Introducing earthquake engineering in civil engineering curriculum

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In view of the earthquake risk in the country, it is important that civil engineering students are taught principles of earthquake engineering. A national workshop was conducted at the Indian Institute of Technology (IIT) Kanpur to discuss various issues related to introduction of earthquake engineering in the civil engineering curriculum. The issues discussed included a review on current status of earthquake engineering curriculum, model curricula of AICTE for undergraduate programme, and implementation issues. The participants included a wide cross section of faculty members, professional engineers and architects, and administrators. This paper summarises the workshop discussions.

The aftermath of the 2001 Bhuj earthquake witnessed many new initiatives in the country towards better earthquake safety. One such initiative was the *National Programme on Earthquake Engineering Education* (NPEEE) by the Ministry for Human Resource Development (MHRD), government of India. Eight resource institutes (seven IITs and Indian Institute of Science (IISc) Bangalore) came together to develop earthquake engineering in numerous colleges of engineering, architecture and polytechnics through teacher training, curriculum development and a number of other such activities (www.nicee.org/npeee). Curriculum changes in established branches such as civil engineering can be quite tedious. NPEEE envisaged that issues related to curriculum are to be discussed at all levels – national and regional. To this end, a national level invitation workshop on "*Introducing Earthquake Engineering in Civil Engineering Curriculum*" was organised during August 22-23, 2003 at IIT Kanpur. This workshop was a sequel to an earlier workshop organised by IIT Kanpur in 1996 for the same purpose[1]. The urgent need for improving the curriculum was reiterated in another workshop held at IIT Kanpur in 1998[2]. Fifty seven academicians, practising engineers and architects and administrators participated in the workshop.

To ensure a holistic approach in addressing the above concern, a broad agenda was prepared for the workshop. The major questions that figured in the agenda at the start of the workshop included the following.

(i) Should earthquake engineering be taught as a separate subject in the engineering curriculum, or should topics related to earthquake engineering be merged with the existing courses?

(ii) How can a practising professional or municipal engineer be imparted the basic knowledge of earthquake resistant construction?

(iii) What are the parameters that can properly define the qualities of a fresh civil engineer? To what extent will a fresh civil engineering graduate be able to design an earthquake-resistant construction?

This paper presents a summary of the discussions that emanated during the workshop on various themes, and concludes with the recommendations of the workshop.

Current status of earthquake engineering curriculum

Review of recommendations of the 1996 workshop

Model curricula for under-graduate (UG) and post-graduate (PG) programmes were developed during the 1996 workshop. The workshop held intensive discussions on several important topics related to the status of earthquake engineering education in India. Some of the recommendations of this workshop can be implemented in the short-term, while the others require long-term efforts for their implementation. The fol-

lowing steps were identified as those that needed to be initiated urgently.

(i) Working notes and teaching aids should be developed and widely disseminated for model UG and PG curricula in "Earthquake engineering" and "Structural dynamics".

(ii) 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.

(iii) There is also an urgent need to develop short-term training programmes in the area of earthquake-resistant constructions for structural engineering faculty members of different engineering colleges.

(iv) There is an urgent need to demystify earthquake-related design codes by developing detailed commentaries on the code provisions.

(v) A dedicated national-level facility needs to be established for the collection and dissemination of earthquake engineering publications and literature.

(vi) The architecture curriculum in the country should be suitably modified to impart the basic concepts of earthquake-resistant design to architecture students.

(vii) The diploma programmes related to building constructions should be modified to include the essential earthquake-resistant features in buildings.

Based on the above recommendations, the following actions have so far been taken:

(i) A national level repository of literature related to earthquake engineering in the form of National Information Centre of Earthquake Engineering (NICEE) was established at IIT Kanpur in 1999.

(ii) Under the NPEEE, launched in April 2003, short- and medium-term training programmes for teachers are being conducted by the seven IITs and IISc. Up to August 2003, eight courses of one- or two-week duration have already been conducted, and a semester-long programme is currently being held for teachers at IIT Kanpur.

(iii) The curriculum of the diploma programmes in the states of Gujarat, Uttar Pradesh and Uttaranchal have been already revised and implemented.

The Gujarat experience after 2001 Bhuj earthquake

Curriculum upgradation in engineering and polytechnics has been taken up as a part of the earthquake rehabilitation activity in Gujarat. A number of workshops were conducted in Gujarat to develop and implement curriculum changes in polytechnics and degree colleges and training programmes for teachers [3,4]. For polytechnics, four separate modules covering various aspects of earthquake engineering spread over 34 lecture hours were designed, which are included in four already existing courses. These changes have now been adopted in all polytechnics of Gujarat. For degree programmes in civil engineering, two schemes were adopted. About half the universities have chosen to include a compulsory course in earthquake engineering by dropping one of the compulsory courses, usually of structural analysis. In remaining universities, different earthquake engineering topics have been embedded in several existing courses and electives.

ISET effort and Uttaranchal project

In 1978, Indian Society of Earthquake Technology (ISET) developed a UG curriculum on earthquake engineering, which was implemented in two colleges in Assam. The curriculum proposed various modules to be included in regular civil engineering courses such as structural analysis, mechanics, design, soil mechanics, water resources, and foundation engineering, and an elective titled "*Principles of Earthquake Engineering*". In the ADB-sponsored capacity building project in the state of Uttaranchal, recommendations have been developed for curriculum changes. The emphasis is placed on education at various levels starting from school to professional degree programmes as well as mass education and awareness.

Review of responses from colleges

As a preparation towards this workshop, a questionnaire was sent to all the engineering colleges in the country, asking the following information about the current status of earthquake engineering teaching.

(i) If your university or college has already introduced earthquake engineering in the curriculum of BE/BTech., then: *(i)* when and how this was done?; *(ii)* what is the new curriculum with earthquake engineering?; *(iii)* what is the experience with the new curriculum?; and *(iv)* what are the strong and weak points?

(ii) What is the status of earthquake engineering education in PG education?

The response indicated the following:

(i) At the UG level, in some colleges a full course on "Structural dynamics" exists as an elective course.

(ii) In some colleges, elements of earthquake engineering have been introduced into the existing UG courses of structural engineering, and in some cases as a separate compulsory course. This has happened particularly after the 2001 Bhuj earthquake.

(iii) At the PG level, "Structural dynamics" exists in a few colleges as a compulsory course.

(iv) In some colleges, "Design for earthquake forces" was an elective course in the PG programme and was made compulsory at some places after the 2001 Bhuj earthquake.

(v) New PG programme in "Structural dynamics" and "Earthquake engineering" was introduced after the 2001 Bhuj earthquake in a few colleges.

(vi) Desire to learn and disseminate earthquake engineering has improved considerably after the 2001 Bhuj earthquake. However, students are reluctant still to choose earthquake engineering subject, often deterred by the mathematics involved in the "Structural Dynamics" course, but have begun showing interest in project work and thesis research in the subject.

(vii) College administrators are generally not sensitive to the importance of earthquake engineering education. The number of teachers who can teach earthquake engineering is too small. Also, there is inadequate laboratory facility for teaching earthquake engi-

neering. Thus, even though the structural dynamics or earthquake engineering related courses exist as electives in the curriculum, they are seldom offered due to shortage of available/interested teachers.

UG programme

Model curriculum and text books

There should be a model curriculum developed which universities and other autonomous institutions may adopt with or without modifications depending on their specific needs. It was felt that more than one model curricula maybe made available for individual colleges or universities to choose from depending on their teaching resources. Further, the participants of the workshop felt that at the UG level, design aspects should dominate earthquake-engineering related courses that are compulsory.

Availability of good textbooks at affordable prices is absolutely essential for long-term success of curriculum changes. Textbooks make it easier for the teacher to teach, for the student to learn. Hence, efforts are needed to develop Indian textbooks in this subject, and for Indian reprints of otherwise expensive international books. For teaching earthquake resistant design, good illustrative commentaries and handbooks of design codes may be useful resource materials.

Structural dynamics

Considerable discussions took place on structural dynamics versus earthquake engineering. Dynamic analysis is often misconstrued to mean earthquake resistant building without realisation of the fact that for a building to be safe, one needs to give considerable attention to design, detailing and construction aspects. The codes are developed on the basis that an engineer can implement earthquake resistant design and construction for ordinary buildings without having to know principles of structural dynamics. Yet, it is important that the student learns how the equivalent static design forces are connected with ground shaking during earthquakes.

Teaching of dynamics involves considerable amount of mathematics and the students usually tend to find the course "too difficult". There was concern that the way mathematics courses are taught in the early semesters of the UG programmes, needs improvement so that the students can comfortably cope with nominal amount of mathematics in the professional courses in the subsequent semesters.

It was felt that at the undergraduate level, the compulsory course contents in earthquake engineering would have only limited number of lectures. Hence, the extent of coverage of structural dynamics needs to be balanced with other important topics of earthquake engineering. This can be done by covering the basic concept of dynamics in a few lectures without going through the rigour of mathematics. To achieve this, mathematical models may be replaced with the physical models and dynamic effects can be illustrated through laboratory experiments. Computer animation and video clips can be used as a supplement to physical models.

Motivation

Motivation levels of civil engineering students is low due to low paying jobs, less awareness about the importance and social impact of civil engineering profession in general. Efforts should be made to raise their motivation level through exposure and interaction with industry. The motivation of students is likely to increase with more activities being held in the country towards earthquake safety. Overall curriculum of civil engineering should be designed to prepare them better for real-life engineering; this will improve their employability and their morale.

How earthquake engineering can be introduced?

It was unanimously felt that a basic compulsory content of earthquake engineering must be included immediately in the curriculum. The advanced level subject can be optional at the UG level. Broadly speaking, two models were discussed to include the compulsory content of earthquake engineering.

(i) Model 1 - Separate self-contained course(s) in earthquake engineering

Within Model 1, two sub-options were proposed, namely:

Model 1A: One compulsory course (Course A) and one elective course (Course B), or

Model 1B: Two compulsory courses (Courses A and B)

(ii) Model 2 - An integrated approach in which the basic earthquake engineering contents are embedded in existing courses. The advanced level course(s) in earthquake engineering can be offered as electives.

A suggested list of topics for these model courses is given in *Appendix* A.

There are advantages and disadvantages of the above models and different universities may need to consider these options based on their overall civil engineering curriculum and the faculty resources available. These include the following:

(i) In Model 2, several teachers have to be proficient in earthquake engineering to do justice to the contents, whereas in Model 1, only one teacher at a given college is needed to give adequate coverage of earthquake engineering.

(ii) Textbooks currently available for different courses do not cover related earthquake engineering topics, which may hamper proper implementation of Model 2.

(iii) If the earthquake engineering contents are introduced in the existing courses, it is likely that the teachers may not cover those since they lack expertise and the concerned textbooks do not provide the coverage.

(iv) There is an urgent need to develop teaching aids taking earthquake contents for existing courses into considerations, so that teachers taking existing courses can go through, get trained and cover them satisfactorily.

Model 2 has the advantage that it gives the student an integrated view of the entire problem. It removes the notion that earthquake resistant design is needed only in special cases and that it is a speciality that all engineers need not have. In the long run, Model 2 is preferable, while in the short run it may be easy to implement Model 1. Between Model 1A and Model 1B, the decision may be based on the location of the university in a high versus low seismic zone, the potential employers of its graduates, current curriculum of the university, and the available teaching expertise.

There was also a suggestion to develop a *minor* specialisation or an honours degree in earthquake engineering wherein the student takes 2-3 courses in earthquake

engineering. This could act as an incentive for the students to seek courses in earthquake engineering.

It was also felt that engineers of other branches too need basic introduction to earthquake engineering. For instance, electrical engineers need to know about safety of power generation-transmission-distribution systems under strong earthquake shaking, and chemical engineers need to know the implications of damage to chemical plants under strong earthquake shaking. Mechanical/HVAC engineers need to know that all automated production line systems, machine elements and mechanical handling systems need to be secured during earthquake shaking. Hence, some small coverage about earthquakes in the curricula of other branches of engineering too is desirable.

A question arises from the view point of administrators: can the engineers that will graduate with the proposed UG curriculum having earthquake engineering elements in it, be able to construct new earthquake-resistant buildings or effectively conduct seismic retrofitting of existing buildings? The participants were clear that a fresh graduate is not ready for undertaking engineering tasks independently and that it takes a few years of supervision by an experienced engineer before a young engineer can be entrusted such jobs independently. Hence, even though the curriculum changes at the undergraduate level are a very important step in the direction of earthquake safety, these are by no means sufficient for needs of the country in terms of human resource development. It was felt that separate concerted efforts by the government of India in active collaboration with various professional organisations, universities, states, and municipalities, are required to train professional engineers for design, construction and retrofitting of earthquake resistant structures.

AICTE model UG curriculum

Prof V. Kalyanaraman of IIT Madras and Prof G. Venkatachalam of IIT Bombay constituted a committee appointed by the All India Council for Technical Education (AICTE), New Delhi, for reviewing the existing model curriculum for the undergraduate programme in civil engineering and for suggesting modifications therein. They participated in the workshop with a view to integrate the requirements of earthquake engineering education in the model AICTE curriculum. They presented draft modifications to the existing curriculum of AICTE for the bachelor's degree in civil engineering.

This session drew a large section of the participants to express their views. It was felt that minor alterations to the current model curriculum of civil engineering would not suffice. Over the years, the civil engineering curriculum in the universities has become irrelevant to the realities of a job that a civil engineer is expected to perform. It was pointed out that the curriculum has slowly eliminated components on buildings, construction technology and management, construction materials, and contract management, which are the issues that a typical civil engineer spends the maximum time on. For instance, an engineer in the roads sector spends far more time on construction issues, earth work, project management, etc., rather than on designing the road traffic system. Similarly, in the buildings sector one now finds that architects can be far better site supervisors than a civil engineer, primarily because graduating civil engineers do not have the requisite exposure and training.

This distortion in curriculum has been contributed by a number of factors:

(i) teachers are difficult to find in the areas of construction technology and management, particularly in view of the emphasis on Ph. D. for academic career,

(ii) teachers prefer to teach what they are best at (usually, the subject of their own specialisation at masters or doctoral level) and are reluctant to teach subjects in which they may not have that much mastery,

(iii) the civil engineering departments are often sub-divided into specialisation groups such as structural engineering, geotechnical engineering, environmental engineering and there has been a tendency to develop a parity in course coverage by the different groups, disregarding needs of the graduating student and the skills that are required for civil engineering jobs.

It was further emphasised that civil engineers work in diverse sectors, such as buildings, transportation, water resources, and public health/environment. Therefore, they should get exposure to all of these sectors appropriately. Further, to work in these sectors they need skills in construction materials (especially concrete engineering), construction technology and management, maintenance engineering, geoinformatics (surveying, etc), geotechnical engineering, structural engineering, etc. Consequently, the overall curriculum should reflect this reality and be balanced in line with the contemporary requirements of civil engineering profession.

It was recommended that an industry survey be conducted before developing revised model civil curriculum of AICTE. Further, the model earthquake engineering curriculum developed in this workshop should be appropriately integrated with the model UG curriculum of AICTE.

Implementation Issues

Training of teachers

Training of teachers (ToT) was considered to be the most significant task for effective inclusion of earthquake engineering contents in civil engineering curriculum. Earthquake engineering has now acquired very significant sophistication, and therefore, wide-ranging needs exist for teachers training. At one end of the spectrum, the teachers need a minimal level of training to be able to integrate earthquake engineering principles into their own subjects, and on the other hand we need specialist teachers who can provide leadership in developing codes, training professionals, providing consulting services, and contribute to research and development.

Under the NPEEE, short-term (one- to four-week duration) and medium-term (one semester) training is provided. Current participants of the semester programme at IIT Kanpur shared their enthusiasm about the effectiveness of such a course for developing expertise. The participants of the programme felt strongly that the programme must continue in the years ahead, and they urged that something be done proactively to impress upon the college administrations to take advantage of the semester programme for faculty development.

It emerged that many academic administrators (college principals, directors of technical education) still lack the perception on importance of such training and are reluctant to release their teachers

in view of shortage of teachers. It was felt that a multi-pronged approach is necessary:

(i) the academic administrators need to be sensitised about the training needs in this subject,

(ii) colleges be provided some grant to hire ad-hoc substitute teachers during the period for which their permanent teachers go for medium- or long-term training (such as Ph.D., M.Tech),

(iii) suitable incentives in the form of library and laboratory grants should be given to colleges who invest in this subject by letting their teachers undergo medium and long-term training, and

(iv) distance learning methodology needs to be simultaneously implemented for earthquake engineering.

The distance learning programmes have their own limitations: considering that the teachers are engaged in full-time teaching and academic administration, it is not always possible for them to cope with the demands of the distance learning programmes. For example, the experience of the e-course on IS:1893 conducted by IIT Kanpur in January 2003 was that many participants did not complete the study of entire lecture materials in view of their other preoccupations. Hence, even though distance-learning programmes are highly desirable, these should not be seen as substitute to the contact programmes.

The workshop participants recommended that distance-learning programmes (including web-based learning) be implemented in earthquake engineering. It is desirable for such programmes to have limited contact period wherein the trainee teachers assemble at a centralised location and seek clarifications and discuss the subject with the instructor. This contact duration can also be used for conducting the evaluation of the trainees on understanding of the subject. There is also a need to study the existing distance learning programmes around the world (such as the MS Programme offered by Purdue University and the IGNOU distance education programmes) to evolve methodologies that can be most appropriate for Indian conditions.

Teaching material

Availability of textbooks and other literature in earthquake engineering was discussed. The acute shortage of affordable good literature was a serious concern shared by all participants. It was pointed out that the NPEEE provides for book support to about one hundred colleges to the extent of Rs 0.1 million each. This is a very positive development and will contribute enormously towards developing teaching of earthquake engineering. However, this does not take care of the needs of the students since only a few copies of books will be provided to the libraries. Further, it still leaves out the majority of about 1000 colleges/polytechnics in the country that deal with civil engineering or architecture. It was proposed that a list of recommended books and other materials should be placed on NICEE website for wide circulation amongst the teachers of the country. It was also felt that multiple sets of this reading material be acquired by the state governments for distribution to colleges in their states. Further, other capacity building projects such as those likely to be launched by the ministry of home affairs may include a component on providing books to the colleges.

To meet needs of the students, development of textbooks and other resource materials needs to be encouraged. Simultaneously, the book publishers should be encouraged to bring out Indian reprints of reputed international books in earthquake engineering.

Computational facilities and experimental laboratory

Over the recent years, availability of computers in the colleges has improved but it still remains quite inadequate. The commercial software related to earthquake engineering remains out of reach of most colleges. Steps needed in this direction include the following:

- provide computational hardware and software to colleges developing expertise in earthquake engineering
- lobby with the international software firms to make these available in India at a low price commensurate with local purchasing power
- compile a list of free and downloadable software available in the public domain and place it on the website.

It was felt that for many research and consulting assignments, sophisticated software are needed which may be too expensive for even the premier institutions to purchase and maintain. Hence, common national facility (one or more) needs to be developed for computational infrastructure (hardware and software) in line with the NICEE which aims to meet the needs of all interested with regard to books on earthquake engineering. Any interested student, researcher or professional should be able to use the central computational facilities on a need basis.

Many small experiments with low financial input are required to be developed for demonstrating basic earthquake behaviour of structures and concepts related to earthquake resistant design. Details of such experimental set-ups (including fabrication, background theory and use of these models) should be made available to the larger audience of the country through electronic media.

It was also felt that currently the experimental research facilities in our countries are highly inadequate in the area of earthquake engineering. For instance, only one academic institution (IIT Roorkee) has a shake table of substantial size and that too is fairly obsolete by international standards. Most IITs do not have proper pseudo-static testing facilities. Major investments are needed in creating several state-of-the-art experimental facilities in the academic institutions. Development of such multiple facilities would encourage healthy competition between various institutions within the country, and this would be good in the long run for the growth of the profession in the country. Major investments are needed towards this.

Other issues

The workshop was focussed on the curriculum issues for degree level programmes in earthquake engineering. However, small amount of time was also spent discussing curriculum issues for postgraduate education, diploma programmes and the architectural education.

(i) The country has been following two models:

- Master's degree focussed on Earthquake Engineering (at the IIT Roorkee)
- Master's programme in conventional civil engineering (for exam-

ple, structural engineering, geotechnical engineering) integrating suitable coursework in earthquake engineering with thesis on topic connected with earthquake engineering. After the Bhuj earthquake, several other colleges seem to be keen on starting master's programme in earthquake engineering. Hence, the entire issue of earthquake engineering education at the PG level is extremely important and a separate workshop should be held to brainstorm the connected issues. A brief overview was presented on the annual "Earthquake Engineering Review Workshops" being conducted at IIT Kanpur for the masters students pursuing dissertation in earthquake engineering. It was felt that such activities could help improve the level of PG education in earthquake engineering.

(ii) For any serious progress on seismic risk reduction, it is of utmost importance that the architects keep in view the earthquake resistant features in developing building forms. After the 2001 Bhuj earthquake, there was considerable initial enthusiasm among the architectural community towards earthquake resistant technology. However, this has not materialised into any substantial progress towards training of architectural community. It was unanimously felt that the architecture community needs to be motivated to take up training programmes and R&D projects. Also, curriculum development for schools of architecture needs to be taken up at the earliest.

(iii) Significant progress has been made in the last year in at least three states of the country insofar as development of curriculum for polytechnics is concerned. Adequate coverage of earthquake resistant constructions is now introduced in the polytechnics of Gujarat, UP and Uttaranchal. Similar efforts are needed for the other states, and these need to be followed up with training programmes for teachers of polytechnics.

(iv) The participants also deliberated on the need and importance of holding a national level *proficiency test* in earthquake engineering. It was recommended that a model for such a certification be developed, relevant details should be worked out, and resources required for it be identified.

Closure and recommendations of workshop

The workshop concluded on an affirmative note that the curriculum changes are *urgently* required to include earthquake engineering education in civil engineering curriculum in the universities/institutes across India. The salient recommendations of the workshop include:

(i) Two models must be offered to the technical universities/institutes in the country for including earthquake engineering education in civil engineering curriculum; a university/institute may adopt either of these depending on the available resources. The experiences of curriculum changes effected in the state of Gujarat are important precursors to the impending efforts other universities to follow suit.

(ii) The AICTE model curriculum under revision must reflect the national need of including earthquake engineering in civil engineering curriculum. The participants offered all support in this regard the two members of the AICTE Model Curriculum Committee present at the workshop.

(iii) The success of the implementation of the earthquake engineering education at the technical universities/institutes of the country is critically dependant on developing a national resource of teachers who can implement the proposed curriculum. The workshop hailed the objectives of NPEEE in this regard, and urged that the academic administrations across the country need to be impressed upon to undertake the long-term goal of training/re-training their existing teachers in the subject area of earthquake resistant design and construction.

(iv) A severe shortage of teaching resource materials was also identified. It was emphasised that the development of textbooks and cost-effective teaching laboratory resources need to be undertaken immediately.

(v) It was proposed that the power of information technology needs to be exploited for educating large groups of practising professionals on the subject of earthquake engineering. Computational earthquake engineering and distance education modules need to be developed to reach the subject to a larger section of the Indian engineering community.

In closure, awareness amongst the common public on earthquake safety and preparedness has increased after the 2001 Bhuj earthquake. Instead of waiting for the perfect solution, the best available solution (however imperfect though) should be immediately implemented towards national earthquake disaster mitigation. This way both experience and expertise will grow with time, and eventually the incremental earthquake preparedness initiatives will start bearing fruits.

Acknowledgements

The following persons participated in the workshop: M.Arif, S.K. Baishya, P. Banerji, S. Basu, M.K. Bhardwaj, M.V.Bhatti, Amit Bose, P.C. Chandubhai, S. Choudhury, S.V. Anil Das, T.K. Datta, P. Dayaratnam, S.K. Deb, J.A. Desai, S.B. Devaraj, S.K. Duggal, A. Dutta, Alok Goyal, R.K. Grover, Abhay Gupta, J.K. Jain, L.K. Jain, Sudhir K. Jain, Arvind Jaiswal, O.R. Jaiswal, V. Kalyanaraman, S.K. Kaushik, R.A. Khan, R.K. Khare, Sunil Kumar, C.S. Manohar, D. Menon, S.V. Mevada, P.B. Murnal, C.V.R.Murty, H.B.Nagraj, A.S.Pant, J.Pathak, C.C.Patel, A.S.Patil, M.M.Paul, A.M.Prasad, D.C.Rai, Debasis Roy, K.K.Soni, S.Saha, M.P.Sajnani, C.S.Sanghvi, S.M.Satodia, M.R.Shah, Ravi Sinha, S.Setia, Alpa R. Seth, S.P.Singh, S.Tiwari, G.Venkatachalam, and R.K.Yadav. The authors are thankful to all the participants of workshop for their views and suggestions. The activity was held under the aegis of the NPEEE, Ministry of Human Resource Development, GoI, New Delhi. This financial support provided by NPEEE to conduct this workshop is gratefully acknowledged.

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Table 1: Courses A and B of Model I

Topics	*Lectures*
Course A (Basic course in Model 1 - compulsory): Introduction to earthquake engineering	
Engineering seismology	
(Causes of earthquakes; seismic waves; magnitude, intensity and energy release; characteristics of strong earthquake ground motions)	8
Introduction to theory of vibrations	
(Flexibility of long and short period structures; concept of response spectrum)	4
Building forms for earthquake resistance	4
Seismic design philosophy	3
Performance of buildings in past earthquakes	3
Equivalent static lateral earthquake force (IS:1893)	6
Seismic design and detailing of masonry buildings (IS:4326; IS:13827; IS:13828)	5
Seismic design and detailing of RC buildings (IS:13920)	6
Soil effects and liquefaction	3
Total	42
Course B (Advanced course in Model 1 – Elective or compulsory): earthquake resistant design of buildings	
Theory of vibrations	
(Single, two- and multi-degree of freedom systems, response spectrum analysis)	12
Concept of seismic design	
(Reduction factors; over strength, ductility and redundancy)	4
Determination of earthquake forces (IS:1893 (Part 1) - 2002)	9
Seismic design and detailing of masonry (IS:4326; IS:13828), reinforced concrete (IS13920) and steel buildings	14
Concepts of base isolation and energy dissipation devices	3
Total	42

India, *The Indian Concrete Journal*, October 2002, Vol 76, No 10, pp. 629-632.

Appendix: A

Model earthquake engineering curriculum in UG programme

Model 1: Self-contained courses in earthquake engineering

Model 1 consists of courses A and B as given in *Table* 1

Model 2: Fully embedded in existing courses

In the existing following courses, the following elements are to be added.

(i) In *Engineering Geology* course, engineering Seismology (causes of earthquakes; seismic waves; magnitude, intensity and energy release; characteristics of strong earthquake ground motions) to be added.

(ii) In *Structural Analysis I* course, Basic Theory of Vibrations (flexibility of structures; long and short period structures; concept of response spectrum) to be added.

(iii) In *Structural Analysis II* course, Fundamentals of Structural Dynamics (dynamics of single degree of freedom systems; dynamics of two and multi-degree of freedom systems; Duhamel integral; concept of response spectrum) to be added.

(iv) In *Concrete Design II* course, Determination of Earthquake Forces (IS:1893 (Part 1)–2002; seismic coefficient method; response spectrum method); seismic design and detailing of RC Buildings (IS:4326; IS:13920) to be added.

(v) In *Steel Design II* course, add Determination of Earthquake Forces (IS:1893 (Part 1) – 2002; seismic coefficient method; response spectrum method); seismic design and detailing of steel buildings to be added.

(vi) In *Building Construction* course, Seismic design and detailing of masonry buildings (IS:4326; IS:13828) to be added.

(vii) In *Soil Mechanics* course, Seismic Behaviour of Soils (effects of soil shaking and liquefaction); ground improvement techniques to be added.

(viii) In *Hydraulics Engineering* course, Hydrodynamic effects due to earthquake shaking to be added.

(ix) In project work Integrated design, detailing and construction of RC buildings to be added.

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