on ordinary Portland cement. Although LFC mechanical properties are low in comparison to normal weight concrete.

LFC may be used as partition or light load-bearing walls in a low rise residential construction. To confirm this, structural tests were performed on a composite walling system consisting of two outer skins of profiled thin-walled steel sheeting with LFC core under axial compression, for steel sheeting thicknesses of 0.4mm and 0.8mm correspondingly. Using these test results, analytical models are developed to calculate the maximum load-bearing capacity of the composite walling, taking into consideration the local buckling effect of the steel sheeting and profiled shape of the LFC core.

The results of a preliminary feasibility study indicate that LFC can achieve very good thermal insulation performance for fire resistance. A single layer of 650 kg/m3 density LFC panel of about 21 mm would be able to attain 30 minutes of standard fire resistance rating, which

is comparable to gypsum plasterboard. The results of a feasibility study on structural performance of a composite walling system indicates that the proposed panel system, using 100mm LFC core and 0.4mm steel sheeting, has sufficient load carrying capacity to be used in low-rise residential construction up to four-storeys.

# INTRODUCTION

# INTRODUCTION

In recent years, the construction industry has shown significant interest in the use of lightweight foamed concrete (LFC) as a building material due to its many favourable characteristics such as lighter weight, easy to fabricate, durable and cost effective. LFC is a material consisting of Portland cement paste or cement filler matrix (mortar) with a homogeneous pore structure created by introducing air in the form of small bubbles. With a proper control in dosage of foam and methods of production, a wide range of densities (400 – 1600 kg/m3) of LFC can be produced thus providing flexibility for application such as structural elements, partition, insulating materials and filling grades. LFC has so far been applied primarily as a filler material in civil engineering works. However, its good thermal and acoustic performance indicates its strong potential as a material in building construction. In fact, there has been widespread reported use of LFC as structural elements in building schools, apartments and housing in countries such as Libya, Russia, Brazil, Malaysia, Mexico, Saudi Arabia, Indonesia, Egypt and Singapore (Kearsley and Mostert, 2005). Figures 1.1 to 1.4 show some examples of the application of LFC in real project.

**Figure 1.1** LFC blocks being used in a housing project in Malaysia.

**Figure 1.2** Large scale LFC infilling of an old mine in Combe Down, United Kingdom.

**Figure 1.3** Cast in-situ LFC wall in Surabaya, Indonesia.

**Figure 1.4** LFC being employed in a high rise building floor screed in Penang, Malaysia.

This project is concerned with exploring the potential of using LFC as a building material. Although LFC mechanical properties are low compared to normal weight concrete, LFC may be used as partition or light load-bearing walls in low rise residential construction. The first stage to realize the potential of LFC for application as a load-bearing material in building construction is to obtain reliable thermal and mechanical properties at elevated temperatures for quantification of its fire resistance performance and some indication of whether it has adequate load-bearing performance. In order to gain a clearer understanding of the properties of LFC so as to develop a method to dependably predict its performance under ambient and elevated temperatures, this research will involve both experimental and theoretical investigations to ensure that the analytical model is generically applicable and validated. This research is divided into four main stages. The first stage is to develop a theoretical model for temperature dependant thermal properties (thermal conductivity and specific heat) and to conduct transient heating tests in an electric kiln on LFC slabs to establish the through depth temperature profiles for validation of its thermal properties. In the second stage, compression and bending tests are performed at elevated temperatures to establish the mechanical properties of unstressed LFC. Thirdly, experiments are performed to observe the compressive structural behaviour of LFC based composite walling system and to investigate methods of calculating their strength at ambient temperature. Finally, a feasibility study will be executed to assess the applicability and limits of this LFC based system in building construction in terms of its fire resistance and structural performance.

# OBJECTIVES AND SIGNIFICANCE OF LIGHTWEIGHT FOAM CONCRETE

## OBJECTIVES AND SIGNIFICANCE OF LIGHTWEIGHT FOAM CONCRETE

LFC is a relatively new construction material compared to normal weight concrete. The major factor limiting the use of LFC in applications is insufficient knowledge of the material performance at elevated temperatures.

In building application, load carrying capacity and fire resistance are the most important safety requirements. In order to comprehend and eventually predict the performance of LFC based systems, the material properties at ambient temperature and elevated temperatures must be known at first stage. To be able to predict the fire resistance of a building structure, the temperatures in the structure must be determined.

For such calculations, knowledge of the thermal properties, at elevated temperatures of the material is essential. In this research, the important thermal properties of LFC at elevated temperatures will be investigated. These properties include thermal conductivity, specific heat, porosity and density change of LFC. For quantification of structural performance, LFC mechanical properties will be established, including compressive strength, compressive modulus, strain at maximum compressive strength, compressive stress-strain relationship, failure modes, flexural tensile strength and flexural tensile modulus. To indicate feasibility of using LFC in building construction,
it is necessary to carry out investigation of structural performance of LFC based building components. In this research, a composite walling system will be investigated.

The main objectives of this study are:

- ✓ To experimentally study and quantify the thermal properties of LFC at high temperatures so as to obtain material property data for prediction of fire resistance of LFC based systems through transient heating tests.
- ✓ To develop and validate proposed thermal property models for LFC.
- ✓ To experimentally examine and characterize the mechanical properties of LFC at ambient and elevated temperatures.

- ✓ To assess and propose mechanical properties prediction equations of LFC, based on comparison of the experimental results with existing models for normal weight concrete.

- ✓ To experimentally investigate the compressive behaviour of composite wall panels consisting of two outer skins of profiled thin-walled steel sheeting with LFC core and to analytically develop a model to calculate the maximum loadbearing capacity of the composite walling system.

- ✓ To carry out feasibility study on fire resistance and structural performance of using LFC in low-rise residential construction.

# LITERATURE REVIEW

## LITERATURE REVIEW

Since LFC is not a main stream construction material, a brief introduction to LFC will first be provided. LFC is defined as a cementitious material having a minimum of 20 per cent by volume of mechanically entrained foam in the mortar slurry (Van Deijk, 1992) in which air-pores are entrapped in the matrix by means of a suitable foaming agent. The air-pores are initiated by agitating air with a foaming agent diluted with water; the foam then carefully mixes together with the cement slurry to form LFC. Integrating the air-pores into the base matrix gives a low self-weight, high workability, excellent insulating values, but lower strength in contrast to normal weight concrete. LFC can be fabricated anywhere in any shape or building unit size.

LFC is not a new material in the construction industry. It was first patented in 1923 (Valore, 1954) and a limited scale of production was instigated in 1923. The use of LFC was very limited until the late 1970s**,** when it was started to be consumed in Netherlands for ground engineering applications and voids filling works. In 1987 a fullscale assessment on the application of LFC as a trench reinstatement was carried out in the United Kingdom and the achievement of this trial led to the extensive application of LFC for trench reinstatement and other applications followed (Brady et al., 2001). Since then, LFC as a building material has become more widespread with expanding production and range of applications.

Over the past 20 years, LFC has primarily been used around the world for bulk filling,trench reinstatements, backfill to retaining walls and bridge abutments, insulation to foundations and roof tiles, sound insulation, stabilising soils (especially in the construction of embankment slopes), grouting for tunnel works, sandwich fill for precast units and pipeline infill. However, in the last few years, there is developing interest in using LFC as a lightweight non-structural and semi-structural material in buildings to take advantage its lightweight and good insulation properties. LFC can have a wide range of densities and each density is produced for a particular type of application. Table 2.1 shows the range of densities suitable for different applications.

**Table 2.1** Applications of LFC with different densities

| **Density (kg/m$^3$)** | **Applications** |
|---|---|
| 300 – 600 | Used for roof and floor insulation against heat and sound and also for interspaces filling between brickwork leaves in underground walls, insulation in hollow blocks and any other filling situation where high insulating properties are required. |
| 600 – 900 | Used for the production of precast blocks and panels for curtain and partition walls, slabs for false ceilings, thermal insulation and soundproofing screeds in multi-level residential buildings. LFC of this density range is also ideal for bulk fill application. |
| 900 – 1200 | Used in concrete blocks and panels for outer leaves of buildings, architectural ornamentation as well as partition walls, concrete slabs for roofing and floor screeds. |
| 1200 – 1800 | Used in precast panels of any dimension for commercial and industrial use, garden ornaments and other uses where structural concrete of light weight is an advantage. |

## Constituents material of LFC

LFC with low density, i.e. having a dry density of up to about 600 kg/m3, is frequently formed from cement (to which other binders could be added), water and stable foam whilst denser LFC will incorporate fine sand in the mix. The requirements of each constituent of LFC are explained below:

## Cement

Portland cement SEM1 is typically used as the main binder for LFC. Additionally, rapid hardening Portland cement (Kearsley and Wainwright, 2001), calcium sulfoaluminate and high alumina cement (Turner, 2001) have also been used to reduce the setting time and to obtain better early strength of LFC. There was also an attempt to decrease the cost of production by using fly ash (Kearsley and Wainwright, 2001) as cement replacement to enhance consistency of the mix and to reduce heat of hydration while contributing for long term strength.

## Fillers (sand)

Sach and Seifert (1999) suggested that only fine sands having particle sizes up to about 4mm and with an even distribution of sizes should be used for LFC. This is primarily because coarser aggregate might lead to collapse of the foam during the mixing process. Coarse pulverised fuel ash (PFA) also can be used as a partial or total replacement for sand to make LFC with a dry density below about 1400 kg/m3.

## Water

The amount of water to be added to the mix depends on the composition of the mix design. Generally for lighter densities, when the amount of foam is increased, the amount of water can be decreased. The water-cement ratio must be kept as low as possible in order to avoid unnecessary shrinkage in the moulds. However, if the amount of water added to cement and sand is too low, the necessary moisture to make a workable mix will have to be extracted from the foam after it is added, thereby destroying some of the foam in the mix. The range of water-cement ratio used in LFC is between 0.4 to 1.25 (Kearsley, 1996), the appropriate value will be depending on the amount of cement in the mix, use of chemical admixtures and consistence requirement. Plasticizers are not normally necessary to make LFC because of LFC has intrinsic high workability.

## Surfactants (foaming agent)

There is an extensive choice of surfactants (foaming agent) available in the market.Generally two types of surfactants can be used to produce foam: protein and synthetic based surfactants. Protein based surfactants are produced from refined animal products such as hoof, horn and skin whilst synthetic based surfactants are produced using man made chemicals such as the ones used in shampoos, soap powders and soaps (Md Azree, 2004). The surfactant solution typically consists of one part of surfactant and between 5 and 40 parts of water but the optimum value is a function of the type of surfactant and the technique of production. It is very important to store all surfactants accordingly because they are inclined to deterioration at low temperatures. According to McGovern (2000), foams formed from protein based surfactants have smaller bubble size, are more stable and have a stronger closed bubble structure compared to the foam produced using synthetic surfactants. Therefore, protein based surfactants would be best suited for the production of LFC of comparatively high density and high strength.The stability of foam is a function of its density and the type of surfactant. The foam has to endure its inclusion into the mortar mix and the chemical environment of the concrete until it has attained a reasonable set. A number of external environmental factors can exert influence on the stability of the foam such as vibration, evaporation, wind and temperature. Some or all of these may be present on a site and may lead to the breakdown in the foam structure. Currently two methods can be used to produce LFC, either by pre-foaming method or mixed foaming method. Pre-foaming involves preparation of the base mix and the stable foam individually and then is added together. In the mixed foaming method, the foaming agent is mixed together with the base matrix. The properties of LFC are significantly reliant upon the quality of the foam; therefore, the foam should be firm and stable so that it resists the pressure of the mortar until the cement takes its initial set to allow a strong skeleton of concrete to be built up around the void filled with air (Koudriashoff, 1949).

## Design procedure of LFC

At the moment, there is no standard method for designing LFC mix. For normal weight concrete, the user would signify a certain compressive strength and the water-cement ratio would be adjusted to meet the requirement.

As far as LFC is concerned, not only the strength is specified, but also the density. Since the compressive strength of LFC is a function of density, the density can be used to modify the strength but this does not give any indication of the water requirement in the mix. It is not an easy task to achieve an accurate measurement of the density of LFC on site because of the hardened density of LFC depends on the saturation intensity in its pores.

According to Jones and McCarthy (2005), it is difficult to achieve the design density of LFC because it has a tendency to lose between 50 and 200 kg/m3 of the total mix water because it depends on the concrete fresh density, early curing regime and exposure conditions.

# METHODOLOGY

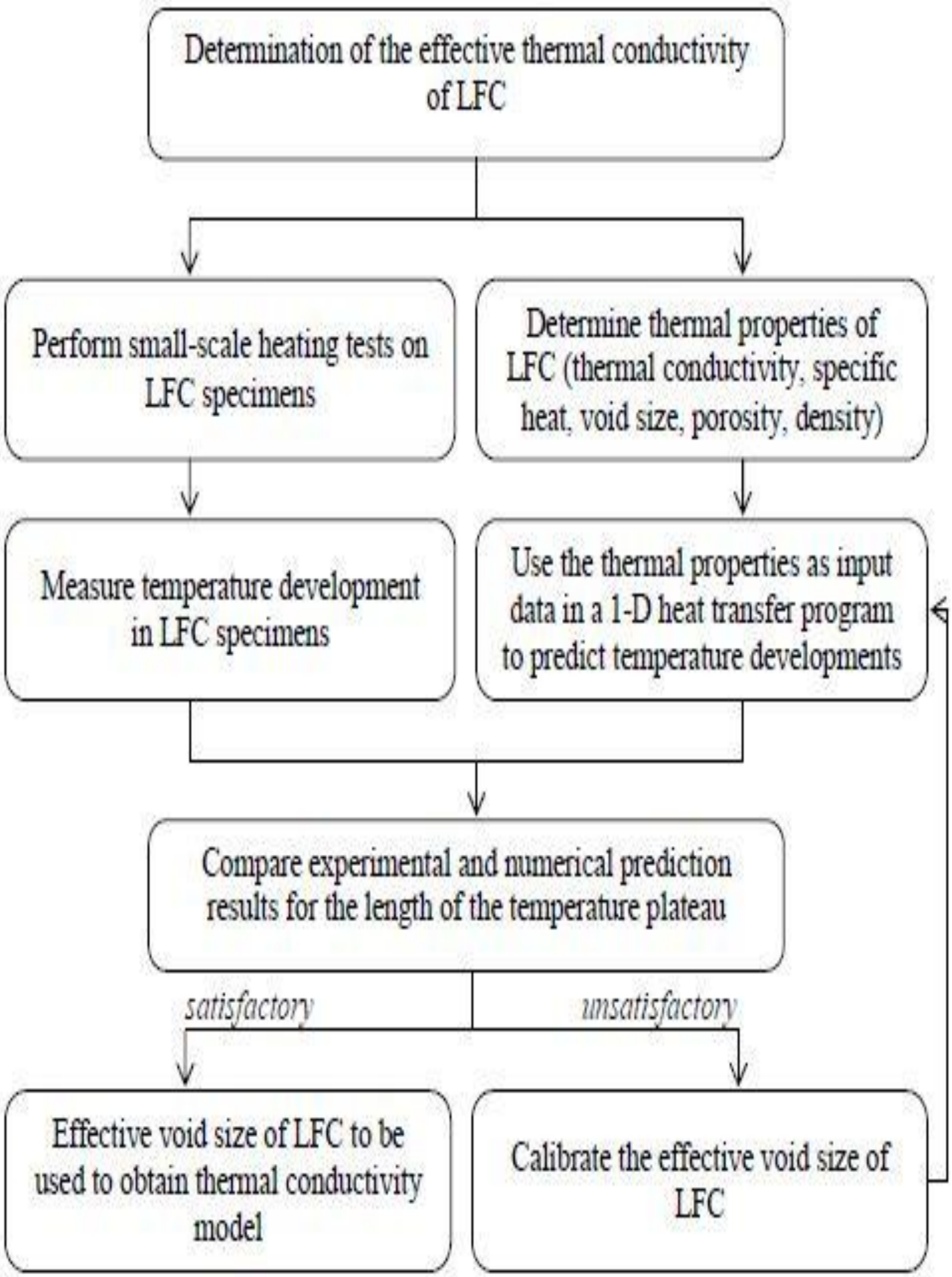


**Figure 1.5** Methodology to determine the effective thermal conductivity of LFC

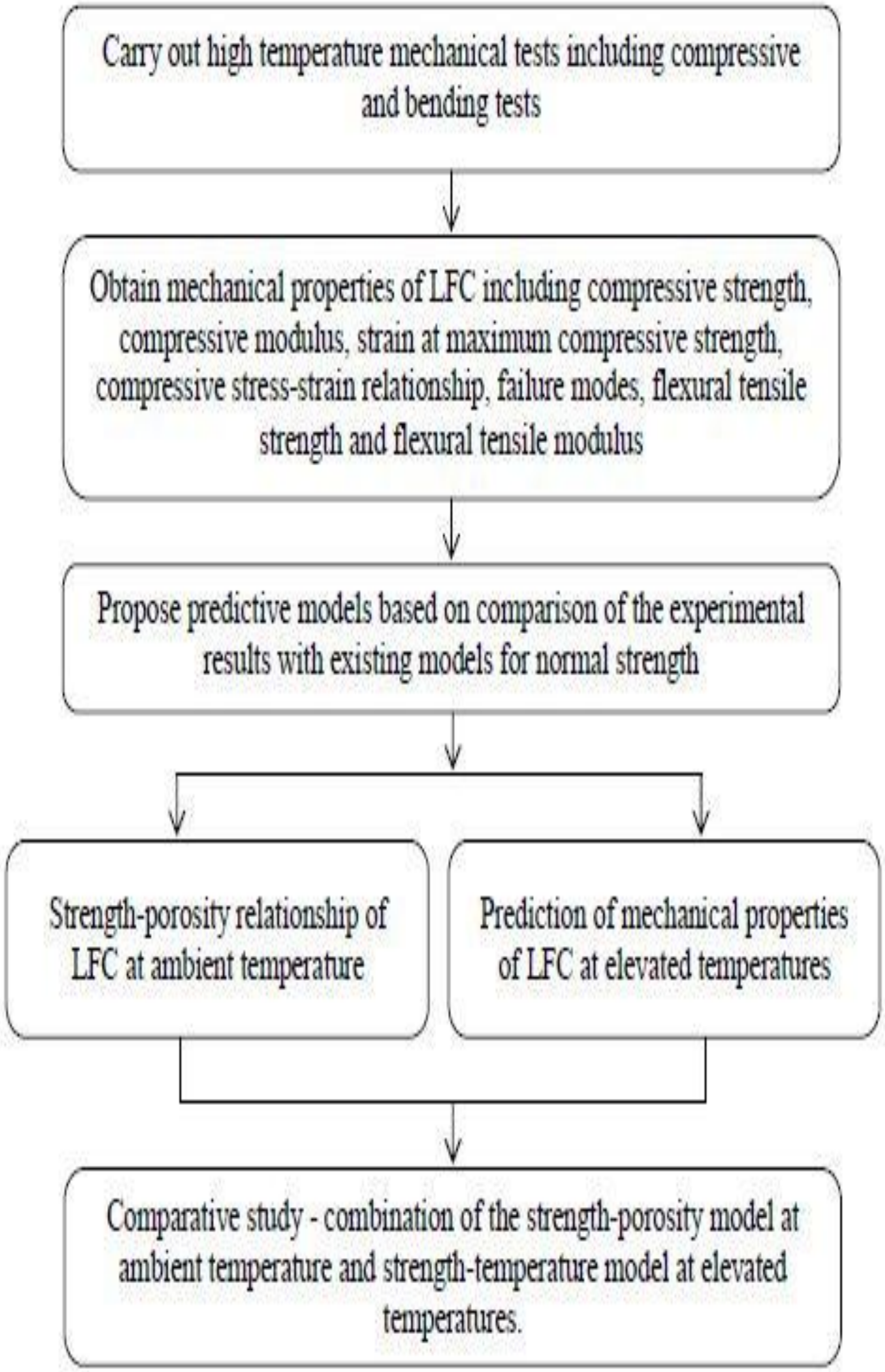


**Figure 1.6** Methodology to examine and characterize the mechanical properties of LFC at elevated temperatures

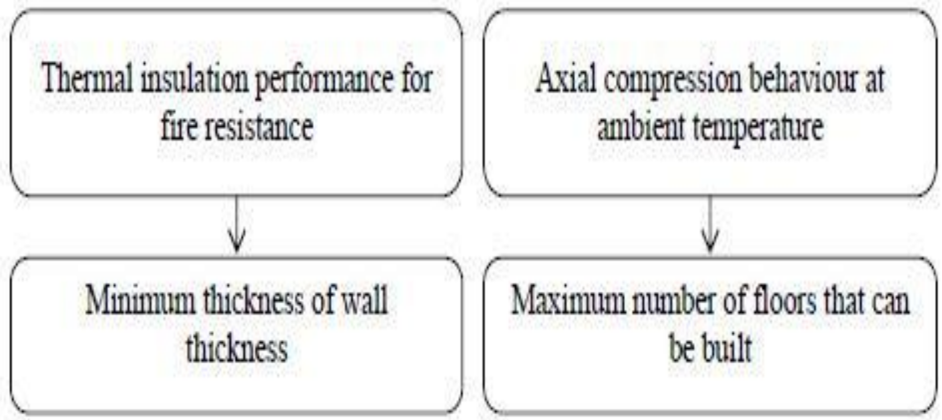


**Figure 2.18** Methodology to assess the feasibility using LFC based wall panels in realistic construction.

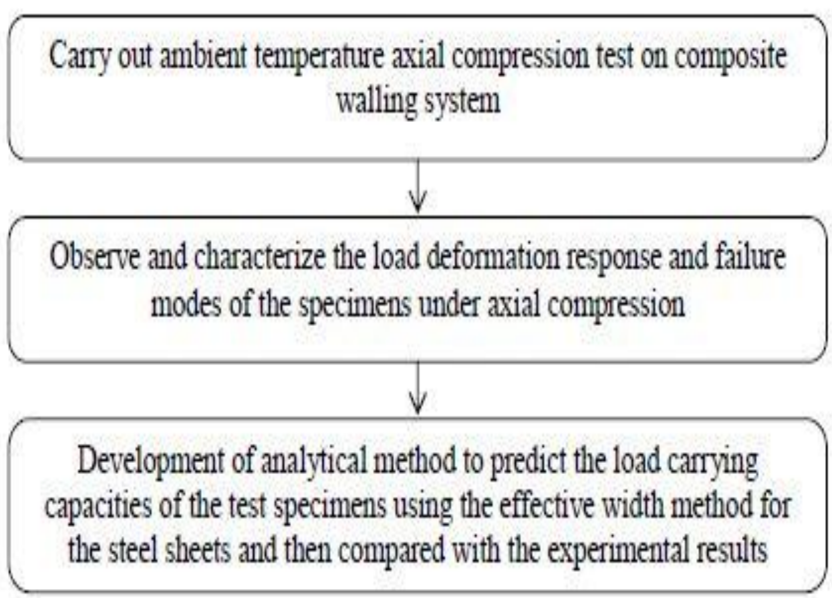


**Figure 2.17** Methodology to examine the structural behavior of composite walling system under axial compression

## REFERENCES


- ✓ https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:94463&datastreamId=FULL-TEXT.PDF
- ✓ www.litebuilt.com
- ✓ www.portafoam.com
- ✓ www.bathnes.gov.uk
- ✓ Md Azree Othuman Mydin, Wang YC. Elevated-temperature thermal properties of lightweight foamed concrete. J Constr Building Mater, in press, doi:10.1016/j.conbuildmat.2010.07.016..
- ✓ BSI. BS EN 197-1: Cement. Composition, specifications and conformity criteria for low heat common cements. London: British Standards Institution; 2000.
- ✓ Wright H. The axial load behaviour of composite walling. J Constr Steel Res 1998;45:353–75.
- ✓ Liang QQ, Uy B. Theoretical study on the post-local buckling of steel plates in concrete-filled box columns. Comput Struct 2000;75:479–90.