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Earthquake engineering in the civil engineering curricula

Sudhir K Jain and Alpa Sheth

In the aftermath of the Bhuj earthquake, January 2001, various issues related to earthquake engineering have been discussed in different fora with renewed fervour. However, earthquake engineering has been largely ignored in the civil engineering curricula. Two workshops were held in Ahmedabad in April 2002 to discuss the inclusion of earthquake engineering topics in the curicula at diploma, degree and post-graduate levels in the colleges and polytechnics of Gujarat. The present feature summarises the workshop recommendations. The authors would be happy if a healthy discussion takes place on this topic through these columns leading to a change in engineering curricula in different states and hopefully at the national level.

The earthquake problem in India cannot be overemphasised. Most parts of the country are prone to damaging earthquakes. The Bhuj, Gujarat, earthquake of January 26, 2001 has clearly demonstrated that even many of the newly constructed multistoreyed buildings made under engineering supervision are highly vulnerable to earthquake ground shaking. To correct this situation, initiatives are needed on several fronts. The human resource development is the most important element in the task of earthquake risk reduction. If the engineers are not competent in seismic engineering, nothing much can be expected from other efforts in this direction. Unfortunately, most civil engineers responsible for design and construction of structures in India do not get an opportunity to learn seismic engineering either in college or later in their professional career.

A typical undergraduate civil engineering curriculum in the country does not include any coverage of earthquake engineering. 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 lack of any formal training in earthquake engineering during the undergraduate or post-graduate studies. This needs to be corrected by introducing the topics of seismic engineering into the curricula of diploma, degree and post-graduate programmes in civil engineering.

The process of syllabus change is a complex one and should be undertaken with sensitivity to what is appropriate and what is practical considering the constraints and concerns. With this in mind, two workshops were held at Ahmedabad in April 2002 under the aegis of Gujarat State Disaster Management Authority to discuss the methodology of incorporating earthquake engineering topics in the curricula at diploma, degree and post-graduate levels in the colleges and polytechnics of Gujarat. The workshops discussed possible changes in course contents and the course structure for these courses. This article summarises some of the workshops recommendations in view of the fact that many of these will be applicable to colleges in the rest of the country too!

Premises for curricula changes

There was a consensus in the workshop that the students are already overly burdened with too much course work and any additions to the existing load would be detrimental to the cause of good education. Hence, the seismic engineering course material should not be an "add-on". Instead, whatever material is added in earthquake engineering, an equivalent material on some other topics must be removed.

The seismic engineering material to be added to the syllabus had to be carefully chosen in view of the availability of resource material and resource faculty.

In general, the concept of elective is not very effective at diploma, degree or post-graduate levels in view of severe shortage of teaching faculty in the colleges. Due to limited teaching manpower, the colleges are not able to offer enough courses to provide the students with adequate choice. Any

changes in syllabus should bear this in mind, that, if the topics of earthquake engineering are introduced as elective courses, chances are that such a course may not be offered.

The degree and post-graduate programmes of the engineering colleges come under the purview of the respective universities. As a result, there are as many different curricula as the number of universities involved. The changes in curricula have to go through the usual processes of the respective universities. On the other hand, the polytechnic system in Gujarat has a special Curriculum Development Cell (CDC) meant to review and revise the curriculum based on the industry requirements as well the changing technologies from time to time. As compared to the degree programme, it is relatively easier to make changes to the diploma programme. The polytechnics are directly governed by the state governments and do not come under the university system. As a result, all polytechnics of the state follow the same curricula.

Diploma programme

Existing curriculum

As per the present curriculum of diploma in civil engineering followed in the polytechnics of Gujarat, a student takes a total of 37 courses in the three year (six semesters) diploma course. Thus in each semester, he takes about six courses. The courses are divided into the following.

Foundation and Hard Core courses which are common to all branches of engineering and include fundamental mathematics and science courses, communication skills, engineering drawing, workshop, engineering mechanics, computers, environment, human resources, engineering elements and so on.

Soft Core Courses such as marketing, advanced mathematics, advanced applied science and others.

Basic Technology Courses specifically for the civil engineering students which include engineering drawing, mechanics of structures I and II, hydraulics, material technology, surveying I and II and soil engineering.

Applied Technology Courses which are advanced courses and include structural design and drawing in RC and steel, quantity surveying, professional practice, transportation, irrigation, public health, construction technology, and project.

Diversified Elective Courses in which a student may choose electives from water resources, advanced construction technology, construction works management, concrete technology, computer aided structural analysis and design, quality control and maintenance, computer based technology, industrial waster water management and architectural rendering.

After the earthquake of January 26, 2001, some coverage of earthquake engineering was introduced in the diploma curriculum. It consisted of 5 lecture hours and 2 practical hours within the elective course of *Advanced Construction Technology*. These contents were reviewed during the workshop and the general consensus was that:

- these contents are too exhaustive to be covered in five lecture hours
- many of the topics were too advanced for diploma level.

Each semester is 18 weeks long and consists of 14 weeks of teaching. The scope of the syllabus is quite wide and it is often not feasible to complete it satisfactorily within the semester time frame.

Introduction of seismic engineering in the curriculum

For introduction of earthquake engineering contents, two options were debated:

(i) having a separate course on earthquake engineering covering whatever contents are considered necessary to be included, and

(ii) introducing the earthquake engineering contents into different existing courses.

Both the options have advantages and disadvantages. After considerable discussion, it was decided to opt for the second model for the polytechnics of Gujarat. In the first model involving an addition of a new course, one of the existing courses will have to be removed from the curriculum and a review of the course structure did not show a clear choice of the course to be deleted. Moreover, the concerned existing courses were found to have adequate scope for introduction of relevant coverage of earthquake engineering topics.

It was recommended that the diploma programme should contain four modules on earthquake engineering to be introduced at different levels.

Module I: Introduction to earthquakes and cyclones

This is the basic module introducing the students to earthquakes and cyclones. This module would include the following topics, and it can be covered adequately in 11 lecture hours.

Introduction to earthquakes: causes of earthquakes, basic terminology, magnitude and intensity, earthquake effects, past earthquakes and lessons learnt.

Introduction to cyclones: characteristics of cyclones, cyclone effects, past cyclones in the region.

It is proposed that these fundamentals should be taught to diploma students of "all engineering branches". Hence, this may be introduced in the hard core course (compulsory to all branches) on "Essentials of Environment" by replacing topics of "Environmental Legislation" and "Environmental Impact Assessment".

Module 2: Seismic detailing of RC structures

There was a consensus that the engineer at site would be sensitive to the ductile detailing practices required in seismic engineering if he had been exposed to it at college level and understands the objectives and advantages of seismic detailing. Hence, the civil engineering diploma students should be exposed to the codal provisions on ductile detailing of RC buildings (IS 13920 : 1993). The estimated hours required to cover this code satisfactorily are estimated to be about 8 hours. An obvious choice for introducing this module is the RC design course which in the present case had obvious scope for adding these lectures.

Module 3: Seismic resistance for masonry houses

A large part of the people in Gujarat and in rest of the country live in masonry homes and it is very important to teach the fundamentals of earthquake resistant masonry structures. In this module, the students shall be introduced to detailing of masonry houses for seismic resistance such as provision of lintel, plinth and roof bands, roof diaphragm action, and provisions of IS 4326 on masonry buildings. About six hours shall be needed to cover these topics. This module is proposed to be introduced in "Construction Technology" course by condensing the existing topics.

Module 4: Earthquake effects on soils

It is proposed that in the course of "Soil

Engineering", about two lecture hours be spent by the instructors explaining the phenomenon of liquefaction and possible remedial measures.

It is also recommended that after sufficient expertise in earthquake engineering is gained by adequate number of teachers in the polytechnics of Gujarat, a new elective course be developed under the category "Diversified Elective Courses".

Degree programme

Existing curriculum

The structure of present degree curriculum differs in different universities. However, some general trends are obvious. For example, most universities in Gujarat have separate departments for civil engineering and applied mechanics. The structural engineering courses are usually covered by the departments of applied mechanics. Hence, any proposals for syllabus change must respond to this. For instance, it will be cumbersome if the proposed changes require that a course in earthquake engineering (to be taught by the department of applied mechanics) be included by dropping a course from amongst those taught by the department of civil engineering.

Almost all colleges in Gujarat have three to four compulsory courses in structural analysis and two to three courses in structural design. Thus, most universities have five to seven courses in structural analysis and design.

Even though the present syllabus is different in the colleges, almost none of the Gujarat colleges currently teach the fundamentals of seismic engineering at the degree level.

As all the universities have a different syllabus and course format, the workshop objective was not to review the syllabus of each university in detail and offer tailor-made modifications for each university. Instead, an effort was made to develop a broad outline that can be considered by the different universities for undertaking changes in their curricula.

Introduction of seismic engineering in the curriculum

Two models are possible for incorporating earthquake engineering in the curriculum at degree level:

Model 1: In this model, a separate course in earthquake engineering can be introduced containing what all a degree student should learn in earthquake engineering. However, this will require that one of the existing courses be removed from the curriculum.

Model 2: In this model, the seismic engineering issues can be incorporated in the existing courses. Thus, the seismic engineering contents will be distributed into a number of existing courses. It will require rationalising some of the existing courses by removing topics, considered not so important, to make space for the new topics.

Considerable discussion took place between the Models 1 and 2 above. Both the models have advantages and disadvantages. It was felt that in the long run, Model 2 would be better since it would enable better integration of earthquake engineering into the civil engineering education, and would help remove the myth that earthquake engineering is a superspecialty which need not be known to civil engineers. However, from the view point of implementation in the short term, several advantages were obvious in Model 1:

- As of now, most teachers in the engineering institutions are themselves not proficient in seismic engineering. In Model 1, the college will need only one teacher at one time to be teaching seismic engineering. With careful choice of the concerned teacher, and with an additional effort on the part of that teacher, it may be possible to do justice with that course. In case of Model 2, it will be much harder to ensure that several teachers involved in teaching seismic engineering in several courses will be able to do similar justice.
- Most text-books used in the colleges do not yet cover the topics of earthquake engineering. This will again be a handicap in the implementation of Model 2.
- A good feedback mechanism can be developed in the initial years on the appropriate level and contents of earthquake engineering topics if the entire thing is done in one course, rather than spread out in several courses.
- Introduction of a separate and compulsory course in earthquake engineering at this stage in the colleges will give a strong signal to students, teachers, and the college administrators for the need to develop earthquake engineering expertise in the technical education system. This could be very helpful towards capacity building in earthquake engineering.

Most of the participants in the Ahmedabad workshop were of the opinion that at this point of time, it is best to introduce Model 1. After gaining enough experience and after a larger number of teachers have acquired expertise in earthquake engineering, the universities may consider moving into Model 2.

The workshop participants agreed that the coverage of structural engineering courses in the degree programme is fairly large and that this can be consolidated to reduce one course to create place for a course on earthquake engineering. There was consensus that with recent developments in the field of computer aided structural analysis, many traditional analysis methods can be eliminated from the curriculum.

Table 1 gives the proposed contents of the new course for earthquake engineering. It may be emphasised here that this is only

Table 1: Proposed compulsory course on earthquake engineering in the B.E. civil engineering curriculum

Topic	*Lecture hours*
Introduction to earthquakes (causes of earthquakes, basic terminology, magnitude, intensity, peak ground motion parameters)	5
Past earthquakes and lessons learnt	3
Introduction to theory of vibrations, concept of response spectrum.	8
Lateral force analysis of buildings, floor diaphragm action, moment resisting frames, shear walls.	6
Concepts of seismic design, lateral strength, stiffness, ductility, and structural configuration. Design spectrum. Base isolation.	4
Provisions of IS:1893 for buildings	
Seismic design of masonry structures, provisions of IS:4326.	
Seismic design and detailing of rc buildings, provisions of IS:13920	
Soil response to earthquakes, liquefaction and remedial measures.	2

Table 2: Proposed course contents for compulsory course in structural dynamics at M.E. level

Topic	Lecture hours
Single degree of freedom systems Equations of motion, free vibrations, damping, response to harmonic excitation, response to general dynamic loading, Duhamel's Integral, concept of response spectrum, numerical methods	20
Multi degree of freedom systems Equations of motion, free vibrations, natural frequencies and modes, free vibration analysis for classically damped systems, damping matrix, Raleigh damping, modal analysis, earthquake analysis of linear systems by response spectrum method	12
Continuous systems Equations of motion, natural frequencies and modes, modal orthogonality	5
Approximate methods for frequency estimation Rayleigh's method, Dunkerley's method	

a suggested outline, and that individual universities should strive to adapt this to suit their own curricula and faculty strengths. This course may be considered for inclusion towards the end of the degree programme after the student has an adequate grasp of basic analysis and design concepts.

Seismic engineering in the post-graduate programme

At post-graduate level, the status of earthquake engineering education is not very different. Most of the Masters' programmes in structural engineering do have some coverage of structural dynamics but hardly any coverage for earthquake engineering. This needs to be corrected so that every post-graduate in structural engineering is adequately prepared to analyse and design buildings and other common structures for earthquake forces.

There was consensus in the workshop that the M.E. programme in structural engineering should have one compulsory course on structural dynamics, and at least one compulsory course on earthquake engineering.

The colleges are already teaching a compulsory course on structural dynamics. With M.E. programme duration being increased from one-and-a-half years to two years with effect from 2002, there will be ample scope to add new courses in the programme. Hence, a compulsory course in earthquake engineering can be added conveniently. However, if a university wishes to strengthen the research component of M.E. and chooses not to add more number of courses despite increase in the course duration, it should be possible to delete one of the existing compulsory courses and replace it by one course in "Earthquake Analysis and Design of Structures". For instance, some of the colleges teach a compulsory course on "Optimisation Methods" which could be made an elective considering its importance vis-à-vis seismic engineering. *Tables* 2 and 3 give the detailed course contents of the proposed courses on structural dynamics and on earthquake analysis and design.

The post-graduate programme should be tailor-made for each college considering the faculty expertise and interest. Therefore, it was recommended that the concerned colleges with post-graduate programme in structural engineering may adopt different levels of coverage in earthquake engineering as per their need and faculty expertise.

Similarly, colleges offering M.E. in geotechnical engineering may also like to provide one compulsory course on theory of vibrations and one compulsory course on geotechnical earthquake engineering. The first course could be a combination of the proposed course on structural dynamics , *Table* 2, and vibration of machine foundations. The course on geotechnical earthquake engineering should deal with topics such as elements of seismology, characterisation of strong ground motion, seismic hazard analysis, dynamic soil properties, site effects, liquefaction, and seismic slope stability.

It is very important to develop an aptitude towards earthquake engineering amongst the M.E. students through seminars, projects, and thesis. Of course, not all students of a batch of students should specialise in earthquake engineering. The colleges should therefore attempt to develop adequate infrastructure and research facilities in earthquake engineering to facilitate work by those M.E. students who may be interested in this subject.

Table 3: Proposed course contents for compulsory course in seismic analysis and design of structures at M.E. level

Topic	Lecture hours
Characteristics of earthquakes Earthquake terminology, magnitude, intensity, measurement of ground motion, frequency – magnitude relationship, liquefaction	
Strong ground motion Acceleration time histories, peak parameters (peak ground acceleration/velocity/ displacement), response spectrum, site effects	5
Earthquake analysis of structures Idealization of structures, response spectrum analysis, equivalent force concepts, torsionally coupled systems	8
Concepts of earthquake resistant design Objectives, ductility, ductility reduction factor, overstrength, response reduction factor, design Response spectrum, lateral stiffness, building configuration, base isolation, concept of structural control	6
Building codes Performance of buildings in past earthquakes, historical perspective on code development, Indian code (IS 1893), provisions for buildings	5
Detailing of reinforced concrete and masonry buildings Provisions of IS 13920, IS 4326	10

Resource faculty and resource materials

It is very important that the teachers be themselves proficient in earthquake engineering. Since most of them have themselves not learnt this subject during their past formal training, it is very important to carry out a vigorous training of trainers programme for them in the subject of earthquake engineering.

In addition to training of teachers, it is necessary to stock the libraries of the colleges with books in earthquake engineering. Since most of the books are published by overseas publishers and are quite expensive, special arrangements are needed in this regard.

Summary and concluding remarks

There is an urgent need for exposing the diploma, degree and post-graduate students to fundamentals of earthquake engineering. This article discusses the recommendations that were developed for the colleges in Gujarat which can be easily extended for other regions of the country. The course contents and the number of lecture hours for each topic as given in the *Table* 3 are only recommendations. Clearly, the curriculum is not something that should be indiscriminately adopted; different universities must adapt these recommendations to suit their own faculty expertise, existing curriculum, and local conditions.

Considering the existing curriculum of diploma in civil engineering followed in the polytechnics of Gujarat, it is recommended that four modules on different aspects of earthquake engineering be included in the existing courses.

A new course in seismic engineering, *Table* 1, is proposed to be introduced in the undergraduate civil engineering curriculum. To accommodate this course, one of the courses on structural analysis and design may be removed. After five to ten years, when adequate expertise is developed in the colleges, they may start introducing the contents of seismic engineering within the regular civil engineering courses.

It is recommended that the M.E. programmes in structural engineering should include one compulsory course in structural dynamics and another compulsory course on earthquake analysis and design of structures. Suggested contents for these two courses are given in *Tables* 2 and 3, respectively. It is recommended that the M.E. programmes in geotechnical engineering should include one compulsory course on theory of vibrations, and one compulsory course on geotechnical earthquake engineering.

In order to achieve an earthquake-resistant building, the role of architects in configuring the building right is very vital. To quote the renowned earthquake engineer Late Henry J. Degenkolb:

> "If we have a poor configuration to start with, all the engineer can do is to provide band-aid – improve a basically poor solution as best as he can. Conversely, if we start off with a good configuration and a reasonable framing system, even a poor engineer can't harm its ultimate performance too much."

It is recommended that the curricula of architecture programmes should also include appropriate coverage of principles of earthquake engineering.

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References

1. Murty, C.V. R, Sinha R. and Jain, S.K. A report on earthquake resistant construction in civil engineering curriculum, *Newsletter of the Indian Society of Earthquake Technology*, January 1998, pp. 1-10.(Also available at: http://www.nicee.org/NICEE/EQ_Engg/iset_ws.htm)
2. Sheth, A.R, and Jain, S.K. Training of teachers in earthquake engineering for capacity building towards earthquake safety in India , *The Indian Concrete Journal* (submitted for possible publication).
3. _____ *Indian standard code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces*, IS 13920:1993,Bureau of Indian Standards, New Delhi.

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