CHAPTER 1

INTRODUCTION

1.1 GENERAL

Ferrocement is a versatile construction material formed by filling hydraulic cement mortar into closely spaced layers of small sized wire meshes over a small thickness. The mesh may be of metallic or any other materials. It has a higher tensile strength to weight ratio and better cracking resistance behaviour when compared to reinforced concrete. It requires less skill and provides low cost serviceability without the loss of structural integrity. Ferrocement is identified as an eco-friendly technology. Ferrocement has proven to be less polluting technology that uses all resources in a more sustainable manner. It handles waste products in a more acceptable manner than other construction technologies. Ferrocement is truly sustainable and eco-friendly as it uses minimum natural resources, thus mitigating the effects of global warming. These potential advantages and the novelty of the concept make ferrocement, an attractive material for construction purpose. Ferrocement originally started with boat building and presently it has got very wide applications, in the fields of agriculture, water supply, sanitation, housing rural energy, repair and rehabilitation of structures etc. The use of industrial by-products as partial replacement of cement in the mortar improves certain characteristics (Selcuk turkel & yigit altuntas 2009).

The maintenance, rehabilitation and upgrading of structural members are perhaps some of the most crucial problems in civil engineering
applications. Moreover, a large number of structures constructed in the past using the earlier design codes in different parts of the world are sometimes structurally unsafe according to the current design standards. Since replacement of such deficient elements of structures incurs a huge amount of money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service durability. Infrastructure decay caused by premature deterioration of buildings and structures has led to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is the selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Strengthening may be needed to allow the structure to resist loads that were not anticipated in the original design. This may be encountered when structural strengthening is required for loads resulting from wind and seismic forces or to improve resistance to blast loading. Thus a complete understanding of ferrocement material behaviour would lead to an innovative technique for strengthening of reinforced concrete beams.

1.2 NEED FOR REPLACEMENT

In ferrocement the meshes serve as reinforcement and mortar serves as matrix resulting as an integral product. Engineers are continually pushing the limits to improve the performance of the mortar with the help of innovative chemical admixtures and supplementary cementitious materials. The development of new construction materials and technology can partly relieve pressures on the existing building material supply and help to arrest the spiraling rise in cost of these materials and also may reduce in situ construction activities. The main benefits of fly ash and silica fume are their ability to replace certain amount of cement in the matrix and still able to
display cementitious property. They reduce the cost of using Portland cement. The fast growth in industrialization has resulted in tonnes of by-product or waste materials such as fly ash and silica fume. The use of these by-products not only helps to utilize these waste materials but also enhances the properties of mortar in fresh and hydrated state (Kazim Turk et al 2013).

Production of one tonne of Portland cement releases 0.9 tonnes of CO₂ into the atmosphere correspondingly, thereby impacting the environment. Portland cement is a highly energy intensive material. In India, about 100 million tonnes of flyash is accumulated every year which is generated as waste from thermal plants. This is causing enough concern as its disposal involves design and installation of ash ponds covering large areas at each plant site. In spite of concerted efforts on a national scale, only a very small fraction (around 6%) of the fly ash is put to use in India, compared to its utilization to a greater extent in other countries (Md Emamul Haque 2013). Silica fume is also a waste by-product from the silicon metal and ferrosilicon alloy industries. An effort has been made to industrial by-products as the substitutes for partial replacement of cement and to reduce waste pollution.

1.3 RESEARCH SIGNIFICANCE

The wide application of admixtures with partial replacement of cement, reduction in embodied CO₂ content and sustainability of the waste materials reuse have been the driving force for researchers to carry out extensive work in ferrocement technology. Ferrocement is a cost effective and versatile material. Only certain types of materials locally available in bulk quantity can be used. There is a need for evaluating admixtures as replacement and simultaneously fulfilling advantages like low cost, abundancy etc. for ferrocement applications. There is also a demand for identifying and evaluating the admixture proportion of ferrocement that
should possess good ductility, less cracking and maximum strength. They should provide a sustainable technology to reuse industrial waste like fly ash, rice bran, wheat husk, silica fume etc along with cement paving the way for reducing CO$_2$ emissions. The combined use of mineral admixtures and super plasticizers with cement resulted in synergistic effects. It led to modification enabled durable mortars to be used in a variety of conditions. The increased strength has to be thoroughly validated. So there is a need to study the flexural behaviour and impact resistance of ferrocement laminates with material replacement. There has been a dearth of research work on studying flexure and the impact behaviour of ferrocement laminates made from cement mortar, partially replaced with fly ash and silica fume at differing volume fraction of mesh. The reinforced concrete beams get strengthened with the use of the ferrocement laminates. The research proposes an abundant, cost effective, strong and sustainable eco friendly construction material for the future through the use of ferrocement technology.

### 1.4 OBJECTIVES AND SCOPE OF CURRENT STUDY

- To explore the salient features of many constituents for the composition of ferrocement laminates and to select the suitable materials to be used in ferrocement laminate preparation.

- To develop cementitious matrix containing a suitable combination of silica fume, fly ash, and superplasticizer, to be used in thin ferrocement laminates that are applied for structural repair and strengthening applications.

- To study experimentally the flexural and impact characteristics for the different chicken mesh and weld mesh specimens of chosen size with different proportions of replacement.
To formulate mathematical models that will compare the experimentally obtained ultimate moment capacity of ferrocement laminates reinforced with chicken mesh and welds mesh.

The investigation shall be further extended experimentally to study flexural behaviour of reinforced concrete beams and to propose an analytical model to calculate the ultimate moment capacity in reinforced concrete beams, strengthened with ferrocement laminates with partial replacement of cement by fly ash and silica fume.

1.5 METHODOLOGY

The methodology of present study is explained by means of a flow chart shown in Figure 1.1. The properties of cement, fly ash, silica fume, fine aggregate, galvanized weld mesh and chicken mesh are studied. The compressive strength of mortar was studied on three principal mixes prepared at 1:2, 1:2.5 and 1:3 by weight and with three water binder ratios of 0.32, 0.35 and 0.38. At every water binder ratio, partial replacement of cement with fly ash content was varied from 10%, 15%, 20%, 25% and 30% together with a constant 5% silica fume by weight of cement. The dosage of super plasticizer ranging from 0% - 1% of the weight of the total binder, with an increment of 0.2%, was adopted. Ferrocement laminates of sizes 150 mm x 25 mm x 500 mm, 1:2 mix ratio, 0.35 water binder ratio, partial replacement of cement with fly ash content varying from 10%, 15%, 20%, 25% and 30% together with a constant 5% silica fume by weight of cement were prepared. The dosage of super plasticizer used was 0.6% by weight of the total binder. The flexure test was conducted with the load applied at one third point. The ultimate moment capacity obtained experimentally was compared with analytical results developed using plastic method and elastic method. The ferrocement laminate
of size 300 mm x 300 mm x 25 mm was cast for impact resistance test. The drop weight impact test, also known as repeated impact test, is defined as the ability of a material to absorb energy and it is used to find out the toughness of a material.

Ten reinforced concrete beams with simply supported span lengths of 1.22 m, and a cross-section of 150 x 100 mm were cast with M20 grade concrete of mix ratio 1:1.5:3 by weight and the water cement ratio of 0.5. The beam was reinforced with two steel bars of 10 mm diameter with two-legged stirrups of 6 mm diameter at 75 mm c/c. Ferrocement laminates were used to strengthen all the beams. The ferrocement laminates were sized 1220 mm x 100 mm x 25 mm with the mortar mix of cement sand ratio of 1:2 and a water binder ratio of 0.35. Four laminates were cast with conventional mortar mix and four laminates were optimum mortar mix of 20% fly ash and 5% silica fume reinforced with galvanized weld mesh of volume fraction 1.761% and 2.348%. Of the 10 beams, four beams were strengthened with ferrocement laminate, made from conventional mortar and four more were strengthened with the optimum replacement mortar and reinforced with galvanized weld mesh of volume fraction 1.761% and 2.348%. Ten concrete beams were tested with loads at one third point monotonically increasing load to failure, for this research. The ultimate moment capacity was compared with analytical results developed using elastic method. Finally, the results are discussed and conclusions are drawn.
Figure 1.1 Methodology flow chart
1.6 ORGANIZATION OF THESIS

The thesis consists of 6 chapters and organizing the chapters is done as follows:

Chapter 1 includes a general background along with the necessity of ferrocement research, the objective of current study and the methodology.

Chapter 2 provides a comprehensive literature review related to the history of ferrocement, its mechanical properties, flexural strengthening of beams and application of ferrocement technology.

Chapter 3 introduces the details of the experimental program on ferrocement laminates covering materials used, mix proportions, specimen preparation, various testing methods of flexure, impact and experimental program on flexural strengthening of reinforced concrete beams with ferrocement laminates.

Chapter 4 contains the analytical investigation that compares the ultimate moment of ferrocement laminates in flexure and the ultimate moment of flexural strengthening of reinforced concrete beams with ferrocement laminates.

Chapter 5 highlights the test results and discussions of flexure, impact behaviour of ferrocement laminates, flexural strengthening of reinforced concrete beams with ferrocement laminates and a comparison of analytical investigation with experimental results.

Finally, in Chapter 6, some conclusions are drawn based on the findings of the current study. A new proportion for optimal replacement of cement for ferrocement laminates is proposed.