15. CONCLUSIONS AND FUTURE SCOPE

15.1 SUMMARY

A great deal of experimental research has been conducted and reported in the literature to improve the understanding of the general behaviour of steel-concrete composite slab, beam and column. An essential component of composite beam is shear connection between steel section and concrete or deck slab. This connection is provided by mechanical shear connectors, which allow the transfer of forces in the concrete to steel and vice-versa and also resist vertical uplift force at the steel-concrete interface. 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.

Complications in the analysis and design of composite structural elements have led numerous researchers to develop simplified methods so as to eliminate a number of large scale tests needed for the design. In the present work also, where possible, a simplified approach was proposed for the design of composite slabs, beams and columns. The calculation of the limit state of different types of composite structural elements was considered. Based on the proposed approach, programs were developed in Visual Basic.NET environment with pre- and post- processing facilities. Steel table was also interfaced. The use of each developed program was illustrated with the help of screen shots of different menus and forms created for supply of data and display of results for a variety of problems.

Genetic Algorithm based programs for the size optimization of various composite structural components were developed and augmented to deal with configuration optimization of composite trusses. An attempt was made, for the first time, to explore Genetic Algorithm for the cost optimization of the composite structures.

The full scale push out test, which is costly and time consuming, is generally used to determine the capacity of shear connection and load–slip behaviour of the shear connector. Hence analytical or mathematical models are required for the analysis. Due to the complexity of the 3D stress-strain state, however, there is a limited success in the 3D modelling of push-off test. In the present work, therefore, a 2D finite element modelling of push out test was carried out using commercially available 'ANSYS' software package. The results obtained from the 2D finite element analysis were verified against experimental results and "ABAQUS" 3D model. A parametric study was also carried out to study the effects on the capacity and behavior of shear connection by changing the profiled steel sheeting geometries, the diameter and height of the headed stud, as well as the strength of concrete. The capacities of shear connection obtained from the finite element analysis were finally compared with the design strengths calculated using the British, American and European Codes. The behaviour of simply supported composite beam was also modelled under the static concentrated and distributed loading applied on the axis of the beam, under full and partial shear connection with different types of slabs. Detailed parametric study was carried using the finite element method and results were compared with the available experimental results to confirm the proposed modelling aspects.

Further, a parametric study of G+3 storied residential composite steel-concrete building was carried out utilizing features of STAAD.Pro software with parameters as different types of beam section, various country codes, orientation of column and type of concrete. Also, earthquake analysis and design of a G+10 storied commercial building was carried out using equivalent static method and response spectrum method. Best efficient and economical section sizes were chosen through optimization process and results obtained were compared to comment on the behaviour of the structure under different seismic zones.

15.2 CONCLUSIONS

1. The programming environment VB.NET selected in the present work, is found quite user friendly due to its windows base menu driven facilities, easy syntax, powerful graphical features, free threading, drag-and-drop design and availability of number of inbuilt functions and object oriented concepts which has helped considerably in the faster development of a number of programs. It also allows easy linking to database created in Microsoft Access and SQL server to facilitate design with appropriate sections.

2. The program developed for composite slabs facilitates the design calculation by considering the three phases of the M–ϕ behavior observed in composite critical cross-sections. It requires knowledge of the geometric dimensions of the slab, the material properties and the characteristic behavior of the steel–concrete connection.
3. Composite steel-concrete section is relatively a new design concept in the Indian context and no appropriate updated codes are available for the design of the same. A number of programs developed in the present work, not only eliminates the costly experimentation required for the design purpose but also facilitates design with multiple options for the steel sections and shear connectors with adequacy checks.
4. A number of forms developed, as part of pre- and post- processors, to facilitate design of different types of composite structural elements not only make the software very user friendly and versatile but also makes the application of the software quite attractive.
5. The proposed computational method, for a number of composite columns with a variety of steel sections encased in concrete and various concrete filled sections, is found to provide very accurate results.
6. Genetic algorithm based methodology is found simple, elegant and mathematically less complex, which can work even without the exact knowledge of the problem domain. In terms of performance, it can be concluded that it is one of the most promising methods in the field of optimization.
7. The GA based composite beam optimization program not only suggests optimum section for given beam spacing but also gives optimum beam spacing and beam section which helps in reducing the overall cost of the building.
8. From the results obtained from GA based optimization for column problems, it is found that the software selects the concrete filled tubular section as an optimum. This confirms the results reported in the literature of the concrete filled tubular column to have more bearing capacity.
9. In conventional GA based truss configuration optimization, coordinates of joints are considered as variables where number of variables depends on number of joints. For truss having large number of joints, large number of variables will slow down the optimization process. In the present study, only two design variables i.e. depth of truss and number of panels define large number of possible configurations without joint coordinates. This helps in finding optimum configuration for truss having large number of joints with greater computational efficiency.

10. In warren truss problem percentage reduction in weight varies from 1 % to 7 % whereas for pratt truss this percentage varies from 2% to 19%. For truss spans 18 m and above, warren truss with vierendeel panel is found to be more efficient.
11. A two-dimensional model of push out test is developed to simulate the load-slip characteristic of headed stud in solid reinforced concrete slab and deck slab. The model takes into account the linear and non-linear material properties of concrete and shear stud. 2D finite element results are found in good agreement with the results available of experimental push-out test and the specified data in the codes.
12. Through sensitivity analysis, focused on the assessment of the influence of small variation in input parameters, it is possible to arrive at optimum section using the developed software.
13. Parametric study of push out specimens with different size headed studs and concrete strengths is successfully carried out using 2D finite element model. The results are found within 5 % of those mentioned in Indian and Euro code.
14. The concrete strength is found to have a remarkable effect on the shear stud capacity and load-slip behavior which is evident from the various graphs plotted in the present work.
15. A two-dimensional finite element model of composite beam developed in the present work using the ANSYS software is found to provide the result of mid span deflection of beam subjected to concentrated or uniformly distributed loads and longitudinal slip at the steel-concrete interface in very close agreement with that of available experimental and 3D analysis results.
16. Despite the fact that the 3D models are able to accurately provide solution for wide range of problems, a 2D or 1D model could be the solution for some complex structural systems due to numerical convergence aspect and processing time. It is clearly seen in the present work that the proposed simplified 2D idealization takes almost one tenth of the computer time taken by the 3D idealization of push-out test set-up.
17. In the composite plane frame optimization, all the design variable are discrete which are stored in database form in the software. Moreover separate database are used to store the sections for beams and columns. This helped the GA based software to arrive at optimum solution quickly.
18. Keeping span and loading unaltered, smaller structural steel sections are required in composite construction compared to non-composite construction. This reduction in over all weight of the composite structure compared to a RCC structure results in less cost of structure and foundation.

19. Not much variation in values of nodal displacements, support reactions, support moments, beam end forces and beam end moments is found with the variation of deck profile. However, it should be noted that in the software one can specify only rib height and rib width; it does not consider effect of friction, thickness and other properties of material in the calculations.
20. It is clear from Table 13.9 that the values of nodal displacements, support reactions and support moments calculated by IS 800 are quite higher than those calculated by American Code and Eurocode. Nodal displacements obtained using Indian code are about 15% more than the other country codes. While support reactions are about 65% higher than the AISC LRFD and 30% more than the Eurocode. This may be due to the combination factor applied by the Indian Code; factor of safety is comparatively high. Thus, one can say that the Eurocode and American code give more economical design compared to the Indian code.
21. In the limit state design, the structure shall be designed to withstand safely all loads likely to act on it throughout its life which gives values of nodal displacements about 35% to 40% more in LSD. Whereas in ASD, in load combinations involving seismic load, the values of support reactions and support moments are about 12% to 17% more in all the three directions.
22. From the results given in Table 13.13, for critical beam number 376, it is clear that the section for the same beam of a column parallel to x - axis is lower (which is safe for construction) than the column parallel to z-axis.
23. One of the disadvantages of the conventional concrete is the higher self weight compare to the light weight concrete. The difference becomes larger if number of storey increases, Due to the above reason, nodal displacements and support reactions are higher in case of conventional concrete structure compare to the light weight concrete structure.
24. From the results given in Table 13.15, it is clear that by using light weight concrete instead of conventional concrete, one can make the structure 15% lighter which will result in the further saving due to the lighter foundation. While composite structure designed by Eurocode and AISC LRFD gives almost the same weight of structure, the Indian limit state design code gives about 12% higher value.
25. In G + 10 storied building, displacements obtained of the joints of the structure are less by Linear Dynamic analysis (LDA) compared to those by Equivalent Static Method of Analysis (ESMA). Though LDA gives somewhat higher support reactions than ESMA,

moments in case of LDA are less. Which makes the design of foundations by LDA economical compared to ESMA.

26. Comparing the behavior of composite structure with concrete structure, it is clear from the result, that the composite structure gives higher displacement of nodes as connections are being considered as flexible against the concrete structure where joints are considered as rigid. Also, a composite structure gives lesser size of substructure as support forces and moments are less compared to concrete structure.
27. For medium class soil, base shear increases by about 35% for different earthquake zones with increase in self weight by about 5-11%.
28. For steel structures, IS: 800 – 2007 specifies that only in zones II and III concentric braced frames should be used. For higher zones it suggests the use of eccentric braced frame. However, from the results obtained in case of composite structure it is clear that the concentric braced frames may suffice the purpose in zone IV also.
29. From the analysis results it is quite clear that the composite construction is more suitable to resist the earthquake forces compared to a R.C.C. construction.
30. The aforementioned advantages strongly advocate for the use of composite beams in multistoried buildings. They are more significant, however, for medium to long spans than for short spans.
31. In case of use of ISMB sections in conjunction with IS: 800-2007 provisions, for G+10 storey commercial building, the initial cost of steel concrete composite construction may be 10-15% higher than the corresponding R.C.C. structure. But if one considers the indirect cost also then the composite steel-concrete structure may prove cheaper.
32. Initial cost of R.C.C. construction is cheaper compare to steel or steel-concrete composite construction. But steel-concrete composite structure is more efficient. It is cost effective in almost all the cases provided the cost benefit analysis is carried out based on the life cycle of structure.
33. Steel frames are ductile in behaviour under horizontal forces and concrete frames provide stiffness to resist excessive displacement at the top of the structure. If used in combination, steel-concrete composite frames provide strength, stiffness and ductility. Such frames provide effective solution to the problems of design of high rise structures and offer more resistance against the earthquake loads compared to RCC construction.

15.3 FUTURE SCOPE

- A further research for development of new technologies in composite construction such as slim-floor slabs with semi continuous connections to the columns, new steel sheets or systems to minimize the time of erection and assembly is desirable.
- The idealizing assumption of beam-to-column connections as hinged or fully rigid due to lack of more realistic guidance in view of modeling advocates for further research on non-linear response of joints considering rotational stiffness, moment of resistance and rotational capacity. Preparation of guidelines for modeling different type of connections may also prove very helpful.
- Preparation of miniature specimens for testing may be thought of to avoid costly experimentation generally carried out on full size models to known the exact behavior of steel-concrete composite structural elements. A numerical analysis of the same will also be highly desirable to correlate the data and result.
- Recent development in composite construction technology, which have successfully transformed the market place in other countries, providing added value to the customers and rapid return on the invested capital. These, if adopted in India for residential and commercial building, could be very beneficial to the Indian community. In this regard, development of suitable design aids may be very fruitful.
- The use of precast concrete and even the prestressed concrete component in certain composite structure applications may prove fruitful as it has potential due to the economy that can be achieved by these components in terms of time, labour and money.
- More complicated type of truss geometries can be tried. The through type of composite truss can be attempted with a few modifications in analysis and design procedure.
- Some of the GA operators like inversion dominance segregation, deletion, duplication, etc. which could not be implemented in the present work may be considered.
- In the present study the total cost of RCC slab and steel truss were included in the objective function. However, the cost of the structure can be calculated precisely by including labour cost, connection cost, stud connection cost and cost of reinforcement in the objective function which will through light on the effect of each in cost minimization.
- Hybridization of different soft computing tools such as Artifical Neural Network, Genetic Algorithms and Fuzzy Logic may be tried. The use of hybrid methods like Neuro-Genetic, Fuzzy-Genetic, Neuro-Fuzzy-Genetic, etc. may prove fruitful in optimization of composite construction.

- Due to the iterative nature of the algorithm, a large number of mathematical calculations are required to be performed in GA based optimization which makes it computationally inefficient. This problem can be avoided by using parallel/distributed processing environment.
- The GA based composite frame program provides facility to select composite sections from design tables of only two countries i.e. India and UK. Attempt may be made to add design tables of other countries.
- GA based optimum design of composite space frame can be tried. However, large number of design variables will slow down the optimization process considereably.
- Finite element analysis of composite slabs and beams with slip theory including non-linearity of material and geometry will be an useful extension of the present work.
- Different types of composite columns can be simulated under various loading conditions using FEM and a database may be created for its practical use.
- Research in the field of fire resistance of composite structure is desirable to maximize their potential use and to clearly understand how steel and concrete progressively lose strength and stiffness at elevated temperatures.
- The use of fiber reinforced concrete, high strength concrete, self compacting concrete etc. instead of the conventional concrete may be explored in steel-concrete composite construction.
- Evaluation the performance of members, connections and connectors (e.g., shear connectors) under severe cyclic and dynamic loading including shakedown behavior is another field which may be of interest to the researchers.
- A hypothetical model or a program can be developed for design and analysis of composite column that can be run as an external program in the STAAD.Pro software.
- The earthquake response of steel and composite building structures is a subject of much interest; therefore there is much scope for research on the use of composite structures in seismic areas. The use of fully and partially encased steel sections in reinforced concrete is particularly beneficial for earthquake-resistant design. A further study on the suitability of other types of composite structural systems for earthquake-resistant design is highly recommended.
- The wind analysis of multi-storied composite structure can be carried out and charts can be prepared for various wind pressure.
- Non-linear dynamic analysis can be carried out of various types of composite structure.

- Composite moment frame, consisting of steel beam and reinforced concrete column is one type of hybrid system. Detailed parametric study of such systems under different types of loadings is highly desirable.
- Seismic analysis and design of a composite G+30 storey or higher may throw some more light on the cost effectiveness and efficiency of such structures.
- Detailed study of various types of composite bridges is another area which requires immediate attention.
- A detailed study on beam with web opening, cellular and castellated beam, stub girder, tapered fabricated beams, hauched beam in composite construction and comment on their suitability under various conditions will be certainly helpful to the people involved in the building industry.
- Design rules for composite construction have been developed gradually over the years and have been undergoing improvements and updating till today. These progressive changes resulted in more efficient uses of the constituent materials and led to better, less expensive structures. There is no doubt that the search for further improvements in this field will be certainly beneficial because it has very wide scope for further development.