1. INTRODUCTION

1.1 INTRODUCTION TO COMPOSITE CONSTRUCTION

The composite structure/construction is the way to arrange different materials in an optimum geometric configuration, with the aim that only the desirable property of each material will be utilized by virtue of its designated position. As per IS 11384 [1] the composite construction consists of the use of prefabricated structural units like steel beams, precast reinforced or prestressed concrete beams in combination with in-situ concrete. The construction should ensure monolithic action between the prefabricated and in-situ components so that they act as a single structural unit. In other way, two load-carrying structural members of different materials such as steel beam and concrete slab are integrally connected so that they behave as a single unit [2]. These essentially different materials are completely compatible and complementary to each other; they have almost the same thermal expansion and have an ideal combination of strengths with the concrete efficient in compression and the steel in tension.

In composite construction, composite slab is defined as a slab system comprising normal weight or lightweight structural concrete, placed permanently over cold-formed steel deck in which the steel deck performs dual roles of acting as a form for the concrete during construction and as positive reinforcement for the slab during service. A composite beam is formed by a reinforced concrete slab attached to the upper flange of a hot-rolled or welded steel beam by shear connectors so that the two components act together as a single section. Their action is similar to that of a monolithic Tee beam. A Steel-concrete composite column is comprising of either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load bearing member in a composite framed structure. With the use of composite column along with composite decking and composite beams, it is possible to erect high-rise structure in an extremely efficient manner.

The first systematic approach in the field of composite construction was reported in 1925 on testing of composite beams [3]. The relevant design criteria for design of composite structures were established in 1930. Later, Newmark et al. [4] developed elastic approach to utilize full and partial composite action. Based on the above work, behaviour as well as flexural strength of steel concrete composite construction was explained by Slutter [5] using ultimate strength approach. During the 1980's in UK and USA, structures with steel concrete composite elements experienced a renaissance, resulting in new construction concept and structural details.

Unfortunately these two important building materials, steel and concrete, are promoted by two different industries. Since these industries are in direct competition with each other, it is sometimes difficult to promote the best use of the two materials. It should be added that the combination of concrete cores, steel frame and composite floor construction has become now the standard construction method for multi-storey buildings in several countries. Consequently, composite construction is just now entering its second phase of expansion and growth.

- In USA, UK and many other European countries most of the multi-storey buildings, office buildings and multi-storey car parking are now constructed with steel concrete composite element.
- Much progress has been made in Japan, where combination of concrete cores, steel frame and composite floor construction is the standard system for tall buildings as they are best suited to resist repeated earthquake loadings, which require a high amount of resistance and ductility.
- For India, composite steel concrete construction is comparatively a new concept as no appropriate updated design codes are available. During the last few decades, however, few such constructions have come up in India due to the potential benefit of composite steel-concrete construction.

1.2 ADVANTAGES OF COMPOSITE CONSTRUCTION

Composite construction offers following advantages [6] over non-composite construction:

- **Speed of construction:** Use of rolled steel sections, profiled metal decking and/or prefabricated composite members speed up the execution. For maximum efficiency and economy the joints should be cheap to fabricate and straightforward to erect on site. Hence one gets a quick return of the invested capital.

- **Effective utilisation of material:** In composite construction, RCC slab is in compression and steel joist is in tension and hence one has the most effective utilization of the material.
- **Higher stiffness:** The bending stiffness of composite beam is about two to three times higher than the steel beam alone thus it experiences less deflection and floor vibrations which results in a safe structure.
- **Shallower construction:** The stiffness and bending resistance of composite beams is higher so beams can be shallower for the same span. This may lead to smaller storey height and saving in cost of cladding.
- **Saving in weight:** Reduction in overall weight of beam by saving in steel weight is typically 30% to 50% over non-composite beam. Lighter beams require smaller columns and less steel tonnage to be supported which reduce the foundation size.
- **More usable space:** Composite construction provides efficient arrangement to cover large column free space. Even keeping span and loading unaltered, a lower structural steel section (having lesser depth and weight) can be provided in composite construction.
- **Structural stability:** The concrete slab or deck slab is tightly connected to steel beam by shear connectors so as to act as a diaphragm to resist lateral loads on the structure.
- **Better seismic resistance:** Due to improved ductility and higher resistance, composite construction is best suited to resist repeated earthquake loadings.
- **Fire resistance:** Less fire proofing of beams exposed faces due to reduced depth. Encased steel beam sections in concrete result in improved fire resistance and corrosion.

1.3 LIMIT STATE METHOD FOR COMPOSITE CONSTRUCTION

1.3.1 BASIS OF DESIGN

The aim of structural design may be stated as the achievement of acceptable probabilities that the structure being designed will not become unfit for the use for which it is required during its intended life. Steel-concrete composite structures shall be designed by the limit state method using the partial safety factor. A composite structure or part of it is considered unfit for use when it exceeds a particular state called the limit state, beyond which it infringes one of the criteria governing its use. The limit states can be classified into: The ultimate limit states, which are those corresponding to the maximum load-carrying capacity; and the serviceability limit states, which are related to the criteria governing normal use and durability.

In steel-concrete composite structures used in buildings, the significant ultimate limit states to be considered are listed below:

- Collapse due to flexural failure of one or more critical sections.
- Collapse due to horizontal shear failure at the interface between beam and the slab.
- Collapse due to vertical separation of the concrete slab from the steel beam.

The important serviceability limit states to be considered are:

- Limit state of deflection.
- Limit state of stresses in concrete and steel.

Other less common serviceability conditions relating to control of vibrations are not included in EC 4 [7] and IS 11384 [1]. No reference is given to limiting values for deflections in EC4. Therefore, calculated deflections should be compared with specified maximum values in EC 3 [8] and IS 11384, which tabulates limiting vertical deflections for beams.

1.3.2 Structural Analysis

For the ultimate limit state, both elastic and plastic global analysis may be used, although certain conditions apply to the use of plastic analysis. When using elastic analysis the stages of construction need to be considered. The stiffness of the concrete may be based on the uncracked condition for braced structure. In other cases, some account may need to be taken of concrete cracking by using a reduced stiffness over a designated length of beam. The effect of creep is accounted for by using appropriate values of the modular ratio, but shrinkage and temperature effects may be ignored.

Rigid-plastic global analysis is allowed for non-sway frames, and unbraced frames of two storeys or less, with some restrictions on cross-sections. Also, elastic analysis must be used for the serviceability limit state. The effective width is as defined for the ultimate limit state, and appropriate allowances may be made for concrete cracking, creep and shrinkage.

1.4 GA As An Optimization Technique

Genetic Algorithm (GA) is very effective at finding the optimal solution to a variety of problems. This innovative technique performs especially well when solving complicated real world problems because it does not impose limitations similar to those imposed by the traditional optimization methods. This technique is inspired by the Darwin's theory of natural evolution and natural genetics [9]. It finds an optimal solution by generating population of solution strings randomly and improving the solutions in succeeding generations.

Since most classical algorithms are serial in nature, not much advantage can be achieved from them. While GAs are stochastic, parallel search algorithms which are designed efficiently to search large, non-linear, poorly understood search spaces where traditional optimization techniques fail [10]. They are flexible (domain independent) and robust, exhibiting the adaptiveness and graceful degradation of biological systems.

A GA begins its search with a random set of solutions usually coded in a binary string form. Every solution is assigned a fitness which is directly related to the objective function of the search and optimization problem. Thereafter, the population of solutions is modified to a new population by applying three operators similar to natural genetic operators-reproduction, crossover and mutation. A GA works iteratively by successively applying these three operators in each generation till a termination criterion is satisfied. GAs have been successfully applied to a wide variety of problems because of their simplicity, global perspective and inherent parallel processing capabilities.

1.5 Scope And Objectives of The Present Work

Composite structural forms have been extensively developed in the western world to maximise the respective benefits of using structural steel and concrete combination, but this technology was largely ignored earlier in India due to the non-availability of skilled labourers, inefficient codes, limitation of rolled sections and misconception regarding corrosion of steel [11]. It is a fact that now due to the availability of skilled labour, new rolled sections, advancement in anticorrosive paints; engineers have started designing composite and mixed building systems of structural steel and reinforced concrete to produce more efficient structures when compared to designs using either material alone. Generally, composite deck slabs comprise of profiled steel decking as permanent formwork to support the underside of the concrete slab spanning between supporting beam. This floor system offers numerous advantages over traditional reinforce concrete construction. Time as well as cost involved in a composite construction comes down, particularly by using pre-fabricated steel beams and profile steel decks, avoiding use of any other temporary shuttering materials or props and utilizing mechanized construction procedure. Also, the life of structures is much higher (more than double) than that of reinforced concrete structures. To accelerate the adoption of such innovations of fast track design and construction methodology in India, ready design codes, simplified modelling techniques, low cost analysis and design software are required so as to utilize the full potential of composite steel-concrete construction.

The growing body of experimental research is increasingly providing engineers with guidance on the analysis and design of composite members and systems. But the full-scaled experimental tests remain a costly and time-consuming option, hence the analytical procedure that can predict the nonlinear response are to be developed in order to replace most of the experiments once the verification of the analytical method has been established from selective, well-controlled experimental results.

The primary goal of this research work is to fill the knowledge gap and to facilitate the greater acceptance and use of composite steel concrete systems as a viable alternative to conventional systems. It is aimed to develop pre-and post-processors in Visual Basic.NET [12] for the analysis and design of composite steel-concrete elements. Visual Basic.NET, environment is selected here because it is designed to make significant improvements in code reuse, code specialization, resource management, multi-language development, security, deployment and administration. The .NET framework is the foundation on which one can design, develop and deploy applications. Its consistent and simplified programming model makes it easier to build robust applications.

Structural optimization is the process of finding optimum shape and size of the structure while satisfying various constraints imposed by design codes and other functional requirements proposed by engineers and designers. From the literature review, it is found that one of the soft computing tools i.e. Genetic Algorithm (GA), which is based on the concept of the survival of the fittest, has been mainly used for the design optimization of steel and RCC structures [13-20]. It has been successfully applied to a variety of problems of size, configuration and topology optimization of structure. However, the use of GA for the optimum design of composite structures has not been taken up in any research study so far. As varieties of shapes and sizes of composite structural components are used in construction, it will be certainly beneficial to find the optimum size of concrete slab and steel beam in composite slab beam construction and optimum shape and size of composite column. Therefore, in the present work, another important objective is to develop GA based programs for the size optimization of various composite structural components and to attempt, where possible, configuration optimization of composite structures.

A number of popular finite element analysis packages are now available commercially. Some of the popular packages are STAAD.Pro, ANSYS, GT STRUDEL, NASTRAN, NISA, ABAQUS, ETABS and COSMOS. Using these packages, one can analyse and design different types of complex structures. For the true representation of the behavior of a complex structure like composite structure, however, it requires sound knowledge of finite element modelling of the problem. In the present work, it is not only planned to simplify finite element modelling of push out test and composite beams but also to carry out detailed parametric study of composite steel-concrete buildings using the suitable commercially available software.

Consistent with the above, the objectives of the present investigation are listed as follows:

- To identify the theory related to the analysis and design of steel-concrete composite components and to study carefully the different codal provisions for the development of the computer code.
- To develop user friendly programs in Visual Basic.NET for the analysis and design of composite steel-concrete slabs, beams, columns, and frames to not only eliminate a number of large scale tests needed for the design but also to promote the use of such programs.
- To use the concept of transformed section and moment distribution method to develop program in Excel for steel - concrete composite sections under various loadings which may prove useful in actual practice due to its simplicity and effectiveness in solving framed structure problems.
- To develop programs based on Genetic Algorithm to find the optimum combinations of sections for beams and columns in the steel-concrete composite frames to achieve greater economy in the high rise structures.
- To develop a program in .Net environment especially for the design of composite truss, using limit state method of design and thus to attempt both size and configuration optimization of composite truss.
- To carry out a simplified modelling of shear connector, which plays a very important role in ensuring the composite behavior in a structural system, with the aim to simulate working of push out test using Finite Element Method (FEM) with solid slab and deck slab options to study the behavior of shear stud under various conditions.
- To carry out parametric study of push-out test specimens with different size headed studs as well as concrete strength using FE models.

- To develop 2D FE models of composite simply supported and continuous beams to know the mid span deflection of beam subjected to concentrated or uniformly distributed load and thus to know the longitudinal slip at the steel-concrete interface.
- To carryout detailed parametric study of a composite building using various codes, different types of profile sheets, sections, column orientations and grades of concrete.
- To study a multi-storey building under the effect of earthquake forces using equivalent static approach and response spectrum method.

1.6 ORGANIZATION OF THE THESIS

Chapter 1 starts with brief introduction to composite construction and its advantages. It also describes the limit state method for composite steel-concrete construction, Genetic Algorithms for optimization followed by the scope and objectives of the present work.

Chapter 2 explains the working principles of Genetic Algorithms with brief description of various GA parameters and operators. Also, the steps required for solving a problem are given in the form of flow chart.

Chapter 3 is devoted to detailed review of literature based on the experimental, numerical and FE modelling work reported in the literature on composite structures.

Chapter 4 introduces the general behavior and role played by the profile steel sheets in composite deck slab. After giving the basic formulation, analysis and design program developed in VB.NET is illustrated with the help of different menus and forms created for supply of data and display of results for composite slab with profiled sheets.

The behavior and design of composite beam are shown in **Chapter 5**. The concept of partial interaction is introduced. A software is developed using VB.NET for composite simply supported and continuous beams and the results are compared with the available solutions.

Chapter 6 is devoted to the design of composite columns where a program is developed incorporating the principal checks of composite column under different loading conditions. Design of steel concrete composite column is carried out according to the Eurocode 4 and demonstrated with the help of suitable examples.

Chapter 7 explains the concept of equivalent stiffness used for the composite steel-concrete members. A program in the form of Excel sheet is developed to facilitate the analysis based on the moment distribution method and the results obtained are compared with those provided by the commercially available ETABS and ANSYS software.

For the size optimization of steel-concrete composite beam and composite columns, a program is developed in VB based on Genetic Algorithm (GA) in **Chapter 8** and is illustrated with the help of suitable examples.

In Chapter 9, GA based optimization module is augmented to tackle problems of moment resistant composite plane frames with equal as well as unequal bay width and storey height. The developed module provides graphical user interface wherein geometry, load and support conditions can be specified graphically.

Chapter 10 describes the various types of composite trusses and a program which is designed for steel-concrete composite trusses using GA. It also considers provisions of limit state method of design as per British Standards.

Chapter 11 explains push out test for shear connector which gives capacity and load-slip behavior of shear connectors. Here a 2D FEM model is developed to simulate the push out test using ANSYS software. A parametric study is also carried out to study the effect on the capacity and behaviour of shear connectors.

Chapter 12 explains the behaviour of a simply supported composite beam and a continuous composite beam which is modeled using the ANSYS software. Detailed parametric study is carried out using the FEM and results are compared with the available experimental results to confirm the proposed modeling aspects.

In **Chapter 13,** a 3D model of G+3 storey buildings is developed in STAAD.Pro software and analysis and design is carried out with detailed parametric study by changing country codes, design methods, concrete grades, loading conditions, profile sheets etc. to see the effect of change of these parameters on the analysis and design.

Chapter 14 is devoted to highlight the significant advantages of use of multi-storey composite construction of steel-concrete as the primary lateral resistance system in building structure subjected to seismic load. Here equivalent static analysis and response spectrum analysis (Dynamic analysis) are carried out for earthquake loading and 3D model is generated for B+G+9 storey building in STAAD.Pro software for the analysis and design.

Finally, **Chapter 15,** after a recap, highlights the important conclusions of the present work followed by the recommendations for the future work.