Initiatives in Educating Future Architects in Earthquake Resistant Design Practices

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INTRODUCTION

India has suffered the effects of a number of earthquakes in the recent past in which the poor seismic performance of the built environment emerged as a key area of concern. A number of initiatives have been taken in India to address this problem and these include, among others, revision and strengthening of the codes of practice, drafting of development regulations and building bylaws to take seismic safety into account, sensitization and awareness building in the community, and capacity-building efforts directed at various stakeholders in the building delivery process. Architects, as initiators of projects, coordinate the team of professionals responsible for the building-delivery process. Therefore, there is an urgent need to reach out directly to tomorrow's architects through sensitization in seismic safety issues to better prepare them for their professional roles. Earthquake-resistant architecture has fairly recently been included in the academic curriculum of undergraduate colleges of architecture. To supplement and strengthen this, a unique initiative was launched in India in 2008 to directly reach the undergraduate students of architecture through an Annual Workshop Series that is now in its sixth year. Through these workshops, nearly three hundred undergraduate students of architecture have been trained in concepts of the earthquake resistance of buildings. The objective of the series is to sensitize students of architecture in earthquake-resistant design practices through technical lectures followed by design studios in which they are given hands-on guidance in earthquake-resistant design by working on an architectural design project in the Time Sketch format that they are familiar with. This paper presents a brief overview of this activity.

BACKGROUND

India is located in one of the most earthquake-prone regions of the world. The entire Himalayan belt is prone to earthquakes of magnitude exceeding 8.0, and in a relatively short span of about 55 years, four such earthquakes had occurred: 1897 Shillong (**M** 8.7), 1905 Kangra (**M** 8.0), 1934 Bihar–Nepal (**M** 8.3), and 1950 Assam–Tibet (**M** 8.6). Sixty percent of India's landmass, and approximately 65% of India's 1.25 billion population, fall within the moderate to severe hazard levels as per the Seismic Zone Map of India (Bureau of Indian Standards [BIS], 2002; Building Material and Technology Promotion Council [BMTPC], 2007). The past two decades have seen devastating effects of earthquakes striking India with alarming regularity: Sikkim 2011, Kashmir 2005, Bhuj 2001, Chamoli 1999, Jabalpur 1997, Latur 1993, and Uttarkashi 1991 causing over 20,000 deaths (Fig. 1).

The earthquake risk of a community is a function of its location in a known earthquake-hazard zone, its population, and the condition of its building stock. The risk gets exacerbated in the presence of high population densities, especially in urban areas and vulnerable physical built environments for which poor performance causes casualties and losses in earthquakes (Fig. 2). There is thus a real need for the civil engineering and architecture professions to be equipped with the capacity to incorporate earthquake resistance in the built environment. Clearly, the earthquake hazard transforms into a disaster in a vulnerable built environment, in which building and lifeline collapses contribute to loss of lives and huge financial losses. Major factors that determine the satisfactory seismic performance of the built environment are: architectural configuration, structural design, nonstructural elements, and quality of construction.

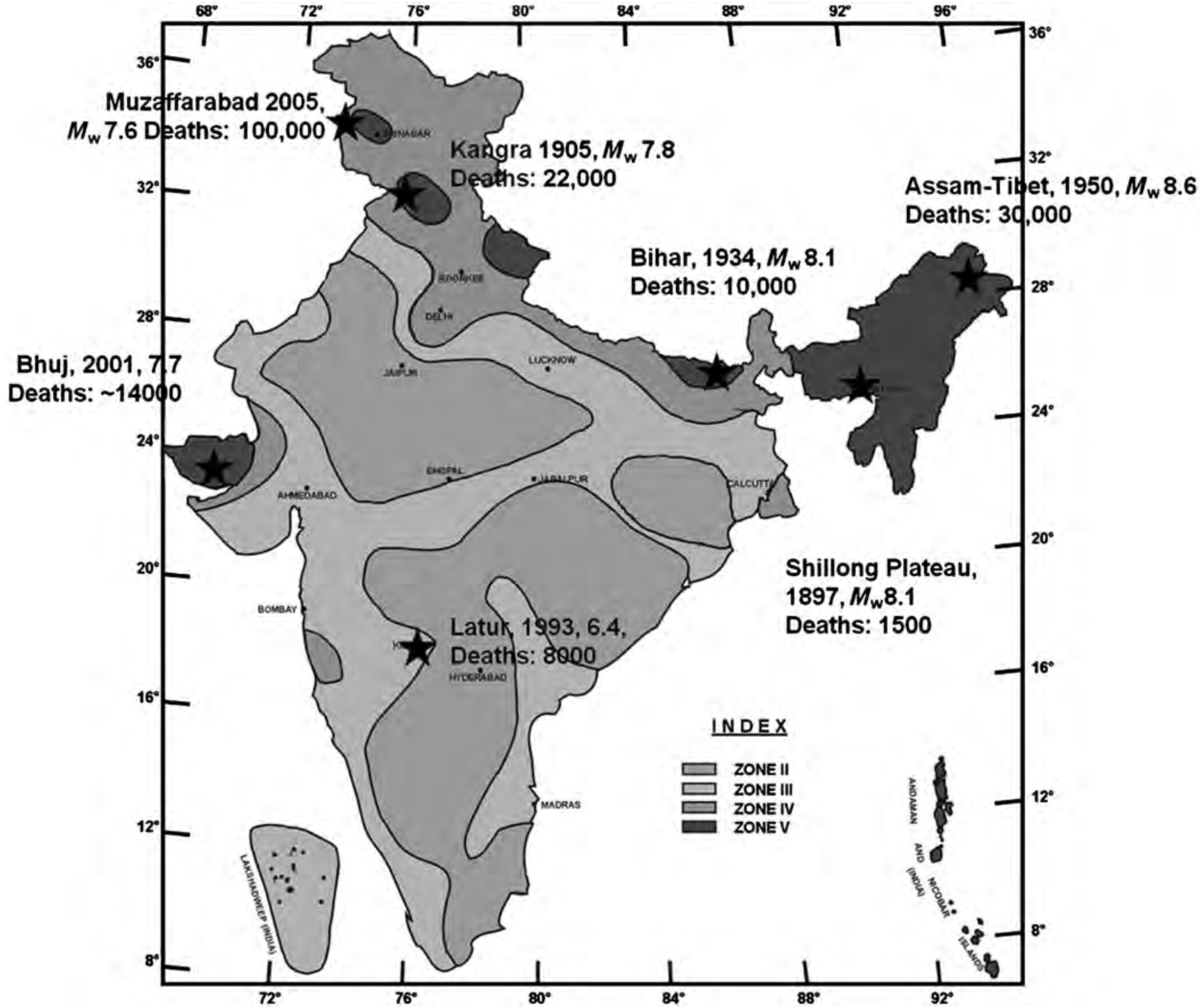
THE ROLE OF ARCHITECTS

Buildings perform poorly during earthquakes due to the absence or inadequacy of earthquake-resistant design processes and features which should have been incorporated in all the stages of conception, design, analysis, and construction. Architects occupy the apex position in project conceptualization, planning, and implementation, coordinating various professionals from different disciplines including, but not limited to civil engineering, electrical and mechanical engineering, geotechnical, sanitary, and plumbing engineering, and urban planning. Poor conceptual design and detailing of various elements by the architect will seriously impair the ability of structural and construction engineers to incorporate adequate earthquake resistance in a building.

INITIATIVES IN CAPACITY BUILDING FOR EARTHQUAKE DISASTER RISK MITIGATION

The National Information Center of Earthquake Engineering (NICEE) was set up in 1999 in the Indian Institute of

 doi: 10.1785/0220120173



▲ **Figure 1.** Seismic Zone Map of India showing significant earthquakes and death tolls; adapted from Bureau of Indian Standards (BIS) 1892 (2002).

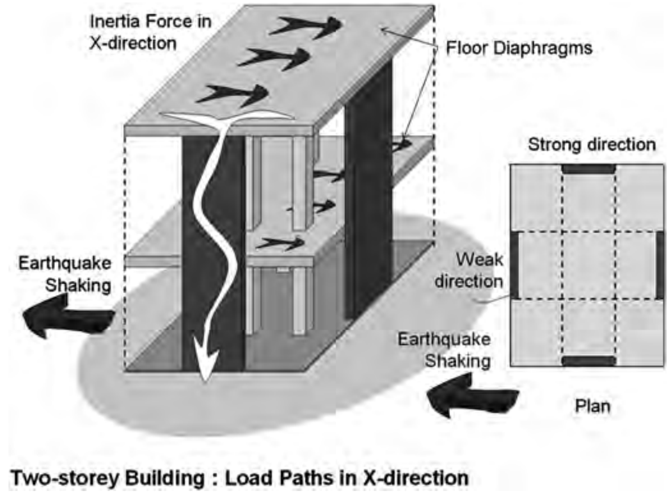
Technology (IIT) Kanpur to address the need for information on earthquakes and earthquake engineering with particular focus on India. NICEE's mandate is to empower all stakeholders in the building industry in seismic safety toward ensuring an earthquake-resistant built environment. NICEE maintains and disseminates information resources on earthquake engineering. It undertakes community outreach activities aimed at mitigation of earthquake disasters. NICEE's target audience includes professionals, academics, and all others with an interest in and concern for seismic safety. Recognizing the key role that architects play in shaping the built environment, NICEE has targeted the architect community in a systematic manner. During 2005–2006, to strengthen and steer the agenda of seismic safety NICEE distributed about 10,000 copies of *Earthquake Tips* (Murty, 2005) to architects nationwide who are members of the Indian Institute of Architects. The then President of the Indian Institute of Architects (IIA) cosigned a letter emphasizing the role of architects in construction of safe buildings.

Since 2007, NICEE has undertaken several activities to sensitize the architectural community on earthquake safety. In December 2007, NICEE participated in the Golden Jubilee Convention of the National Association of Students of Architecture (NASA) at Bhopal by setting up an information booth. About 1000 copies of the publication *Earthquake Tips* were distributed free-of-charge to the future architects. A quiz was conducted (with cash awards) with questions based on the tips.

A booth was set up and a student quiz based on *Earthquake Tips* was conducted at the Conference of the South Asian Association for Regional Cooperation of Architects (SAARCH) 2008 in New Delhi.

A specially created brochure on publications targeting architects was mailed to about 10,000 architects during

▲ **Figure 2.** Pancake collapse of a reinforced concrete (RC) frame building in the Bhuj earthquake, 2001. Photo: Earthquake Engineering Research Institute (EERI, 2002).



▲ **Figure 3.** The role of floor diaphragms in transferring lateral earthquake-induced forces in a building. Source: Murty and Charleson (2006); p. 388.

2008. At the 2009 SAARCH NASA Convention in Pune, the NICEE booth attracted many enthusiastic visitors and saw 300 new registrations. As in the previous year, a quiz was conducted on Earthquake Safety in the Built Environment, this time based on Hugo Bachmann's publication *Seismic Conceptual Design*, which was disseminated free-of-cost (Bachmann, 2003).

WORKSHOP SPECIFICS

Eligibility for Participation

The annual workshop series is targeted at students of architecture after they complete six semesters of architectural coursework in their institutions. The selected students get an opportunity to spend one week at IIT Kanpur and undergo hands-on training in Earthquake Resistant Architecture Practices through a series of lectures and design studios coordinated by professionals with wide experience in this field.

Workshop Structure and Content

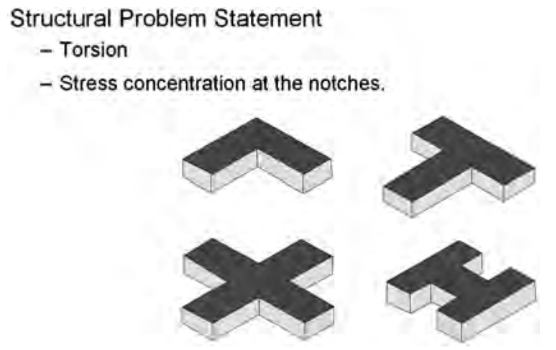
Lectures

Immediately upon formal acceptance and registration to the workshop, each selected student receives a free copy of the NICEE publication *Architectural Teaching Resource Material on Earthquake Design Concepts* coauthored by Murty and Charleson (2006). As this publication forms the backbone of workshop lectures and deliberations, it is expected that the students will go through the publication carefully before arriving in IIT Kanpur. On the first day of the workshop a quiz with multiple-choice answers was given to the participants. Another quiz of similar difficulty level was administered to the participants toward the end of the workshop to evaluate the progress made by the students.

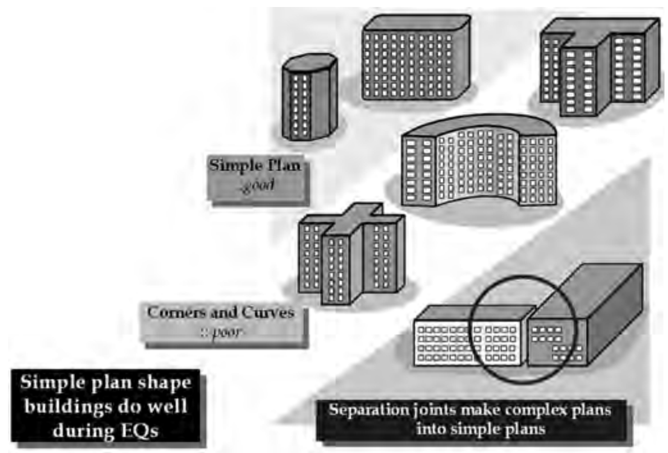
The first day of the workshop commences with an Inaugural Session when the National Coordinator of NICEE welcomes the participants and explains to them the objectives of the workshop. One or two distinguished speakers usually address the students. The first day and half of the second day of the workshop are devoted to a series of lectures. The first lecture introduces the participants to the impacts of earthquakes, both globally and nationally, and establishes the need for developing a clear understanding of and strategy toward designing for earthquake resilience. Movies of devastating earthquakes from the recent past are shown to dramatically illustrate the real-life effects of earthquakes. In the afternoon session, the second lecture attempts to sensitize the participants on how earthquakes induce forces in buildings through an illustration of earthquake loads on simple buildings and an overview of the most commonly used earthquake-resistant structural systems. During the final lecture of the day, the students are given detailed exposure to some common typologies that are used by architects, namely, load-bearing brick masonry, buildings with reinforced concrete (RC) shear walls, and RC moment-resisting frames. The structural behavior of these typologies is explained at a conceptual level that is fairly simple to grasp.

The second day begins with two very important lectures. The first covers a number of critical aspects of earthquake resistant design, namely, the role of horizontal components in a building such as Floor and Roof Diaphragms, and on the transfer of forces or load paths (Fig. 3).

Satisfactory performance of a building during an earthquake depends on a number of critical factors including, among others, the strength of the connections between different building components, the quality of building materials and construction, the adequacy of the structural members, and building configuration. Out of these, configuration is arguably the key issue that is within the realm of professional responsibility of the architect. Hence the issues of plan configuration



▲ **Figure 4.** Buildings with re-entrant corners. Source: Murty and Charleson (2006); p. 449.

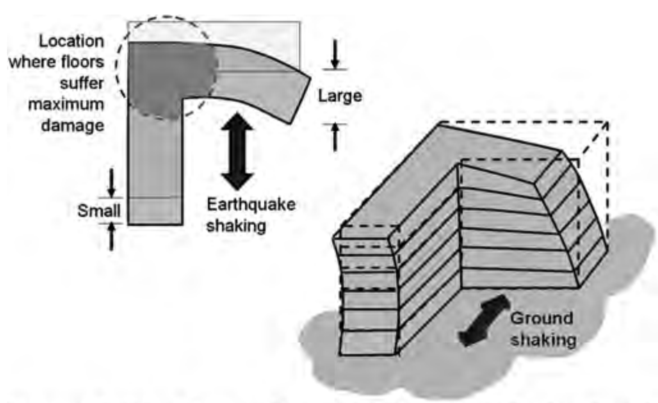


▲ **Figure 6.** Plan configuration for earthquake performance. Source: Murty and Charleson (2006); p. 460.

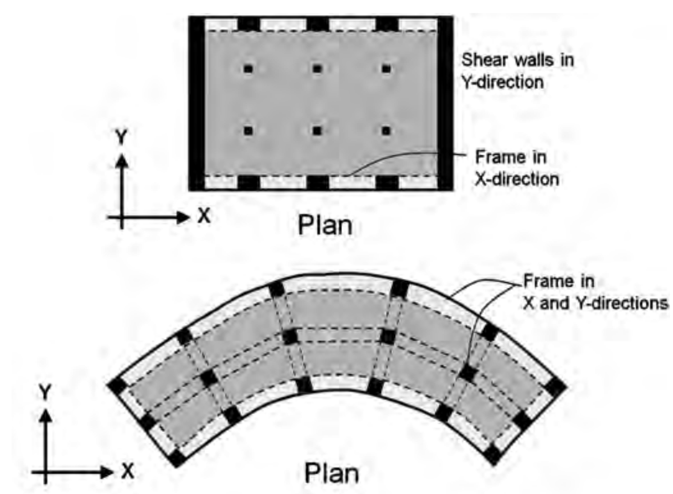
and vertical configuration are emphasized and the students are sensitized to the inherent inadequacies of certain types of very commonly used irregular configurations, such as plans with odd shapes and buildings with substantial offsets/overhangs (Figs. 4–6). Whereas the participants are taught the reasons for the poor earthquake performance of such types of configurations, they are also exposed to the ways of mitigating the negative effects of such design decisions through the use of rational structural systems (Fig. 7). The lecture contents are totally conceptual and attempt to effect the technical knowledge transfer in a graphical and qualitative way that is congruent with the way architecture students address design problem solving.

Recognizing that the collapse of nonstructural components has contributed to more than half the fatalities due to earthquakes worldwide, the last formal lecture of the workshop is devoted exclusively to nonstructural elements. This lecture primarily concerns two types of nonstructural elements, namely, the unreinforced masonry infill walls used in RC-frame buildings and a host of other elements such as false ceilings, chimneys, parapet walls, piping and ducting systems, to name a few.

The design assignment is introduced to the students at the end of the two lectures and this is followed in the afternoon with a session on RESIST© software (http://www.nicee.org/npeee/showpage.php?id=149/, last accessed July 2013). The original RESIST© software was developed as per building design code requirements of New Zealand. The software has been modified for Indian codes of reinforced concrete and masonry structures as well as loading codes of gravity, wind, and earthquake loads. RESIST© is a computer program that enables designers to determine the numbers and sizes of earthquake and wind-load resisting elements in a building. RESIST© undertakes structural analyses using the approach an experienced structural engineer would take for preliminary structural designs. RESIST© has a graphic interface that makes it very user-friendly for students of architecture. It helps students to conceptualize the number and sizes of structural members necessary without any complex structural calculations. RESIST© allows the user to try out different structural systems for resisting lateral loads for a particular configuration. It also allows the user to change the floor weights and see how that affects the size of the structural members. A significant benefit



▲ **Figure 5.** Poor earthquake behavior of buildings with re-entrant corners. Source: Murty and Charleson (2006); p. 451.



▲ **Figure 7.** Illustration of how to use two lateral-load-resisting systems in plans. Source: Murty and Charleson (2006); p. 177.

of the program is that it enables students to quickly explore many different structural solutions before arriving at the one that best integrates with their overall design. The input required for RESIST© is therefore kept to the bare minimum. No calculations are required at all. This deliberate simplification of input does reduce the accuracy of the results somewhat and has limited the maximum height of the buildings analyzed to eight storeys. It also means all buildings must be converted to equivalent rectilinear buildings.

Studio Sessions

During the studio sessions, the students work on PCs in groups of two and they are guided by architecture resource faculty. They receive structural engineering inputs in a hands-on format during the studio sessions from the structural engineering faculty of IIT Kanpur and other institutes. Individual cases are used to demonstrate different ways of incorporating earthquake resistance in architectural design. So in addition to solving their own architectural design problems, the students are exposed to many different scenarios being undertaken by other groups.

Evaluation

In the six-day workshop, studio sessions start on the second half of the second day and continue until the end of the fifth day. The last day is reserved for Jury Review and Valedictory Functions. The groups are required to present their design solutions to a Jury Board comprising eminent architects, structural engineering professionals, and academics. The presentations are followed by a brief question-and-answer session moderated by the Jury. Six groups are shortlisted by the Jury Board, and they make a second and more detailed presentation followed by further questions. The Jury selects winners for the First, Second, and Third positions.

Resource Faculty

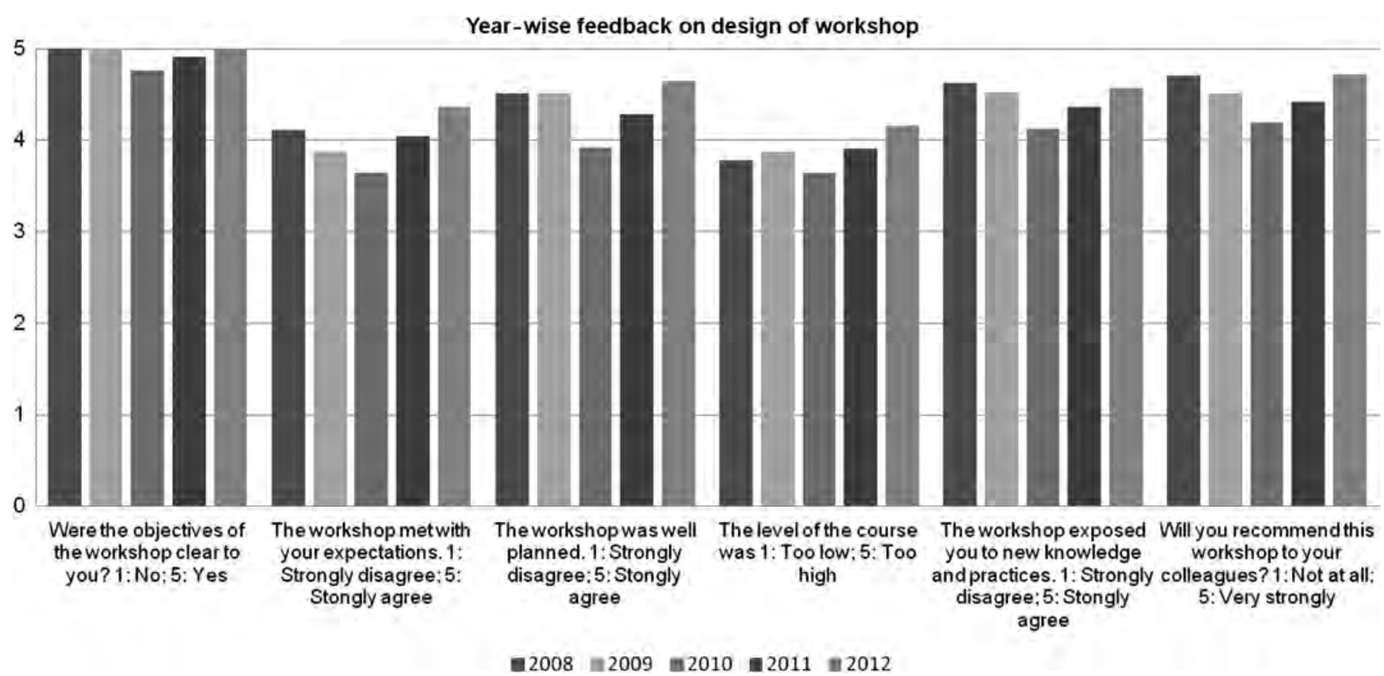
Since its inception in 2008, the Architecture Workshop has hosted twelve resource faculty members from the Architecture and Structural Engineering disciplines drawn from ten institutes from all over India. International organizations working at reducing the earthquake risk to vulnerable communities in the developing world have also volunteered resource faculty for the workshop.

Participation

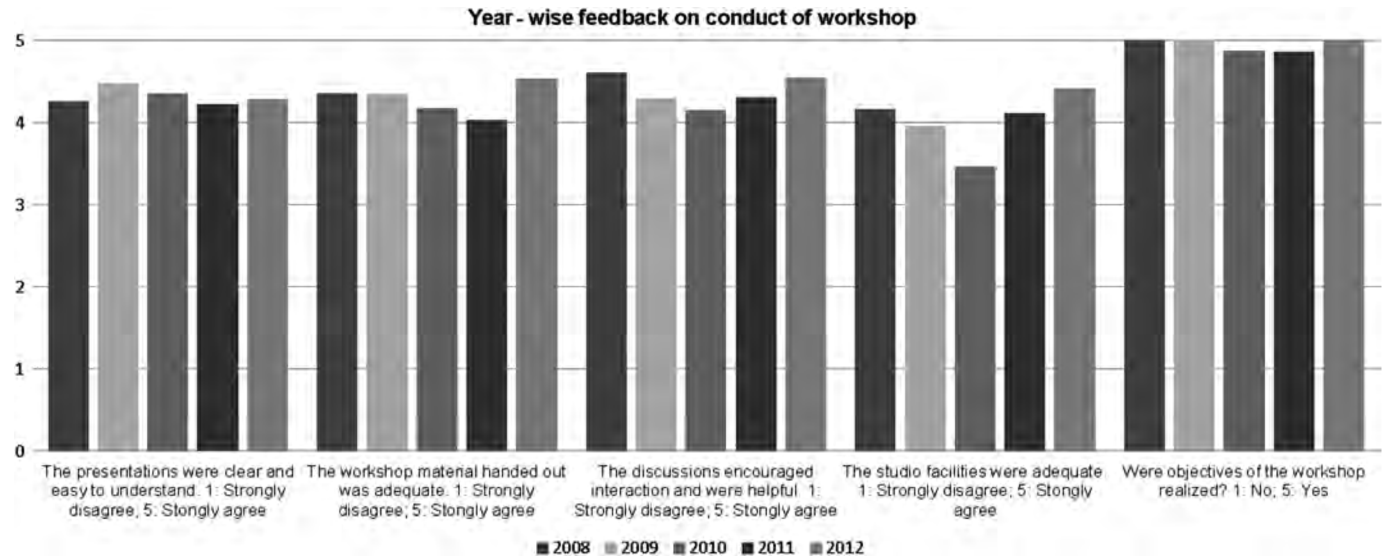
During the course of the past five years, 48 institutes from India and Nepal have sent a total of 284 participants to the Architecture Workshop Series. These 48 institutes represent nearly all the states that offer a Bachelor's degree program in Architecture.

Feedback

At the end of each workshop the participants are requested to fill feedback forms. Feedback was sought on three broad areas, namely, design of the workshop, conduct of the workshop, and overall rating. The detailed feedback on the questions asked including the scores for each question for the period 2008–2012 are given in Tables A1 to A4 in Appendix A. In the first two categories, in addition to providing scores on a five-point scale in response to a set of questions, participants were asked to assign a rating in any one of the ranges: 90%–100%, 80%–90%, 70%–80%, 60%–70%, 50%–60%, and below 50%. Based on the feedback from the past five years, the average rating given in the first category, namely, the design of workshop,



▲ **Figure 8.** Year-wise participant feedback on design of workshop.



▲ **Figure 9.** Year-wise participant feedback on conduct of workshop.

was 84%. Under the first category participants were also asked to rate the workshop on a scale of 1–5 (1 for strongly disagree and 5 for strongly agree) on a set of six questions (Fig. 8).

In the category, conduct of workshop, the average rating based on feedback from five years was 84%. Further, the participants were asked a set of five questions, rated in a scale of 1–5 (Fig. 9).

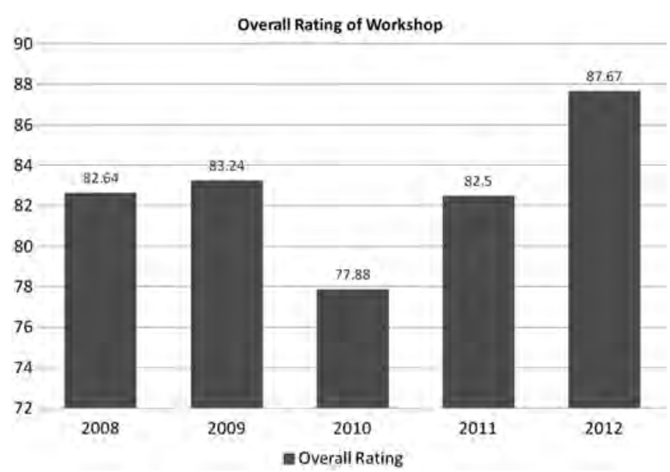
Workshop participants were also asked to give an overall rating to the workshop (Fig. 10). Based on the past five years, the average overall rating was 83%. Around 25% of the participants gave the workshop a 70%–80%, whereas 45% gave a rating of 80%–90% and 23% recorded a rating of 90%–100% (Fig. 11).

CONCLUDING REMARKS

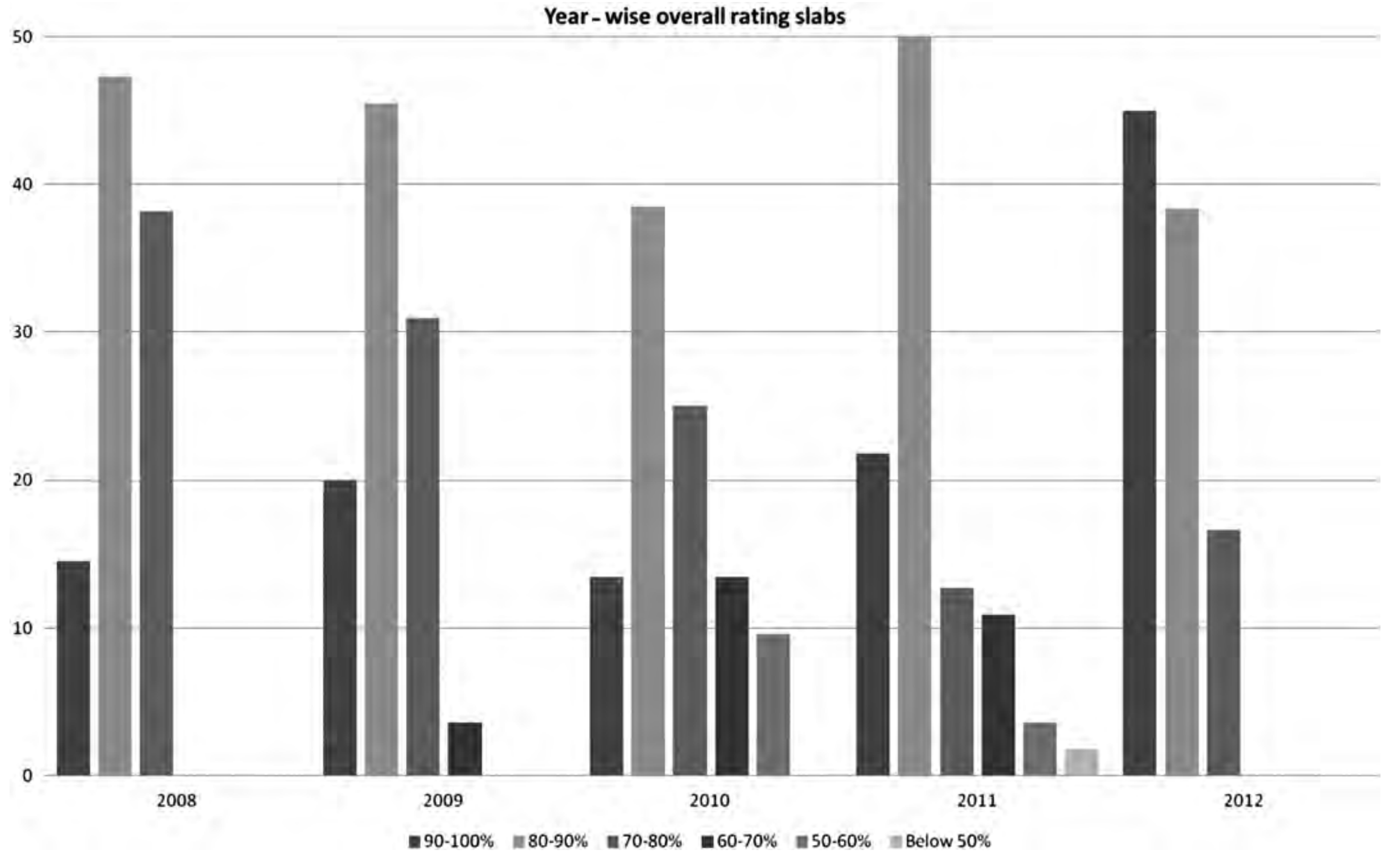
The NICEE Architecture Annual Series is a unique program that brings together architecture and structural engineering faculty and professionals with expertise in and commitment to an earthquake-resilient built environment. The workshops provide an intense knowledge-transfer and capacity-building exercise targeted at the architects of tomorrow. It is hoped that this experience will better prepare future architects in addressing earthquake safety issues in their professional lives and help in spreading this very important agenda in a systematic and holistic way over the years. The workshop affords the participants a unique opportunity to grapple with and strike a balance between the requirements of earthquake-resistant design and a host of design considerations that they normally consider in their architectural design exercises.

ACKNOWLEDGMENTS

The authors express their thanks to a host of individuals and organizations whose support has sustained this Annual Workshop series since 2008. Organizations that we wish to thank are The National Information Center of Earthquake Engineering (NICEE), Poonam and Prabhu Goel Foundation Indian Institute of Technology (IIT) Kanpur, Computers and Structures Inc., Council for Scientific and Industrial Research (CSIR) India, Geohazards Society India, Ministry of Earth Sciences, Government of India, UltraTech Cement Ltd., and Indian Concrete Journal. Individuals who deserve our thanks include our Resource Faculty, members of the Jury Boards and graduate students of IIT Kanpur who have assisted during the workshops. They are A. K. Mittal, Alpana Dongre, Amit Bose, Atanu K. Dutta, Balbir Verma, Bhavna Vimawala, C. V. R. Murty, Hemant B. Kaushik, Kaustubh Dasgupta, Mahesh Tandon, Mahua Mukherjee, Meera Shirodkar, Narendranath Mitra, Nehal Desai, O. R. Jaiswal, Persi Engineer, Puneet Chugh, R. K. Kakar, Rajarshi Maitra, Rajat Ray, Rajeev Kacker, Sudhir K. Jain, Supratik Bose, Sushmita De, Tapan Kumar Sinha, V. R. Shah, Vaibhav Singhal, Vasudha Gokhale, and Vijay Pal Singh.



▲ **Figure 10.** Year-wise distribution of participants' overall rating of the workshop.



▲ **Figure 11.** Year-wise overall rating slabs.

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APPENDIX A

Table A1
Year-Wise Participant Feedback on Design of Workshop

	2008		2009		2010		2011		2012	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A. Were objectives of the workshop clear to you? 1 (No) 5 (Yes)	5.00	0	5.00	0	4.76	0.95	4.91	0.66	5.00	0
B. The workshop met with your expectations. 1 (Strongly disagree) 5 (Strongly agree)	4.11	0.78	3.87	0.96	3.65	0.81	4.04	0.96	4.36	0.77
C. The workshop was well planned. 1 (Strongly disagree) 5 (Strongly agree)	4.51	0.57	4.51	0.66	3.92	1.01	4.28	1.00	4.65	0.76
D. The level of the course was 1 (Too low) 5 (Too high)	3.78	0.69	3.87	0.75	3.65	0.86	3.91	0.97	4.16	0.69
E. The workshop exposed you to new knowledge and practices 1 (Strongly disagree) 5 (Strongly agree)	4.63	0.70	4.53	0.63	4.12	1.04	4.37	0.92	4.57	0.59
F. Will you recommended this workshop to your colleagues? 1 (Not at all) 5 (Very strongly)	4.71	0.57	4.51	0.66	4.19	1.05	4.42	0.86	4.72	0.56

Table A2
Year-Wise Participant Feedback on Conduct of Workshop

	2008		2009		2010		2011		2012	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A. The presentations were clear and easy to understand. 1 (Strongly disagree) 5 (Strongly agree)	4.25	0.64	4.47	0.66	4.35	0.65	4.21	0.84	4.28	0.71
B. The workshop material handed out was adequate. 1 (Strongly disagree) 5 (Strongly agree)	4.35	0.64	4.34	0.70	4.17	0.96	4.02	1.11	4.53	0.75
C. The discussions encouraged interaction and were helpful 1 (Strongly disagree) 5 (Strongly agree)	4.60	0.68	4.29	0.60	4.14	0.89	4.30	0.84	4.54	0.62
D. The studio facilities were adequate 1 (Strongly disagree) 5 (Strongly agree)	4.15	0.98	3.95	1.01	3.46	1.35	4.11	1.11	4.41	0.84
E. Were objectives of the workshop realized? 1 (No) 5 (Yes)	5.00	0.00	5.00	0.00	4.87	0.63	4.85	0.76	5.00	0.00

Table A3
Year-Wise Distribution of Participants' Overall Rating of the Workshop

	2008		2009		2010		2011		2012	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Overall rating of the workshop	82.64	6.93	83.24	7.91	77.88	11.77	82.50	10.31	87.67	7.33

Table A4
Year-Wise Overall Rating Slabs

Overall Rating of the Workshop	2008	2009	2010	2011	2012
90%–100%	14.55	20.00	13.46	21.82	45.00
80%–90%	47.27	45.45	38.46	52.73	38.33
70%–80%	38.18	30.91	25.00	12.73	16.67
60%–70%	0.00	3.64	13.46	10.91	0.00
50%–60%	0.00	0.00	9.62	3.64	0.00
Below 50%	0.00	0.00	0.00	1.82	0.00

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