CHAPTER 9

CONCLUSIONS

The roof slab considered in this research work plays an important role in the structural health of a nuclear reactor as it supports the entire load of the reactor. Hence, the structural integrity assessment of roof slab is mandatory and has been investigated in this work. The scaling down concept needs to be established for experimental analysis and the experimental results are used for validating the finite element model developed for the roof slab. A preliminary investigation has revealed the scope for design optimization of roof slab for which metamodels have been developed using the results of finite element model. The optimum configuration of roof slab is checked for the design adequacy using static, harmonic and seismic analysis. The outcome of the research is summarized in the following section.

9.1 MAJOR CONCLUSIONS

A summary of the major conclusions and contributions of the present work is presented below:

- A methodology towards applying the similitude relationships for investigating scaled down models has been proposed to predict the behavior of a complex structure like roof slab of a nuclear reactor. The similitude relationships have been established for simpler structures and extended to roof slab after validation. The validity of the relationships has been ascertained at various locations of the structure.
The proposed relationships can be effectively used to predict the behavior of actual roof slab since the ratio of deflection of prototype to that of the model is always maintained as the scaling ratio even though the material properties of prototype and model are different. Another advantage of the proposed approach is that the loads to be applied on the scaled down model are significantly reduced which in turn makes the experimental effort much easier.

The scaled down model of roof slab made of perspex material was fabricated with a scaling factor of 12. Perspex material is chosen as it increases the static deflection during experimentation and thereby reducing the fundamental natural frequency to a measurable range.

The component weights acting on the roof slab are applied as equivalent loads on the finite element model using three approaches, viz., uniformly distributed loading, nodal loading and altering the density of support flanges. The results on deflection obtained using varying density approach have a 2.25% deviation when compared to that obtained using the first two approaches. The varying density approach has been adopted since it can be used for static as well as dynamic analysis.

A parametric numerical model of roof slab using shell elements is developed using ANSYS software. A comparison of the results of static analysis obtained using numerical model and experiments reveals a maximum deviation of 5% and hence the parametric model with adequate accuracy of prediction is used for design optimization. The desired accuracy is achieved by incorporating bonded joint in the
finite element model which replicates the behavior of acrylic bond used to fabricate the perspex model.

- The results of numerical model have been used to develop a metamodel since it can be effectively used for design optimization. Based on the analysis of metamodel for test problems, it is noted that the space filling designs are most suited for metamodel development than classical designs. Among space filling designs, latin hyper cube-MNMX design performs well for most of the metamodels. Quadratic correlation function gives better results when the number of design variables is more than three and for other complex functions.

- The design optimization of roof slab using metamodels has yielded a weight reduction of 19.44% as the weight of roof slab is reduced by 30.37 tonnes from the total weight of 155 tonnes.

- The optimum configuration of the roof slab is tested for design adequacy based on static, harmonic and seismic analysis. It is observed from static analysis that the maximum local deflection is 4.28 mm which is less than the design limit of 5 mm. The slope at LRP flange location is found to be 9.88x10^-4 radians while the design limit is 43.6x10^-4 radians.

- It is observed from modal analysis that the mass participation becomes more than 90% of the total mass accounting for 330 modes which is sufficient for performing dynamic analysis. It is found that the majority of modal masses are participating in the seismic frequency range of upto 30 Hz both in horizontal and vertical directions.
The excitation force during the operation of primary sodium pump due to rotor unbalance is found to be 17.11 kN at 9.83 Hz. The maximum amplitude of vibration of the roof slab due to harmonic load is found to be 3.6 μm and the maximum fluctuating stress is 3.43 MPa which are less than the design limits.

Single point response spectrum analysis is used to perform seismic analysis of roof slab subjected to ground excitation in horizontal and vertical directions. The maximum primary stress intensity is found to be 125 MPa which is less than the design limit of 360 MPa. Hence, the proposed optimum configuration with a considerable saving in weight of the roof slab is satisfactory when subjected to dynamic loads.

9.2 SCOPE FOR FUTURE WORK

The present work deals with the investigation of box type configuration of roof slab. The above configuration is a welded structure and is prone for failure due to shear buckling of stiffeners in the presence of geometrical imperfection and manufacturing uncertainties like crack in weldment, lack of penetration in weldment, slag inclusion, etc. Moreover, the high cycle fatigue due to the operation of primary sodium pump supported on the roof slab may lead to crack initiation and subsequent propagation in the defective weldment. The above aspects need to be further investigated for determining the collapse load and hence establish the structural integrity of roof slab with a higher reliability.

The present investigation could be extended for dome shaped configuration of roof slab which has certain advantages like enhanced load carrying capacity for a given thickness, separation of shielding from the component, fully stainless steel construction, easier fabrication, etc. The box
configuration has the advantage of structural redundancy in the event of collapse in comparison to dome configuration. In view of the above, a comparative evaluation of the structural integrity of box and dome configurations of roof slab could be undertaken for further research.