A Report on the Workshop on Earthquake Resistant Construction in Civil Engineering Curriculum[1]

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Abstract

The field of *Earthquake Engineering* has existed in our country for over 35 years now. Indian earthquake engineers have made significant contributions to the seismic safety of several important structures in the country. However, as the recent earthquakes have shown, the performance of normal structures during past Indian earthquakes has been less satisfactory. This is mainly due to the lack of awareness amongst most practising engineers of the special provisions that need to be followed in earthquake-resistant design and thereafter in construction. A workshop was conducted at IIT Kanpur to discuss the role of earthquake-resistant construction in Civil Engineering curriculum. The workshop also discussed the avenues for dissemination of this knowledge to the students, practising engineers and other people. In this paper, the main recommendations of the workshop and an action plan, that can be implemented in the next few years, have been described.

Introduction

Formal activities in the field of Earthquake Engineering in the country were started in the late fifties at the University of Roorkee (UOR). The first Indian code was published by the Bureau of Indian Standards in 1962. Since then, Indian earthquake engineers have handled numerous prestigious and challenging projects in high seismic regions of the country. However, it has often been felt that an average civil engineer in the country even today looks at earthquake engineering as an area of *super-speciality* to be handled only by *researchers* and *professors*. The cause of earthquake-disaster mitigation through constructions that can appropriately withstand earthquakes, can be achieved only when the professional civil engineers in India take it upon themselves to ensure earthquake-resistant constructions.

A typical undergraduate civil engineering curriculum in the county does not include any coverage of earthquake engineering; the situation is no different in most other countries of the world. Even at the post-graduate level, only a small fraction of structural engineering students gets a chance to study earthquake engineering and design. This results in most civil engineers not receiving any formal training in earthquake engineering during the undergraduate or post-graduate studies. This needs to be corrected for a country like ours with an enormous earthquake problem.

A three-day workshop was held at the Indian Institute of Technology Kanpur during 10-12 October 1996 to discuss all aspects related to *earthquake-resistant construction in civil engineering curriculum*. The questions that prompted this workshop include:

(1) Should we continue to let earthquake-resistant constructions to be handled by specialists only, or should an average civil engineer responsible for construction be expected to know about appropriate earthquake technology for day-to-day constructions?

(2) Should earthquake-resistant construction be taught as a separate subject in the engineering curriculum, or should the topics related to earthquake engineering be merged with the existing courses? For instance, it may be more effective to teach students about ductile detailing of reinforced concrete structures in the regular design course on reinforced concrete, than covering all aspects of earthquake engineering in one single course.

(3) Should earthquake engineering maintain an identity outside the normal civil engineering industry or become a part of civil engineering industry itself?

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(4) How best to achieve the following goal: professional civil engineers should be able to ensure earthquake-resistant constructions without seeking help from "earthquake engineering experts," particularly for the run-of-the-mill constructions.

As a preparation towards this workshop, two questionnaires were sent to all engineering colleges in the country. These questionnaires solicited information from the colleges, regarding: (a) state of teaching curriculum at undergraduate as well as at graduate levels *vis*-à-*vis* earthquake-resistant constructions, and (b) profile of faculty members, having expertise in earthquake-resistant constructions or interested in developing expertise in earthquake-resistant constructions. Responses received during this survey were made available to the workshop participants in the form of a directory.

To ensure a holistic approach to addressing the above questions, a very broad agenda was prepared for the workshop. Most of the time during the workshop was spent in across-the-table discussions. Participation was by invitation. This paper gives a summary of the discussions and recommendations made during the three days of deliberations.

Discussions and Recommendations

Theme 1 :: Earthquake-Resistant Constructions in India

1.1 Engineered and Non-Engineered Constructions

- Most building constructions are non-engineered. However, formal education is imparted only on engineered constructions. Focus of discussions should also be placed on non-engineered constructions.

1.2 Building Material Technology and Know-How

- There is a need for greater discussion on the different building materials and their utility for earthquake-resistant constructions in technical curriculum.

1.3 Division of Responsibilities between Consultants, Contractors and Owners

- The consultant plays the most important role in realising earthquake-resistant constructions. The consultant has to educate the owner regarding the consequences of not providing earthquake-resistant features; this may motivate the owner to incur the extra costs for safety. The responsibility of adhering to the minimum requirements specified by the design codes shall remain with the consultant. The consultant also needs to ensure that the detailing provided is fully implemented by the contractor.

1.4 Earthquake-Resistant Design Practice versus Traditional Design Practice

- Earthquake-resistant design and detailing should be considered under normal design situations. These should be an integral part of design process, even though these may not govern the final design in all cases. This situation would then be similar to the current treatment of design for wind loads. *This will d-mystify the myth of earthquake-resistant design and construction being a special requirement.*

1.5 Code Provisions And Issues

- Design codes are the *minimum* specifications of the society's *expectations* of the structures. There is a need to ensure that the codal provisions are faithfully complied with. Since the building codes also fulfill a social obligation, the costs incurred by individuals involved in the code development should be provided.
- The code revisions sometime require technological upgradation or other major changes in the prevailing practices. Appropriate technological innovations and developments must take place in order to help the implementation of the difficult provisions.
- The code compliance in the country is currently very poor. This can be improved through necessary regulations and legal provisions. Introduction of tender specifications and changes in the city bylaws are some strategies for this. Also, there is a need for speedy action against defaulters to encourage compliance.
- The professional societies should take the initiative to develop model codes or to discuss specific issues. These may be used as a basis for arriving at the practical codes. These model codes should be regularly revised based on continuous technological developments. This will greatly benefit through increased involvement of professional engineers in code development.

1.6 Quality Control through Total Quality Management

- Use of ISO:9000 type control processes would help improve both design and construction practices.
- Implementation of ISO:9000 is initially expensive but experiences show that it pays off in about 2 years through greater economy in operations.

- Use of TQM concepts checks the common mistakes made in the prevalent practice.

Theme 2 :: Teaching Philosophy

2.1 Earthquake Engineering and Structural Dynamics

- Structural dynamics forms a relatively small segment of earthquake engineering; the former is not a substitute for the latter. Hence, the course on structural dynamics has to be viewed differently from that on earthquake engineering.
- Typical course on earthquake engineering has four main elements: (1) characterisation of ground shaking; (2) structural analysis under ground motion; (3) behaviour of structural systems; and (4) earthquake-resistant design and construction.
- It is necessary to prescribe the content of model courses on earthquake-resistant analysis, design and construction for both the UG and PG programmes. The different engineering colleges may use these model syllabi as a basis for introduction of earthquake-resistant construction in their curriculum. The AICTE has also initiated efforts to develop a model undergraduate curriculum. The curriculum proposed in this workshop for earthquake-resistant analysis, design and construction may be taken as an input by AICTE in its efforts.
- Engineering curriculum should also inculcate in the students their social responsibilities, the necessity of using sound design principles and compliance with code provisions.

2.2 UG Programme

- It may be possible to introduce, at the 1st year level, an introductory course on natural disaster mitigation open to undergraduate students from all branches of engineering to appreciate the related issues. This course may be strengthened through laboratory demonstrations, and use of multi-media tools to show the behaviour of structures, consequences of failures and societal implications.
- In view of the drastic improvement in analysis tools, static structural analysis curriculum currently imparted at the 2nd/3rd year level may be significantly altered. The essentials of static analysis may require only about 60% of the time currently assigned in most curricula. With appropriate changes, the remaining 40% of the time may be employed for exposure to dynamic analysis.
- This will enable the introduction of wind/seismic design concepts in the preliminary design courses at the 3rd/4th year levels of the undergraduate programme. The design courses should also discuss the need for specialised/ductile detailing provisions.
- It is also desirable to introduce an elective at the 4th year level exclusively dealing with winds and earthquakes, analysis, design and construction.
- Earthquake-resistant design course can be introduced in the undergraduate curriculum in two different ways. In the first, the provisions of earthquake-resistant design may be amalgamated with the existing design courses. Alternatively, some institutions may find it useful to introduce a full course on basic earthquake-resistant analysis and design procedures.
- The proposed curriculum for the model U.G. courses are enclosed in Appendix-A.

2.3 PG Programme

- There is a need for some engineers to be fully trained in all aspects of earthquake engineering. These engineers will cater to the requirements of highly seismic regions of the country and major projects anywhere. Thus, a few institutions/universities may provide such specialisations.
- In general, structural engineering students with exposure to earthquake-resistant analysis, design and constructions would fulfill the needs of most industries. To achieve this, an appropriately designed course on earthquake engineering should be offered to the students as a continuation of the (usually) compulsory structural dynamics course.
- Regional seismicity concerns may decide the priority of individual institutions/ universities, and hence their curriculum. This is particularly so when these institutions are financially supported at the regional level.
- At the post-graduate level, it is necessary to have atleast a two-course sequence of structural dynamics followed by earthquake engineering. Alternatively, some colleges may choose to offer two separate courses in lieu of the single course in earthquake engineering. In such cases, the first course may focus on seismological background and earthquake analysis of structures. The second course may be devoted to earthquake-resistant design philosophy and practice.
- The proposed curriculum for these model P.G. courses are enclosed in Appendix-B.

2.4 Architecture Programme

- Introduction of seismic considerations in the architectural curriculum at the UG level is essential. To attend to the short-term needs, short courses for architects on earthquake-resistant constructions are required to increase their awareness. Slides showing failures in past earthquakes may be effectively used to illustrate sound earthquake-resistant architectural provisions.
- The experiences from past earthquakes should be included in the curriculum related to urban land usage and town planning.

2.5 Diploma-Level Programme

- Since the Diploma-holders play a key role in the implementation of designs and supervision of constructions, there is a need to introduce the basic concepts of earthquake-resistant constructions in the polytechnic curriculum. Suitable thumb-rules need to be imparted to facilitate this learning.
- The importance of quality control in construction of earthquake-resistant structures should be emphasised in Diploma curriculum. This will require explaining the concepts of quality and providing check-points for constructions.
- There is also a need to introduce simple booklets and other teaching materials illustrating the seismic resistant provisions for commonly used structural systems. These can be widely distributed to current Diploma-holders to assist them with upgrading their skills.
- It is also necessary to include ductile detailing requirements in the Diploma curriculum.

Theme 3 :: Faculty Resource Generation

3.1 Status and Needs

- Based on a survey of engineering colleges in the country carried out by IIT Kanpur, it has been found that about 85% faculty members interested in earthquake engineering (either having expertise or interested in developing expertise in earthquake resistant construction) have studied structural dynamics while only about 30% have formally studied earthquake-resistant constructions during their postgraduate education.
- There is a need to train more faculty members in earthquake-resistant design and construction techniques.
- The Quality Improvement Programme (QIP) of AICTE can be used to impart both short-term as well as long-term training. The AICTE has already identified about 15 to 20 course modules in earthquake engineering that may be of interest to teachers in engineering colleges.

3.2 Training Strategies

- The training programmes for college teachers must cover the model curriculum (that was discussed in Theme 2). The training programmes should include significant amount of take-home reference materials and teaching-aids for subsequent use by these trainees.
- Short-term courses can be effectively used for training teachers for UG and PG courses. Sufficiently large number of training modules should be offered each year so that all teachers who are interested in these courses are able to find a convenient training programme.
- It is not necessary to always offer training courses at the parent institution of the resource persons. Depending on the geographical spread of the interested teachers, such courses can also be arranged at other colleges to ensure convenient access to the trainee teachers.
- Training of teachers is different from training of design professionals. During the training of teachers, more emphasis should be given on explanation of basic concepts rather than the use of thumb-rule based design procedures. The teacher trainees are expected to consolidate their understanding and implementation through self-study.
- Short-term visits (up to 6 months) to specific institutions can be extremely effective for advanced training of teachers. During the short visit, specific project-based research may be carried out. Such short-term visits should be followed by regular interactions.

3.3 Collaboration with Institutions

- Greater interaction between institutions will help in the dissemination of information on earthquake-resistant construction procedures. Both formal collaboration through joint projects as well as informal collaboration need to be encouraged.
- During collaborative projects it is necessary to ensure optimal utilisation of resources of both the institutions.
- The maintenance of some laboratory equipments may be very expensive. If these equipments are required to be used during the collaborative project, their maintenance expenses may need to be allocated from appropriate sources.

Theme 4 :: Experimental Facilities

4.1 Requirements of Experimental Facilities

- Experimental facilities serve two purposes. They should be used for (1) demonstrating concepts during teaching, and (2) carrying out research and development. Laboratories dedicated to the former need not include advanced and expensive experimental set-up. These need to be established at most of the colleges engaged in teaching earthquake-resistant constructions. Since laboratories suitable for research and development require significant amount of resources, they need not be duplicated at all colleges. However, modalities of sharing available experimental facilities between institutions need to be worked out.

4.2 Experimental Demonstration and Courses

- Experimental exposure is required at both the UG and PG levels. At the undergraduate level, the experiments may be demonstration-type illustrating the consequences of earthquake disasters. These demonstrations should illustrate the advantages of earthquake-resistant features. At the postgraduate level, three different semester-long modules are suggested. The first module consists of a number of experiments to demonstrate the important concepts of structural dynamics. The second module is basically the traditional structural engineering laboratory with added emphasis on earthquake-resistant construction features. This module should also include demonstration of preferred ductile detailing requirements. The third module is a comprehensive laboratory programme on earthquake engineering demonstrating all the important concepts. The proposed experiments for these modules are described in Appendix-C.
- The laboratory courses may also include appropriate experiments on material behaviour and on practical aspects of constructions.
- A number of relatively small gadgets can be fabricated to demonstrate the basic design principles for earthquake-resistant structures. These may be used as teaching-aids for earthquake engineering course.

Theme 5 :: Teaching Materials

5.1 Text Books

- Very few inexpensive text books highlighting prevalent construction practice are currently available for use in our colleges. There is a need to augment this with more text books relevant to India and containing the latest developments in this field.
- There is a necessity to augment the current design text books to include the basics of earthquake-resistant design procedures. The authors and publishers of these text books need to be persuaded to act expeditiously.
- There is also a need to develop completely new text books covering on all aspects of earthquake-resistant analysis and design.
- As a modest beginning, comprehensive lecture notes may be prepared for widespread circulation among engineering colleges. These notes should not have any distribution or copying restrictions.
- A joint effort may be taken up by a group of committed individuals to contribute different sections of a professionally coordinated text book. This book must contain detailed examples of analysis and earthquake-resistant design. The structure of the book must be well focused and should reflect continuity of thought.
- It is also desirable to develop separate books containing complete analysis and design case studies on some common types of buildings using the current provisions of the associated codes.
- Several excellent text books on earthquake engineering are in print in the international market. There is a necessity to persuade these publishers to introduce low-cost Indian editions of the same.

5.2 Journals and Reports

- A lot of international Earthquake Engineering literature is published by different societies and professional organizations outside the mainstream publishing business. It is a difficult task to keep track of such literature coming out of a very large number of sources and to procure them.
- Most international journals and reports published outside India are very expensive. As a result, most institutions in our country are constrained to procure only a small fraction of the available literature in earthquake engineering.
- A national facility dedicated to the collection and dissemination of *all* available publications in earthquake engineering needs to be established. This facility, which may be in the form of a national centre, would be responsible for convenient sharing (through loans and selective photocopying) of the collected resources and would act as a clearing house in this respect. Information regarding the resources available with the clearing house may also be placed on the world-wide web so as to facilitate

sharing. These centres may be set-up in collaboration with institutes/research centres.

- A coordinated effort is required to persuade the appropriate authorities to assign priority to this endeavour and to allocate the necessary financial support for the setting up of this clearing house. This effort may require collaboration between professional societies (for example, ISET), institutions and universities such as IITs and UoR.

5.3 Code Commentaries

- Lucid commentaries on earthquake-related codes are required to explain the basis of design code provisions. These should also include complete worked out examples for different types of structural systems in order to assist in the correct understanding and use of the codal provisions. These commentaries need not be published by the Bureau of Indian Standards and may, preferably, be taken up by committed individuals.
- Professional societies such as ISET may also be requested to give wide publicity to these commentaries through its journals.
- The commentaries on design codes need to be updated at regular intervals to incorporate the comments and concerns of the users.

Theme 6 :: Research in Earthquake-Resistant Construction

6.1 Status and Needs

- Research in earthquake-resistant constructions must be based on the needs of the society. In addition, there is need for developing a conducive atmosphere to promote research in these topics through appropriate encouragement to the researchers.

6.2 Perceptions of Society

- There is a general misconception amongst builders, architects, engineers and society, in general, that earthquake-resistant constructions are too expensive and are unnecessary. The additional cost due to earthquake-resistant construction features are only nominal, and these costs are more than justified through better response of buildings and reduced potential for earthquake disaster. The society needs to be educated on the tremendous advantage of earthquake-resistant construction.
- There is a need to place importance on quality control in structural design and construction process. It is also essential to explain the effects of poor quality structures in inducing damage during earthquakes.

6.3 Research Evaluation and Funding

- There is an urgent need to increase the volume of applied research in earthquake engineering. The results of such research would lead to development of technologies and methods of improving the performance of structures, which are appropriate for the Indian construction industry.
- Wider publicity is required for greater use of earthquake engineering technologies already available.
- Most research problems being undertaken at leading institutions in India seem to be extension of work being done in the advanced countries. While these research efforts are useful, there is also a need to devote greater efforts on problems of immediate concern to India. Such efforts should be adequately rewarded to encourage greater commitment.

6.4 Professional Organisations

- Active participation of both researchers and practicing engineers is solicited in the different professional societies. This would provide the forum for development of greater understanding between the two communities and may lead to useful collaborative efforts.
- The professional organisations and governmental agencies must play a more pro-active role to reduce the level of ignorance about earthquake-resistant provisions.
- Periodic exercises to disseminate and exchange information on the different technologies developed or otherwise available to the industry are essential. These need to be carried out at different locations at regular intervals.

6.5 Experimental Facilities

- Experimental facilities are essential for validation of the developed technologies. More research organisations and institutions should be provided such facilities in order to facilitate research in earthquake-resistant constructions.
- A national dynamic testing facility capable of supporting experiments on full-size prototype structures and components is urgently required. The national facility may be established in collaboration between the leading research institutions and centres. This facility will be invaluable for the entire research community for carrying out necessary experiments on development and validation of earthquake-resistant design and construction features suitable to the Indian scenario.

6.6 Regulatory Issues

- The performance standards of engineers need to be ensured through a professional certification procedure. This process will ensure that all practicing engineers meet the minimum prescribed understanding. The requirement of professional certification may also encourage compliance with the specified quality standards during design and construction phases. Willful violation of the minimum quality standards should be promptly punished.
- Recommendations of the Bureau of Indian Standards are not mandatory; in any case, these represent the minimum requirements for analysis and design. The level of compliance with these provisions needs to be improved.

Theme 7 :: Professional Ambiance

7.1 Status and Needs

- Professional bodies need to play a pro-active role. For instance, ISET requires visibility and should hold more meetings outside Roorkee.
- Topic-wise capsules for half-a-day may be developed by faculty members/professional bodies for training of professional engineers on specific aspects of earthquake-resistant construction.
- Development of seismic standards and codes in the country is presently dominated by academicians. It is extremely important that the practicing engineers also take a lead role in developing these standards.
- A national level examination conducted by a neutral professional organisation/body is necessary to accredit the professional performance of practicing engineers. For instance, the AMIE certification procedure may be revised to now include earthquake-resistant construction in it. This certification must be renewed every 5 years for all engineers responsible for the design and construction, after successfully re-appearing at the national examination.
- Engineers should steer the decision-making process in more construction companies than is currently practiced due the domination of builders and financiers. Since the level of earthquake-protection necessary for structures is a highly technical decision, this will help sensitise the construction companies to the issues related to earthquake-resistant design and construction.
- While personal crusades do motivate other individuals to also put in their best, high quality team effort is required for proper execution of large engineering projects. Both practicing engineers and researchers should contribute a certain portion of their time (say, 5%) towards bridging the gap between the states of the art and of the practice.
- *The quality of the final product directly reflects on the profession*. It is essential for practicing engineers engaged in earthquake-resistant design and construction to maintain high professional standards.
- Positive professional ambiance can be created through interaction in an atmosphere of mutual respect between practicing engineers and researchers on each others' expertise.
- User-friendly computer softwares for earthquake-resistant analysis and design need to be developed within India to overcome the usually very expensive international software. The detailing provisions usually require satisfying several conflicting constraints simultaneously. Hence, software tools for detailing may not be necessary.

Theme 8 :: Implementation Plans

- While most CE industries enjoy the fruits of the research work conducted using Grant-in-Aid from government agencies, they do not themselves seem to invest on research. To begin with, scholarships may be invited from industry to support post-graduate research students. Standards of academic quality can be maintained only if a critical mass of students are continually supported at research institutions/universitites. Lobbying for increased financial support from the industry needs to be stepped-up.
- The JRF scheme of CSIR may be explored for possibility of supporting M.Tech. students.
- A special issue of the science magazines like *Resonance*, *Current Science* and *Sadhana*, on earthquake-resistant construction from the Indian context can be edited by a learned group once a year. This will provide a means of lobby for the improved earthquake-resistant construction in India with policy makers, educated persons and general public.
- Several alternative modules for imparting education on earthquake-resistant construction have been evolved during this workshop. Since the AICTE has already initiated development of a model UG curriculum for use in technical institutions, they may be requested to also consider the inclusion of the modules in the model curriculum.

- Due to the inherent flexibility present in the IIT course structure, they should be strongly urged to include the proposed modules at appropriate levels of the undergraduate curriculum.
- Policy makers, decision makers, other educated persons and lay public should be educated through regular publication of popular articles explaining the different concepts related to earthquake-resistant constructions and the need for implementation of the same.
- It is essential to consider earthquake-resistant design and construction under the framework of national disaster reduction plan.
- The course modules that have been developed during this workshop need to be disseminated to the Vice-Chancellors and Chairmen of the Boards of Studies of different universities for inclusion in their curriculum.

Conclusions

The workshop held intensive discussions on several important topics related to the status of earthquake engineering in India. The major conclusions that were arrived at during the discussions have been discussed in this paper. Some of the recommendations of this workshop are implementable in the short-term, while the others require long-term efforts for their implementation.

The authors believe that the following steps should be initiated urgently:

1. Working notes and teaching aids should be developed and widely disseminated for model UG and PG curricula in Earthquake Engineering and Structural Dynamics.
2. Model experiments should be developed to illustrate the concepts in earthquake engineering, using low-cost and easily available instruments. These experiments should be integrated with the theory courses to illustrate different concepts of earthquake engineering and structural dynamics.
3. There is also an urgent need to develop short-term training programs in the area of earthquake-resistant constructions for structural engineering faculty of different engineering colleges.
4. There is a very urgent need to d-mystify the earthquake-related design codes by developing detailed commentaries on the code provisions.
5. A dedicated national-level facility needs to be established for the collection and dissemination of earthquake engineering publications and literature.
6. The architecture curriculum in the country should be suitably modified to impart the basic concepts of earthquake-resistant design to architecture students.
7. The diploma programs related to building constructions should be modified to include the essential earthquake-resistant features in buildings.

Since the conduct of this workshop, based on the above recommendations several initiatives have already been taken at some of institutions. For instance, some faculty members at IIT Delhi and IIT Bombay have already incorporated earthquake-resistant construction in the regular undergraduate courses. An arrangement has been finalised and implemented between the Central Building Research Institute Roorkee (CBRI) and IIT Kanpur regarding the M. Tech. Programme, where; CBRI financially supports a few students at IIT Kanpur and the students carry out their M. Tech. Thesis in joint supervision of one CBRI scientist and one faculty member of IIT Kanpur. Also, many participants felt that such workshops should be conducted at regular intervals at different locations in the country, as these improve collaborations between participants from the different sectors and different organizations in India.

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Appendix A: Proposed Undergraduate Curriculum

A. 1 Preferred Material in UG Programme

Ist year UG Level

As part of a humanities course, the following content may be included :

Natural disaster mitigation, lessons from past disasters, social and economic aspects, preparedness, public policies and role of engineers.

A.2 Mandatory Material in UG Programme

A.2.1 2nd year UG Level

As part of traditional building construction course, the following content may be included :

Earthquake-resistant features in non-engineered constructions and masonry structures (e.g., lintel band, through stones in stone masonry); Specific reference to IS:13927-1993 and IS:13928-1993 may be made.

A.2.2 3rd/4th year UG Level

As part of the traditional structural design courses, the following content may be included :

Equivalent seismic lateral loads using seismic coefficient method as per IS:1893; ductile detailing requirements (specific reference to IS:13920-1993)

A.3 Optional Material in UG Programme

4th year UG Level

A separate course or two courses may be considered with the following content:

A.3.1 ONE COURSE MODEL

Analysis and Design for Wind and Earthquake Effects

SDOF systems; Forced and Free Vibrations; Damping; Response Spectrum

MDOF systems; Dynamic Properties; Response Spectrum Analysis

Wind Design Philosophy; Fatigue

Earthquake Resistant Design Philosophy; Ductility

Codal Provisions for Wind and Earthquake Effects

Design and Detailing for Fatigue and Ductility

Review of Damage to Buildings

A.3.2 TWO COURSE MODEL

Structural Dynamics

SDOF systems; Equation of Motion; Free and Forced Vibrations; Damping;

Response Spectrum

MDOF systems; Dynamic Properties; Modal Superposition Method; Practical Considerations

Introduction to Earthquake Engineering

Earthquakes- Magnitude and Intensity; Ground Motions; Sensors; Design Response Spectrum

Earthquake Analysis; Idealisation of Structures; Response Spectrum Analysis; Equivalent Force Concepts

Earthquake Resistant Design Philosophy; Ductility; Codal Provisions

Detailing Provisions; Strategies for Quality Control

Review of Damage during Past Earthquake

Appendix B :: Proposed Postgraduate Curriculum

B.1 TWO COURSE MODEL

Structural Dynamics (Mandatory)

SDOF systems; Equation of Motion; Free and Forced Vibrations; Damping; Response Spectrum

MDOF systems; Dynamic Properties; Modal Superposition Method; Practical Considerations

Continuous Systems; Free and Forced Vibrations; Wave Propagation

Numerical Methods

Approximate Methods (Rayleigh's Method, Dunkerley's Method).

Earthquake Engineering (Optional)

Earthquakes- Magnitude and Intensity; Ground Motions; Site Effects; Sensors; Design Response Spectrum

Earthquake Analysis; Idealisation of Structures; Response Spectrum Analysis; Equivalent Force Concepts; Torsionally Coupled Systems; Effects of Soil-Structure Interaction

Earthquake Resistant Design Philosophy; Ductility; Base Isolation; Codal Provisions

Detailing Provisions; Review of Damage during Past Earthquake

Dynamic Properties of Soil; Liquefaction and Ground Improvement Techniques

Strategies for Quality Control

B.2 THREE COURSE MODEL

Structural Dynamics (Mandatory)

SDOF systems; Equation of Motion; Free and Forced Vibrations; Damping; Response Spectrum

MDOF systems; Dynamic Properties; Modal Superposition Method; Practical Considerations

Continuous Systems; Equation of Motions; Free and Forced Vibrations; Wave Propagation

Numerical Methods
Approximate Methods (Rayleigh's Method, Dunkerley's Method).

Earthquake Engineering Analysis (Optional)

Earthquakes - Magnitude and Intensity; Ground Motions; Site Effects; Sensors; Design Response Spectrum
Earthquake Analysis; Idealisation of Structures; Response Spectrum Analysis; Equivalent Force Concepts; Torsionally Coupled Systems; Frequency Domain Analysis; Time Domain Analysis
Nonlinear Analysis; Push-over analysis
Soil-Structure Interaction; Dynamic Properties of Soil; Dynamic Earth Pressures; Liquefaction
Fluid-Structure Interaction

Earthquake Resistant Design (Optional)

Earthquake Resistant Design Philosophy; Ductility; Base Isolation; Code Provisions
Detailing Provisions; Review of Damage during Past Earthquake
Design of Bridges, Dams, Industrial Structures and Retaining Walls
Retrofitting and Strengthening of Buildings and Bridges
Concepts of Structural Control
Liquefaction and Ground Improvement Techniques
Strategies for Quality Control

Appendix C :: Proposed Experimental Curriculum

C.1 UG Programme : Demonstrations

Natural Frequency and Damping in SDOF Systems
Modal Properties of MDOF Systems
Effectiveness of Ductile Detailing

C.2 PG Programme : Experiments

FIRST MODULE

Natural Frequency and Damping in SDOF Systems:Free Vibration; Decay Curves Harmonic Excitation; Frequency Response Function; Half-Band Width Method
Modal Properties of MDOF Systems using Impact Hammer
Damping in Different Materials

SECOND MODULE

Effectiveness of Ductile Detailing: Confinement
Practical Joint Detailing Schemes
Member and Section Ductility

THIRD MODULE

Natural Frequency and Damping in SDOF Systems: Free Vibration; Decay Curves Harmonic Excitation; Frequency Response Function;Half-Band Width Method
Modal Properties of MDOF Systems using Free vibrations techniques using Impact Hammer
Modal Properties of Continuous Systems: Damping in Different Materials Response of Structures to Ground Motions (Symmetric and Torsionally Coupled Building)
Effectiveness of Ductile Detailing
Confinement
Practical Joint Detailing Schemes
Member and Section Ductility
Ambient and Forced Vibration Tests
Modification in Dynamic Properties - Fluid Structure Interaction
Geophysical Refraction
Liquefaction