RESUME'

Name	**Shailesh Kr. Agrawal**
Date of Birth	Nov. 6, 1965; Moradabad (UP)
Educational Qualification	Ph.D. (Earthquake Engg.), 2001 (IIT Roorkee) Master of Science (S&T), 1990 (BITS Pilani) M.Tech. (Structural Engg.)- Topper of the Group, 1988 (IISc Bangalore) B.Tech.(Civil Engg.) - Silver Medalist, 1986 (GB Pantnagar Univ.)
Place of work	Central Building Research Institute, Roorkee (*a constituent establishment of CSIR and a premier research Institute involved in R & D in the area of Building Science & Technology) from 8th March 1989 – 16th Janury 2008.* Building Materials & Technology Promotion Council, New Delhi (*an apex inter-ministerial organisation under the aegis of Ministry of Housing & Urban Poverty Alleviation, Govt. of India*) w.e.f. *17th January 2008*
Present Designation	**Executive Director**
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Professional Experience:

- Joined CBRI, Roorkee as Fellow on *June 14, 1988*
- Started working as Scientist B on *March 8, 1989*; and subsequently promoted on merit basis as Scientist C in *March 1992*, and Scientist E-I in *March 1997*; Scientist E-II in *March 2001*. At present working as Executive Director, BMTPC, New Delhi
- Established Building Dynamics Laboratory at CBRI Roorkee, which provides S&T backup in the area of disaster mitigation.
- Conferred with degree of Doctor of Philosophy by Indian Institute of Technology, Roorkee on December 15, 2001 for the thesis entitled Strong Motion Array Data as Response of Layered Elastic Medium of Philosophy.
- Leading major R&D projects of international & national importance in the domain of Earthquake Resistant Design & Construction; Seismic Vulnerability of Buildings; Repair & Rehabilitation of Structures, health monitoring of important structures. Few of them are: Improving Seismic Resistance of Cultural Heritage Buildings under EU-India Cross Cultural Programme; Estimation of Seismic Vulnerability of Buildings for Jabalpur, Delhi; Experimental investigation of masonry buildings under earthquake loads of Govt. of India, DST, New Delhi; Health Assessment of Multistoried Buildings under Ambient & Forced Vibrations, Planning Commission, Govt. of India.
- Overall in charge and coordinator of technical visit made by European researchers to install dynamic monitoring system and Qutb minar and to carry out non-destructive testing at Qutb minar in September 1-10, 2005 & September 21-27, 2006. The system is being up kept by CBRI to gather ambient vibration signatures on regular basis. This is first of its kind study being done on Heritage structure such as Qutb Minar in India in technical collaboration with European experts from universities.
- Programme Coordinator at CBRI for *National programme on Capacity Building for Engineers in Earthquake Risk Management* of Ministry of Home Affairs, New Delhi.
- Organising short-term course on '*Earthquake Resistant Design & Construction*' for professionals at CBRI on regular basis.

- Coordinator of *V^th International Conference on Structural Analysis of Historical Constructions* held at India Habitat Centre, New Delhi from 6-8th November 2006 under EU-India Economic Cross Cultural Programme on *Improving Seismic Resistance of Cultural Heritage Buildings.*
- Coordinated and organised a half-day workshop on Conservation of Architectural Heritage: Strengthening Possibilities in collaboration with European Experts on December 8, 2005 at Archeological Survey of India in Delhi for ASI officers, professionals.
- Key note speaker, chairman, co-chairman and reporteur in several national and international conferences.
- Organized a course on Earthquake Resistant Design & Construction for senior level engineers of DDA, MCD in the capacity of Course Coordinator March 17-19, 2004 at CBRI, Roorkee
- Published the lecture notes for the course in form of a book entitled Earthquake Resistant Design & Construction authored by Shailesh Kr. Agrawal, Ajay Chourasia, Pankaj Agarwal, March, 2004, CBRI, Roorkee
- Organized a course on Earthquake Resistant Design & Construction for practicing engineers of various organizations such as UPRNN, THDC, BARC, UPHSDP etc. in the capacity of Course Coordinator December 15-17, 2004 at CBRI, Roorkee
- Published the lecture notes for the course in form of a book entitled Earthquake Designer Manual for Practicing Engineers authored by Shailesh Kr. Agrawal, December, 2004, CBRI, Roorkee
- Compiled a Special Publication entitled Applications of GIS in Earthquake and Landslide Hazard Assessment, Seismology Division, Department of Science & Technology, New Delhi, Government of India, July 2003.
- Contributed a Chapter on Vulnerability Analysis and Engineering Seismological Studies at Jabalpur Urban Area, , MP (Chapter 8 & Annexure Volume-VI) in special report on Seismic Hazard & Risk Microzonation of Jabalpur DST Report published by GSI, Nagpur, Vol. I & II, 2004
- Organized one day course on Earthquake Resistant Design & Construction in collaboration with Consultancy Development Centre, New Delhi specially designed for practicing engineers of Delhi in the capacity of Course Coordinator June 15, 2005, New Delhi
- Organized a Training programme on Seismic Microzonation of Hilly Areas, February 11-15, 2003 in collaboration with DST, CDMM, Chennai at CBRI, Roorkee.
- Structural Consultant for technical audit & quality assurance for state buildings under Gujarat Emergency Earthquake Reconstruction Programme
- Programme Coordinator at CBRI for National programme on Capacity Building for Engineers in Earthquake Risk Management of Ministry of Home Affairs, New Delhi for training the trainers i.e. faculty members of Engineering colleges of Punjab, Haryana, J & K from 10th May – 10th June 2005.
- Invited and felicitated as faculty member to deliver key note lectures in the domain of Earthquake Resistant Design and Construction at various professional levels, national & international conferences, short term courses, invited lectures, training programmes etc.
- Guided students visiting CBRI under Summer Training Programme for B.Tech. Students of different Engineering Colleges.

M.Tech. Thesis Guided

- Non-linear Static Analysis procedures for seismic evaluation and retrofit of RCC buildings, M.Tech Thesis in Civil Engineering (with specialization in Building Science & Technology), Department of Civil Engineering, Indian Institute of Technology, Roorkee, February, 2003.
  (Name of the Student : Mr. Susmit Priyadarshi, Supervisors : Dr. Pradeep Bhargava & Dr. Shailesh Kr. Agrawal)
- Seismic evaluation and retrofit of RCC building using Pushover Analysis, M.Tech Thesis in Civil Engineering (with specialization in Building Science & Technology), Department of Civil Engineering, Indian Institute of Technology, Roorkee, February, 2003
  (Name of the Student : Mr. Lalit Verma, Supervisors : Dr. Pradeep Bhargava & Dr. Shailesh Kr. Agrawal)
- Investigation of IS Code provisions on Seismic Design of Reinforced Structural Walls, M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology Kanpur, August 2002
  (Name of the Student : Mr. Kaustubh Dasgupta, Supervisors : Dr. C.V.R.Murty, & Dr. Shailesh Kr. Agrawal)

- Seismic Evaluation and Retrofitting of Multi-storeyed RC Framed building using Push-over analysis, M.Tech Thesis in Civil Engineering (with specialization in Computer Aided Design), Department of Civil Engineering, Indian Institute of Technology, Roorkee, June 2002
  (Name of the Student : Mr. Sunil Bhardwaj, Supervisors : Dr. Pradeep Bhargava & Dr. Shailesh Kr. Agrawal)
- Effectiveness of a steel twin lintel belt on performance of a brick masonry building with precast RC roofing system under quasi-static lateral cyclic loading, M. Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology, Kanpur, August, 2001
  (Name of the Student : Mr. Jayanta Dutta, Supervisors : Dr. C.V.R.Murty, & Dr. Shailesh Kr. Agrawal)
- Development of an Expert System for Distressed RC Buildings, M. Tech. Thesis in Civil Engineering (with specialization in Computer Aided Design), Department of Civil Engineering, University of Roorkee, Roorkee, February, 2001
  (Name of the Student : Mr. Thaore Sangharatna Bhaurao, Supervisors : Dr. Jagdigh Prasad & Dr. Shailesh Kr. Agrawal)

Apart from above, external examiner to Deptt. Of Civil Engineering & Deptt of Earthquake Engineering, IIT Roorkee, IIT, Kanpur, TIET, Partiala on regular basis for M.Tech & Ph. D. evaluations.

Lectures Delivered

- Invited lecture at National Disaster Management Authority (NDMA), Ministry of Home Affairs, Govt. of India, New Delhi on **Seismic Hazard & Risk Assessment : Challenges Ahead**, at NDMA meet on 2nd-3rd April March 2007 at Hotel Centaur, New Delhi
- Invited key note lecture on **Methodology for Estimation of Vulnerability of Existing Building Stock in City** at 13th symposium on earthquake engineering held at Department of Earthquake Engineering, IIT, Roorkee from 18-20 December 2006.
- Invited key note lecture on **Estimation of Seismic Velnerability of Existing Buildings of Delhi Municipal Area** at Vigyan Bhavan, New Delhi in First India Diaster Management Congress organised by National Institute of Diaster Management from 29-30 November 2006.
- Key note lecture on **Seismic Rehabilitation of Multistoried Buildings in India** at National conference on High Rise Buildings : Materials & Practices at New Delhi from October 30-31, 2006.
- Delivered and coordinated a one day lecture series on **Earthquake Resistant Design & Construction** for the architects and engineering professionals of Delhi at Consultancy Development Centre (CDC), New Delhi, 2005.
- Delivered invited talk on **Microzonation Studies as impacted by recent earthquake in India** to the invited professionals of Delhi at Consultancy Development Centre (CDC), New Delhi, 2005
- Training masons, contractors and engineers of Himachal Pradesh on **Safe Construction Practices under Seismic Loads** under HP Department of Science & Technology programme on earthquake awareness on regular basis at Dharamsala, Reckong Peo, Shimla, 2004-2005.
- Delivered key-note address on **Seismic Rehabilitation of Heritage Buildings in India – Problems & Prospects** at Fourth International Seminar on 'Structural Analysis of Historical Constructions', November 10-13, 2004, Padova, Italy.
- Delivered several lectures on **Earthquake Resistant Design & Construction; Codes, Seismic Vulnerability of Buildings; Repair & Rehabilitation** at various platforms.
- Delivered series of lectures on **Earthquake Resistant Design & Construction, Seismic Microzonation** to Sr. Level Engineers, Geologists at GSI, Nagpur during Sept. 2003.
- Delivered lecture on **Philosophy of Seismic Design** at a course organised by UNDP for MDDA engineers at Dehradun, 2003.
- Delivered lectures and coordinated the overall course as Course coordinator on **Earthquake Resistant Design & Construction** to DDA & MCD engineers at CBRI from March 17-19, 2004.
- Delivered a concept lecture on Seismic Design Philosophy, repair and retrofitting of structures for Hilly region on 13th December, 2002 at H.P. Secretariat, Shimla in the interaction meet on Prevention and Mitigation of Geological Hazards in Himachal Pradesh organized by State Council for Science, Technology and Environment, Shimla and DST, New Delhi
- Delivered a inaugural lecture on Experimental Investigations on Earthquake Resistance of Reinforced Concrete and Masonry Buildings on concrete day (6th September, 2002) at Department of Civil Engineering, Thapar Institute of Engineering & Technology, Patiala

- Delivered lecture on Concept of Seismic Design and codal provisions in the training Programme on ***Design & Construction of Earthquake Resistant Concrete Structures*** held at Ahmedabad by National Council for Cement & Building Materials from 9-11th July, 2001.
- Delivered a Key note lecture on Earthquake Resistant Design & Construction in the Workshop on Road Construction & Maintenance held at Indira Gandhi Kala Kendra, NOIDA by NOIDA authorities from 22-23rd November, 2001.
- Delivered a lecture on Concept of Seismic Design and Requirements of seismic code provisions for buildings in a special training programme on Design & Construction of Earthquake Resistant Concrete Structures held at India International Centre, New Delhi from 10-12 December, 2001 organized by National Council for Cement & Building Materials.
- Delivered series of lectures to personnel related with oil sectors on Earthquake resistant design and construction. The deliberations were organised by Oil India Safety Directorate and engineers from all over India working in IOCL, BPCL, HPCL, OIL etc. were called. The lectures were held at Mirza Galib auditorium, New Delhi on 8th May, 2001.
- Delivered series of lectures on Earthquake resistant design and construction, philosophy of seismic design and various codal provisions vis-à-vis changing scenario to IOCL Executive Directors, Managers at New Delhi on 26th March, 2001.
- Delivered series of lectures on Recent Trends in Civil Engineering, Computer Softwares for Building problems to engineers of all state departments of Himachal Pradesh (HP), at HP Institute of Public Administration at Shimla during Apr. 24-26,1994.

MERIT DISTINCTIONS & AWARDS

- Topper of college in high school examination
- Prize awarded by the Vice-Chancellor Shri Anand Swaroop for Meritorious studentship
- Second position holder of college in Intermediate
- Recipient of **Silver Medal in B.Tech**.
- Recipient of University Merit Certificate for all four years (i.e. 1982-83, 1983-84, 1984-85, 1985-86) in B.Tech**.**
- Ranked **First** in Structure Group in **M.E.**
- **Merit Assessment Promotion** ***from Scientist-B to Scientist-C*** in three years
- **Merit Assessment Promotion** ***from Scientist-E-I to Scientist-E-II*** in four years

SCHOLARSHIPS

- Merit Scholarship for maintaining scholastic standards in the examination from class 6th to 12th
- Awarded National Merit Scholarship by the Ministry of Education & Social Welfare, Govt. of India in 11th , 12th, and for B.Tech. degree programme
- Awarded GATE Scholarship for completion of ME Programme by University Grants Commission

MEMBERSHIP

- Member, Indian Society of Earthquake Technology
- Member, Institution of Engineers (India)
- Member, Indian Geotechnical Society (India)
- Member, Indian Society of Wind Engineering
- Member, Expert Group on Delhi Seismic Microzonation (DST)
- Member, Expert Group on Preparation of Manual on Seismic Microzonation, EREC, IMD
- Member, Computer Society of India
- Member of Indian Society of Construction Materials & Structures, Roorkee
- Structural Consultant for technical audit & quality assurance for state buildings under Gujarat Emergency Earthquake Reconstruction Programme

Visits Abroad

- Visited International Center for Theoretical Physics (ICTP), Trieste and Department of Earth Sciences University of Trieste, Trieste (Italy) from May 15, 1998 to July 10, 1998, as visiting scientist on Realistic Modeling of Seismic Input for Megacities and Large Urban Areas (UNESCO Project No. 414).

- Visited University of Minho, Portugal to attend Kick-off meeting of International Project on Improving Seismic Resistance of Cultural Heritage Buildings during Feb. 4-10, 2004.
- Visited University of Padova, Italy and Deptt of Culture, Verona, Italy to deliver key-note address at the international conference on 'structural analysis of historical constructions' and to attend Third meeting of International Project on Improving Seismic Resistance of Cultural Heritage Buildings during Nov. 9-16, 2004. A special lecture was given to the engineers of archaeology department at Verona, Italy and a technical visit was made to Reggio Emilia Cathedral to assess rehabilitation work along with experts from Portugal, Spain & Italy.
- Visited Majorca, Spain to attend fourth meeting of International Project on Improving Seismic Resistance of Cultural Heritage Buildings during June. 19-20, 2005. A technical visit was made to Mallorca cathedral to give recommendation on seismic rehabilitation and assess installed monitoring systems along with experts from Portugal, Spain & Italy.

Annexure

Professional Experience

On completion of Master of Engineering in Structural Engineering with special emphasis on structural dynamics from Indian Institute of Science, Bangalore in February 1988, joined CBRI as Fellow (Scientist) on June 14, 1988 and then offered an appointment as Scientist B on March 8, 1989. Since then, I have been working in CBRI and at present holding the post of Scientist EII. On 17th January 2007, assumed the charge of Executive Director, BMTPC, New Delhi.

I have 19 years of R&D experience and committed to provide S&T backup to all areas of building science & technology through continued R&D with quality objectives in applied research, societal based R&D programmes, resource generation, and publications & patents. During the period, I was actively associated as a project leader, principal investigator and as co-investigator/team member in various in-house R&D, sponsored research, consultancy, laboratory-cum-field investigations.

My professional contribution can be classified in ***four discipline of Building Science & Technology*** viz. *Earthquake Engineering; Repair, Rehabilitation & Earthquake Resistant Construction; Computer Aided Structural Analysis & Design; and Distressed Buildings.*

Earthquake Engineering

Backdrop

The assessment of seismic hazards to the built environment is of prime concern to planners and engineers. CBRI is working on several aspects of this problem, with a view to understand, quantify and possibly mitigate the risks to the settlements. Keeping in view the charter of CBRI for Disaster Mitigation, I started working in the area of Earthquake Engineering. The topic of my research for Ph.D. is "***Strong Motion Array Data as Response of Layered Elastic Medium***" which is submitted at Department of Earthquake Engineering, University of Roorkee, Roorkee in March 2000. The synopsis of the thesis is given below:

Synopsis

Earthquake records, both near and far field are studied the world over to estimate possible ground motion due to future earthquakes. Near field records, also called strong motion records provide valuable information for aseismic design of structures. In the past, such records have been analyzed to abstract information on strong motion parameters. The most popular amongst these have been the peak ground acceleration (PGA) and its attenuation pattern. These analyses were initially based on isolated samples recorded from different earthquake events. Stochastic modelling of strong motion and generation of standard response spectra have been other important developments in the early years. With the advent of strong motion arrays (SMA) in various seismically active parts of world, ensembles of records originating from the same events are readily available. This provides an excellent opportunity to understand spatial variability of strong motion, going beyond attenuation of PGA. The popular descriptors of spatial variability have been cross-correlation, cross power spectral density and coherence functions. These have been found in cases where the arrays were designed suitably to record data at sufficiently nearby stations. The question arises how one can benefit from SMA data recorded at arbitrarily located stations at varying distances. Can any additional information on strong motion be extracted using such data? Since stations may be at distances of tens of kilometers, what type of spatial correlation exists with such data? Strong motion data on ground displacements in the near field tend to be highly correlated. What methods are to be used to understand this correlation?

Strong motion records have been used by engineers to mainly compute response spectrum and to develop empirical models for ground motion. Since SMA records are nothing but the response of the earth, can the data be modelled as the response of a finite elastic medium comprising of the part of earth in the immediate vicinity of the recording stations? An attempt is made in this thesis to answer some of these questions. The outline of the thesis is briefly as follows:

Chapter 1 introduces the background for the research work followed by the motivation and scope of the thesis. A brief outline of the work done in subsequent chapters is presented.

Chapter 2 reviews briefly the literature on strong motion data, analysis and modelling. Current methods to study spatial variation are discussed. The limitations in the present understanding are highlighted to identify possible alternate approaches to handle SMA data.

Chapter 3 raises the question whether a new method, for considering all the strong motion data of an array originating from a single event, can be developed. To this end, a new parameter called **Force Centre** for SMA data is introduced. Strong motion accelerograms are discrete point measurements, whereas ground motion is essentially continuous in space.

Thus, any record has to be attributed to a control area surrounding the particular station. The area weighted accelerograms are like time histories of force experienced by a rigid body in that specific area. If all the station data are taken together, one gets the analogy of a rigid body with forces acting in three orthogonal directions at various points. This analogy will be useful, if used in two dimensions when the forces are coplanar. It is shown that when the two horizontal accelerations are considered together as a set of coplanar forces in the X-Y plane, the point of resultant of this set of forces is closely related to the epicentre. Since, the forces thus defined are random in nature, the **Force Centre** is found statistically. The ground accelerations are modelled as Gaussian processes and the locus of the point of application of resultant of the analogous coplanar random forces is obtained. On similar lines, one can find the locus of the **Force Centre** in the X-Z and Y-Z planes. The mathematical analysis is illustrated numerically by finding the locus of the force centre in time for seven SMA data.

The above rigid body approximation of the medium and 2D coplanar force analogy can be seen as an engineering model for a complex dynamic situation. Seen from such a perspective, the question arises whether the method can be improved further to include the elasticity of the soil-rock medium below the strong motion array. **Chapter 4** explores the above possibility. In classical structural dynamic problems, one is interested in finding the response of a known system to a given set of forces, applied at specified locations. In system identification problems, the input (excitation) and the output (response) are known and one is required to find the structural system in terms of its stiffness or other characteristics. The third type of problem is where the system and the responses are known but not the source of excitation. The problem of source determination during strong earthquakes can be seen to belong to this class of problems. It is common practice to determine the focus, epicentre and related parameters from wave propagation principles, with the help of teleseismic records. This is a well-established approach in Seismology. In recent years, large numbers of SMA have been installed in seismic zones around the world to record ground motion near the epicentre. These records are in fact the response of earth as a structural system, to unknown forces acting at unknown locations. Far away from the epicentre the amplitudes are small, the filtering effect is stronger and hence wave forms are recognizable. But in the near field, the ground motion is erratic, the frequency spectrum is continuous and the accelerograms are more like transient vibration records. Thus, if the part of the earth participating in this motion is modelled as a known elastic medium, one can attempt to model the source location and forces generated as an inverse problem in structural dynamics. First, the approach is illustrated with simple problems where the source of the forces is known and exact solutions are possible like in 1-D beam vibration problems. This is further extended to 2-D elastic medium, where surface displacements are known. The work in this chapter is mainly one of numerical experimentation. Well-defined 1-D and 2-D mediums are subjected to known forces at known locations. The responses at a few locations are measured (computed) through analytical or finite element codes. These are used further to demonstrate the application of the proposed source identification method.

In **Chapter 5**, the method of the previous chapter is extended to find an engineering model for the earthquake source. Here, only a 2-D finite elastic model is adopted for the earth medium. The SMA data are treated as measured responses of the medium. Since, the spatial extents involved are large of the order of 100-150 km, FEM methods are too time consuming. Thus, here, a layered medium with specific boundary conditions is used to get non-dimensional closed form solutions. Numerical work has been performed on SMA data of two earthquakes namely Uttarkashi, India (1991) and San Fernando, USA (1971). The engineering model of the source thus obtained is compared with the already available seismological information on the two earthquakes.

The 2-D layered medium model presented in the previous chapter presumes that the surface displacements are available at a few points along a cross section. In practice, since recording stations are located arbitrarily, a 2D section may not contain large number of stations. This has to be circumvented by interpolating the desired displacements from recorded data. It is desirable that such interpolated information utilizes all the array data and not just one or two stations nearer to the considered point. With this in view, a novel, statistical approach is presented in **Chapter 6** to handle SMA data on ground displacements through Principal Component Analysis. With the help of actual SMA data, it is shown that generally four to five principal components and their corresponding eigen vectors are sufficient to describe the variability of ground motion. A method for estimating displacements at points other than stations with instrumental records is presented.

The thesis ends in **Chapter 7** with a summary and a set of conclusions. A few suggestions for further research are also given.

Significant Conclusions

The major conclusions of the present work are as follows.

(i) The **Force Centre** found as the mode of the joint probability density function of the coordinates of the resultant point of the 2-D coplanar area-weighted ground accelerations, is valuable strong motion parameter.

(ii) The principle of minimization of the mean square error leads to a robust approach for estimating the location and magnitude of the buried point sources in elastic media.

(iii) The normal mode approach of structural dynamics can be used to develop an engineering model for the source description of strong earthquakes.

(iv) The geometrical structure of the estimated source is expected to be closely linked with the underlying fault responsible for the earthquake.

(v) SMA displacement data are highly correlated. Principal Component Analysis can be beneficially used to explain this correlation and also to find ground displacements at places without instrumental records.

Earthquake Resistant Construction

I have been working in the area of ***Natural Disaster Reduction*** with reference to buildings and environment. In the process, I have conducted number of studies on earthquake resistant construction of buildings, damage assessment during earthquakes, design and construction of immediate shelter for earthquakes, repair and rehabilitation measures to the structure affected during earthquakes, strong motion seismology studies, experimental investigations on masonry buildings, prefabricated building components etc.

I am actively associated in all these activities in form of sponsored, R & D, consultancy, laboratory and field investigations and damage assessment survey of distressed buildings due to earthquake, remedial measures for their rehabilitation, designs for intermediate shelters for earthquake affected people. Some of the important works undertaken are as follows:

Damage Assessment of Distressed Ordnance Factory during Jabalpur Earthquake of 22nd May, 1997
The extensive damage assessment survey was carried out of important structures housed in the premises of Ordnance factory and their residential area. Also surveyed colonies of M.P. housing board, distressed schools/colleges and health buildings in the Jabalpur and its surrounding area. On-the spot remedial measures for rehabilitation were suggested for some cases.

Rehabilitation and Reconstruction Programme in Earthquake Affected parts of U.P. in Garhwal Region
This project was undertaken after Chamoli earthquake of March 29, 1999 with U.P. Govt. Under this project, damage assessment of distressed buildings was carried out in the Districts of Chamoli & Rudraprayag. The suitable remedial/retrofitting measures were also suggested for their rehabilitation. Designs were supplied for temporary shelters for immediate relief and also for permanent shelters.

Projects on Repair and Re-strengthening of Earthquake Damaged Buildings/Structures in Gujarat
A devastated earthquake struck Gujarat area on 26th Jan, 2001 causing unprecedented loss to life and property. Actively involved in repair, rehabilitation, and construction of some of the affected structures of IOCL. Also, vetted the design basis for IOCL refinery site with regard to earthquake forces. The efficacy of various structural configurations to withstand earthquake forces has been evaluated and innovative structural schemes have been suggested so as to make the structures earthquake resistant.

Behaviour of Masonry Buildings and Prefabricated Building Components under Earthquake Conditions
This project is undertaken to understand the behaviour of masonry buildings and to establish scientifically the economically viable practices for strengthening/retrofitting of masonry buildings against seismic forces. Experimental investigations were carried out on prefabricated RC-plank and joist flooring system and on a full-scale masonry house with RC channel roofing system roofing system. The details are discussed briefly in what follows:

Experimental Investigation of In-plane Diaphragm Action of the CBRI Precast Plank and Joist Flooring System for Earthquake Resistant Construction
The inertia forces generated during earthquake shaking are transmitted through the floor slab to the different lateral load resisting elements such as walls and frames. Thus, the floor slabs provide the critical in-plane action. In the past, numerous studies have been conducted on the in-plane behavior and characteristics of cast-in-situ floors. However, the in-plane diaphragm behaviour of precast floors is still not understood. Most of the seismic design codes either assume floors to be rigid or attempt to make them rigid. But, efforts to make precast system resemble a cast-in-situ system may take away the economic advantage for the precast systems.

Two full-scale specimens of the precast plank and joist floor systems without screed concrete developed by the Central Building Research Institute, Roorkee, were tested under in-plane monotonic loading to study their in-plane diaphragm behaviour. The in-plane stiffness and relative displacements in the slab system and the performance of joints between the precast elements and between the slab and walls was investigated. The specimens were tested in both the orthogonal principal directions, because the presence of joist in the slab along one of the direction makes the stiffness characteristic considerably different in the two directions. A sliding test was performed on one of the specimen to obtain the load at which the floor slides off atop the masonry wall.

The system performed well upto an in-plane load of 230 kN along both the directions, although the first specimen entered the non-linear range at a load of about 145 kN in-plane load. However, the designed base shear for the structure is about 36 kN for seismic zone – V. The CBRI plank and joist system has sufficient in-plane floor diaphragm action to resist the lateral inertia forces that may be generated in it in seismic zone V. The test shows that the CBRI system does provide the adequate in-plane diaphragm action. However, the slab system is vulnerable to sliding from atop the masonry wall under earthquake shaking. This shows the necessity of fastening the slab system to the masonry wall by anchoring the vertical corner reinforcement in the masonry wall with the slab system.

The above slab system was also modeled using the finite element program, NISA. In analytical study, both linear and non-linear analyses were performed using solid and shell elements; elastic perfectly plastic behavior of the concrete was included in the latter. The analytical study showed general agreement with the experimental results.

Behaviour of an Unreinforced Masonry Building with Precast RC Channel Roofing System under Cyclic Loading

Masonry building represents a major part of the building stock in the developing world. They also constitute the old urban nuclei in many cities and towns. Many of these buildings are exposed to potential seismic hazard and vulnerable to even moderate intensity earthquakes. Their performance in the recent earthquakes has been poor and enough devastation in terms of loss of life and property has taken place. Earthquake does not pose any risk, but it is the man-made structures, which pose risk to the life and property. So disaster can only be prevented by building earthquake resistant houses and it can be achieved through experimental as well as analytical studies. As the brick masonry possesses heterogeneous material properties, it is less understood analytically. In India, almost no experiment has been conducted on a full-scale masonry house and now a days as precast roofing system provides a faster construction technique, hence, an experimental study on unreinforced masonry building with precast RC channel roofing system without screed concrete under lateral cyclic loading was undertaken at CBRI. In-plane behaviour of the precast roofing system was also observed. The building also had one opening in each wall. Displacement controlled monotonically increasing cyclic loading was applied to the building at the roof level and the building was subjected to distributed loading along the direction of the precast RC channel units.

During the first phase, the experiment was carried out without seismic strengthening measures with RC Channel roofing system. The results indicated that the maximum deformation was 0.997 mm at the roof level with a failure load of 43.66 kN and distress in the building were also noted. Subsequently, retrofitting and strengthening of the building was carried out as per IS standards. It has been observed during the experiment that the retrofitted building was capable of taking more load (i.e. 58.5 kN) and the failure was restricted above lintel band. However, the slab system was found to be sliding from atop the masonry wall at this load. This shows the necessity of fastening the slab system to the masonry wall. The hystertic loops shows the retrofitted model has more energy dissipation capacity and its strength is enhanced.

Seismic Vulnerability of Buildings for Jabalpur Urban Area

The seismic hazard & risk microzonation (SHRM) offers an effective tool to generate inputs for hazard mitigation planning. In order to evolve an expert system of SHRM, at the behest of Department of Science & Technology, New Delhi, a multi-disciplinary & multi-institutional experiment on microzonation has been conducted for Jabalpur urban area. The study comprises review of the built environment of Jabalpur in the light of guidelines for earthquake resistant construction in India, behaviour of buildings during 1997 earthquake, construction practices being adopted in Jabalpur urban area (pre & post earthquake), building typology, designing of questionnaire for detailed survey of buildings, zoning of the Jabalpur urban area, selection of representative building samples, detailed survey of selected buildings, and creation of database. Subsequently, seismic vulnerability of existing building stock has been estimated quantitatively and qualitatively.

Estimation of Building Vulnerability in Delhi: An approach towards building damage scenario

History of earthquakes in our country demonstrates vulnerability to seismic hazards. The recent past, devastating earthquakes in urban areas in India causing heavy economical losses in terms of loss of life, property, disruption of services and damage to environment have been of great concern; the experiences have prompted to carry out in-depth studies and come out with solutions and policies which will go a long way in minimizing the damages caused by seismic ground motions. In this context, microzonation of urban areas have assumed new dimensions.

Delhi, the capital city of India has a long seismic history and is being affected by local as well as by the Himalayan earthquakes. Delhi is located at the northern end of Aravali mountains and is surrounded by Gangetic alluvium from almost all sides. The Delhi region is having several small tectonic features, which

have been rocking it with minor and major earthquakes since historical times. Qutab Minar's cracks (on its wall) are proof of these past earthquakes. In this regard several authors often mention 1720 earthquake of intensity VIII-IX and the 1803 earthquake of intensity VIII from this region. It has been highlighted time and again that Delhi might face an earthquake of magnitude of 7 in future based on past history of earthquake and the geotechnical setting in the background. Delhi, being the socio-political and economic nerve center of the country, demands much more attention from planners, engineers and decision-makers towards disaster preparedness. Hence, a need is felt to carry out prognostic damage scenario of existing building stocks in urban area, review the existing codal provision of buildings so that appropriate disaster mitigation measures can be evolved.

Experimental Investigation on Earthquake Resistance & Retrofitting Measures of Full-scale Masonry Houses under Quasi-Static Conditions
This project is undertaken to understand the behaviour of masonry buildings and to establish scientifically the economically viable practices for strengthening/retrofitting of masonry buildings against seismic forces through experimental investigation. With this view, the proposed research plan envisages to review the existing state-of-the-art on seismic strengthening and retrofitting technologies, seismic behaviour of masonry buildings and analytical tools on dynamic response of masonry buildings highlighting the gap areas, and to carry out full-scale tests on single room masonry buildings (brick and stone masonry) with or without seismic strengthening measures under quasi-static loading to evaluate effectiveness of various schemes.

Computer Aided Structural Analysis & Design

I worked on Development of PC based computer programs for analysis of 2D and 3D frames, trusses, grids and shear walls. Also worked on development of computer code STRSJT (Finite Element Package for Static and Dynamic Analysis of Plane Stress, Plane Strain and Axisymmetric Problems with elastic or elasto plastic material behaviour and considering the linear and non-linear interface behaviour of joints, fissures, cracks etc. in the continuum.

A notable contribution made by me was to develop pre and post processor of above programs with on line graphic display. The processors are developed in Turbo-C and fully compatible with the softwares.
Involved in development of softwares for design and drafting of RCC members viz. Footing, Column, Beam, and Slab, based on limit state method of design of BIS code.

I take pride in associating myself in the following inhouse developed packages which have been licensed to number of industries:

- SFP (Space Frame Program)
- STRSJT (Finite Element Package)
- SLAB (Design & Drafting of RCC slab)
- BEAM
- FOOTING

I also worked on number of versatile Finite Element packages to cater for analysis & design of complicated structures, some of which are depicted below:

ANSYS (Engineering Analysis System)
A general purpose finite element program developed by Swanson Analysis Systems Inc. The package is installed on Apollo workstation NEXUS-3500. It has been used extensively for modelling and analysing special type of structures and practical problems. The following problems have been solved using ANSYS:

- 3D modelling of "Kedar Kuti" (an emergency shelter for homeless in Uttarkashi Earthquake)
- 2D modelling of "Pyramidal roof" (developed for cyclone prone areas)
- Modelling of Folded plate roof at Govt. Textbook Press, Chandigarh
- Design of Machine Foundation for IOCL, New Delhi
- 3D Modelling of Airborne Synthetic Aperture Radar Antenna developed by Space Application Centre, Ahmedabad (I consider this work as meritorious since this was the first of its kind project on structural analysis of special structure in CBRI. Based on revised design as suggested by CBRI, prototype was made by SAC, Ahmedabad and tested for air worthiness and imageries was obtained).

NISA (Numerically Integrated Element for System Analysis)
A comprehensive and versatile FE software developed by EMRC for analyzing a wide spectrum of problems encountered in engineering mechanics. Solutions were obtained for the followings:

- 2D & 3D modelling for Tehri Dam
- Earthquake response of Himalayan cross section profiles
- Analysis of CBRI developed products viz. EPS doors, IPN Coating, Under reamed Piles
- Analysis of SMC panel as shuttering

Besides this, the other packages used are STAAD, M-STRUDL , AUTODESIGN, FEAST-C, and STARDYNE.

Distressed Buildings

I have been dealing with relevant field problems related with distressed structures. The studies carried out at field and Institute are mainly:

- Monitoring of extent of distress by Non-destructive testing
- Assessment of structural safety of the structure by computer aided analysis and design
- Suggesting suitable remedial cum strengthening measures

The number of important structures have been taken up consultancy assignments and remedial cum strengthening measures were provided to check the extent of distress and revitalising the structure to certain extent.

International Project

Improving Seismic Resistance of Cultural Heritage Buildings under EU-INDIA economic cross cultural programme *(Sponsor: European Commission to India, New Delhi and University of Minho, Guimaraes, Portugal)*

European commission to India recently entrusted a project on *Improving the seismic resistance of the cultural heritage buildings* under EU-India Economic cross cultural programme to Central Building Research Institute (CBRI), Roorkee as a Indian partner. The main objectives of the project are to develop an integrated system of assessment, which can accurately predict the seismic risk of monuments. The system will be based on definition of local seismicity, geometrical and constructional survey and vulnerability analysis and will create a performance library for monuments, to collect, systematically organize and disseminate available knowledge and expertise. The project also aims to define the guidelines and user's manuals for repair, rehabilitation and prevention procedures on monuments in India, not only to upgrade the existing codes but also to define new regulations for application of innovative techniques for Cultural Heritage Buildings (CHBs). The guidelines will be in the form of a widely disseminable document offering strengthening strategies to all professionals, including conservation bodies building owners who intern would disseminate the results obtained by the project to the community.

The above programme will lead to the exchange of expertise between Europe and India, in the field of conservation of CHBs, taking into account the best trade-off between the local constraints in a developing country such as India. Invaluable cultural heritage and own specific building techniques, materials and structural shapes, and the most advanced techniques applicable for building surveying, testing, monitoring, modelling and restoring will be deployed. The restoration techniques and materials for the Indian case study will be defined, taking into account their compatibility with local and ancient construction techniques and materials.

A statewise inventory of Indian Heritage buildings has been compiled and extensive study has been conducted to study Indian literature on heritage buildings with reference to their seismic resistance aspects. Based upon the study, typical CHBs were identified as case study buildings and modus of operandi to study various aspects as site like geological, geotechnical, in-situ testing and structural monitoring was carried out.

Under the project, the damage survey of Qutb has been carried out to find out the vulnerable and damaged portion. In order to carry out material characterization, sonic pulse velocity test, tomographic studies have also been conducted on Qutb Minar. Further, a dynamic monitoring system was installed at Qutb minar in September 2005. The system composed of eight capacitive acceleration transducers positioned in biaxial configuration at different heights, was expanded in order to control other physical quantities meaningful from a structural point of view. The Qutb Minar in New Delhi was in fact selected within the research programme as the Indian case study.

The widening of the existing system is done in Sept. 2006 which consists of positioning of new acceleration transducers (4 in no.), with an increased sensitivity, of temperature and relative humidity sensors (2 in no.)), of displacement transducers (2 in no. for monitoring of the main cracks) and of an anemometer for the evaluation of the velocity and direction of the wind, placed on the top of the Qutb Minar. Such sensors allow i) to extend the evaluation to further physical quantities of structural meaningfulness (i.e. important information may arise from the time evaluation of the distance variation between the edges of significant cracks), ii) to relate them to the environmental conditions, iii) to provide more precise data about the dynamic behaviour of the structure. The results emerged/emerging from the investigation campaign & monitoring are a precious source of information concerning the implementation of calibrated models able to define in a satisfactory way the structural behaviour of the minaret, with particular reference to the seismic response.

The project culminated with the organization of 5th International conference on Structural Analysis of Historical Constructions at New Delhi in which more than 200 delegates participated from all over the world. The conference provided a rare opportunity to get international exposure in the field and it is hoped that it helped in our endeavour of restoring Indian heritage in big way. The main aim of the conference was to promote an exchange of knowledge, information and views among researchers and experts in the field of preservation, protection and restoration of historical constructions, including monuments and urban compounds. A second aim was to discuss case studies in emblematic historical constructions at international level, stressing the diversity and cultural context. The conference covered the main aspects related with preservation of the architectural heritage such as methodology, survey, inspection, non-destructive testing, structural analysis, diagnosis, strengthening techniques with the objective to provide an overview of existing resources useful for the rigorous and scientifically based study of the state of ancient structures. It was a rare event and a unique opportunity to contact practitioners and researchers and to find out about the recent developments in the field of ancient structures.

List of Publications

Books Published

1. Lourenco B. Paulo, Roca, Pere, Modena Claudio, **Agrawal, Shailesh, Structural Analysis of Historical Constructions : Possibilities of Numerical & Experimental Techniques**, Proceedings of the 5th international conference, 6-8 December, 2006, Vol 1-3, Macmillan India Ltd. 2007.
2. **Agrawal, Shailesh Kr**, (2004), A Book on **Earthquake Designer Manual for Practicing Engineers**, CBRI, Roorkee, December 2004.
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Dissimenation CD Published

1. Lourenco B. Paulo, Roca, Pere, Modena Claudio, **Agrawal, Shailesh, The Qutb Minar New Delhi, India & Project Deliverables** under EU-India International Collaboration on *Improving Seismic Resistance of Cultural Heritage Buildings*, Jan 2004-Jan 2007.
2. Lourenco B. Paulo, Roca, Pere, Modena Claudio, **Agrawal, Shailesh, V International Conference on Structural Analysis of Historical Constructions : Possibilities of Numerical and Experimental Techniques** at New Delhi, India, India Habitat Centre, November 6-8, 2006
3. **Seismic Hazard & Risk Information System of Jabalpur Urban Area**, Madhya Pradesh, India, 2005

Papers Published in International/national Journals

1. **Agrawal, Shailesh Kr.**, Chourasia Ajay & Parashar Jalaj, **Performance Evaluation of Seismic Resisting and Retrofitting Measures for Full-scale Brick Masonry Buildings under Earthquake Loads,** Journal of Structural Engineering, April-May 2007.

2. **Agrawal, Shailesh Kr.**, Chawla Jyoti **Seismic hazard Assessment for Delhi,** Current Science, Vol. 91, No. 12, 25 December 2006, pp 1717-1724.

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4. **Agrawal, Shailesh Kr. Generation of Synthetic Accelerogram using Engineering Earthquake Source Model,** International Journal of Structural Stability & Dynamics, Vol. 4 (4), 2004, pp 1-18.

5. **Agrawal Shailesh, Force Centre : A New Strong Motion Parameter**, Journal of Structural Engineering, Vol 31, No. 2, July-September 2004, pp 111-118

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8. *Agrawal Shailesh,* Chourasia Ajay, **'Application of GIS in Assessment of Building Damage Vulnerability Due to Earthquake in Jabalpur Urban Area'**, Special Publication of DST (Seismology Division) on 'Application of GIS IN Earthquake & Landslide Hazard Assessment', Department of Science & Technology, New Delhi, July 2003.

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10. Iyengar, R.N. and **Agrawal, S.K., Earthquake Source Model using Strong Motion Displacement as Response of Finite Elastic Media**, Earth and Planetary Sciences, Indian Academy of Sciences, Vol. 110, No. 1, March 2001, pp-9-24

11. **Agrawal Shailesh,** Chourasia, A. and Parashar Jalaj, **Response of Flyash Ponds under Dynamic Loads**, Indian Geotechnical Journal, July, 2000

12. Iyengar R.N. and **Agrawal, S.K.**, **Statistical Analysis of Ensembles of Strong Motion Records**, Current Science, Vol. 76, No. 5, 10 March 1999, pp 684-687

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17. Chakrabarti, S.C., Mittal Abha, and **Agrawal S.K., Contribution of Infills to the Response of Multistoreyed Frames**, Journal of The Institution of Engineers (India), Civil Engineering Division, Vol 76, November 1995, pp 160-167

Papers Published in International & National Seminars, Symposia and Conferences

1. **Agrawal, Shailesh Kr**., and Chourasia, Ajay, **Assessment of seismic vulnerability of existing building stocks**, National seminar on Role of Urban Local Government in Disaster Management, Regional Centre for Urban & Environmental Studies, Lucknow, Mar. 23-24, 2007.

2. Chourasia, Ajay, **Agrawal, Shailesh Kr**., and Singh S.K. , **Seismic vulnerability analysis of buildings in Delhi**, National seminar on Role of Urban Local Government in Disaster Management, Regional Centre for Urban & Environmental Studies, Lucknow, Mar. 23-24, 2007.

3. **Agrawal Shailesh Kr**., and Chourasia, Ajay, **Estimation of seismic vulnerability of existing buildings of Delhi Municipal Area**, First India Disaster Management Congress, National Institute of Disaster Management, New Delhi, Nov. 29-30, 2006

4. **Agrawal, Shailesh Kr**., and Chourasia, Ajay **Methodology for estimation of vulnerability of existing building stock in a city**, 13th symposium on earthquake engineering, IIT Roorkee, Dec. 18-20, 2006.

5. **Agrawal, Shailesh Kr**., Chourasia, Ajay, and Parashar, J. **Experimental evaluation of earthquake resisting & retrofitting measures of full-scale masonry houses**, 13th symposium on earthquake engineering, IIT Roorkee, Dec. 18-20, 2006.

6. **Agrawal, Shailesh Kr**., Chourasia, Ajay, and Singh, S.K. **Seismic rehabilitation of multistoried buildings in India**, National Conference on High-Rise Buildings: Materials & Practices, Indian Society for Construction Materials & Structures, New Delhi, Oct. 30-31, 2006.

7. **Agrawal, Shailesh Kr**., Chourasia, Ajay, **Seismic vulnerability assessment of buildings in Delhi**, National symposium on structural dynamics, random vibrations & earthquake engineering, IISc Bangalore, July 21-22, 2005.

8. **Agrawal, Shailesh Kr**., Chourasia, Ajay, **Seismic Risk Analysis of Buildings in Jabalpur**, Sym. On Managing Safety: Challenges Ahead, The Institution of Engineers (I), New Delhi, Feb. 14-16, 2005.

9. **Agrawal, Shailesh Kr.**, and Chourasia, Ajay, **Experimental Investigation of Seismic Strengthening & Retrofitting Measures of RC Multistoried Buildings**, Intl. Conference on Advances in Concrete Composites and Structures, Structural Engineering Research Centre, Chennai, Jan. 2005.

10. **Agrawal, Shailesh Kr**., Chourasia, Ajay, and Parashar, J. **Seismic vulnerability analysis of buildings in Jabalpur urban area**, Symposium on Seismic Hazard Analysis & Microzonation, IIT Roorkee, Sept. 23-24, 2005.

11. **Agrawal, Shailesh Kr.**, **Seismic rehabilitation of RCC structures- experiences from Bhuj earthquake**, Indo-Taiwan Joint Workshop on Seismic Evaluation & Retrofit of Buildings, IIT Roorkee, Nov. 22-23, 2004.

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13. **Agrawal, Shailesh Kr**., and Chourasia, Ajay, **Vibration Monitoring of Residential Buildings around Compressor Stations**, Asia-Pacific Conf. on System Integrity & Maintenance, Indian Institute of Technology Kanpur, December 2004.

14. **Agrawal, Shailesh Kr, Seismic rehabilitation of heritage buildings in India – Problems & Prospects**, 4th International Conference on Structural Analysis of Historical Constructions, Nov. 10-13, 2004, organised by University of Padova, Italy, pp 1-14.

15. **Agrawal, Shailesh Kr.,** Chourasia Ajay**, Seismic Vulnerability Analysis of Buildings in Jabalpur Urban Area**, Third International Symposium on New Technologies for Urban Safety of Mega Cities in Asia, Oct. 18-19, 2004, organised by Indian Institute of Technology Kanpur at Agra, pp 5-18.

16. Mathur, V.K., **Agrawal, S.K**., and Chourasia, Ajay, **Microzonation Studies as Impacted by Recent Earthquakes in India,** World Congress on Natural Disaster Mitigation, The Institution of Engineers (I), New Delhi, Feb. 19-22, 2004.

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19. Mathur, V.K., **Agrawal, S.K**., and Chourasia, Ajay, **Demand-Capacity Approach for Seismic Rehabilitation of RC Residential Buildings,** 9th International Conference on Civil & Structural Engineering Computing (CIVIL-COMP 2003), Heriot Watt University, Edinburgh, UK, 2003.

20. **Agrawal, S.K**., and Chourasia, Ajay, **Seismic Rehabilitation of RCC Structures – How Far From Reality?,** Third Sequinquennial International Symposium on Innovative World of Concrete, Indian Concrete Institute, Pune, Sept. 19-21, 2003.

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23. **Agrawal Shailesh Kr.**, Chourasia Ajay and Parashar Jalaj, **Seismic Evaluation & Retrofitting of Existing Building – A Case Study**, 12th Symposium on Earthquake Engineering, 16-18th Dec, 2002, IIT, Roorkee.

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25. **Shailesh Kr. Agrawal, Safety of urban habitat – an approach towards seismic hazard assessment,** Indo-China meet at New Delhi organised by DST, 21-23rd January, 2002, New Delhi

26. Mathur, V. K. and **Shailesh Kr. Agrawal, Safety and Security of Tall Buildings in India,** CTBUH London Conference, Council of Tall Buildings and Urban Habitat (CTBUH), London, December, 2001

27. **Agrawal, Shailesh Kr**. and Vipul Prakash **An Engineering Approach for Earthquake Source Modelling,** International Conference on Seismic Hazard with particular reference to Bhuj Earthquake of January 26, 2001, 3-5 October, 2001, New Delhi, Govt. of India, Deptt. Of Science & Technology, India Meteorological Deptt.

28. **Agrawal, Shailesh Kr.,** Chourasia Ajay, Parashar Jalaj, and Dutta, Jayanta, **Experimental Investigations on Earthquake Resistance and Retrofitting Measures of Masonry Houses – A Review**, International Conference on Civil Engineering (ICCE – 2001), 23-25 July 2001, Indian Institute of Science, Bangalore

29. **Agrawal, S. K., Generation of Synthetic Accelerogram using Engineering Earthquake Source Model**, International conference on Natural Hazards : Mitigation & Management (ICNHMM), March 12-15, 2001, Guru Nanak Dev University, Amritsar

30. **Agrawal, S. K., Estimation of Strong Motion Displacements at Non-Instrumental Locations**, International Conference on Mathematical Modelling, Jan. 29-31, 2001, University of Roorkee, Roorkee

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33. **Agrawal, S.K.**, **Force Centre: A New Concept in SMA Data Analysis**, ASC 2000, Symposium on Seismology, Earthquake Hazard Assessment and Earth Interior Related Topics, Oct 10-12, 2000, Tehran

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Projects Handled/associated

International Project

Improving Seismic Resistance of Cultural Heritage Buildings *(under EU-INDIA economic cross cultural programme, Sponsor: European Commission to India, New Delhi and University of Minho, Guimaraes, Portugal)*

List of In house R & D Projects

1. Experimental Investigation on efficacy of various materials & techniques used for seismic retrofitting of structures under quasi-static conditions, CSIR network project coordinated by CBRI Roorkee, March 2007.
2. Health assessment of multistoried buildings under ambient & forced vibration, CSIR network project coordinated by SERC, Chennai, March 2007
3. Experimental investigation of RC frame buildings under quasi-static condition, Sept. 2004.
4. Lateral Strength of Brick Masonry Buildings with Precast RC Channel and Brick Panel Roofing System under Quasi-Static Testing, March, 2000
5. System Identification of 8 storied steel framed structure under ambient vibration , 1999
6. Behaviour of Buildings & Foundations under Earthquake Conditions , 1998
7. Investigation of Distressed Structures, 1997
8. Computer Aided Optimal Design of Structures, 1996
9. Computer Aided Structural Analysis & Design :
    a. Structural Response of Infilled Frames , 1993
    b. Softwares for Design & Drafting of Reinforced Concrete Members, 1993

List of Sponsored Projects

The sponsored projects so far handled are:

1. Estimation of Seismic Vulnerability of Building in Delhi: An approach towards building damage scenario (Sponsor : DST, New Delhi), 2006.
2. Experimental Investigation of masonry buildings under quasi-static conditions (Sponsor : DST, New Delhi), 2006
3. Health Assessment and quality audit of Health Care Buildings in Uttaranchal (Sponsor: UA Health System Development Project, Dehradun), March 2006.
4. Risk assessment & engineering solutions for buildings along Metro Corridor (Sponsor: International Metro Civil Contractors, New Delhi), March 2005.
5. Structural Integrity Test on 1/5th Scale Model of Core Support Structure (Sponsor : IGCAR, Kalpakkam), 2004
6. Seismic Vulnerability of Building in Jabalpur Urban Area (Sponsor : DST, New Delhi), 2003.
7. Projects on Repair and Re-strengthening of Earthquake Damaged Buildings/Structures in Gujarat (Sponsor : IOCL), 2003
8. Inspection of Plant and Township Buildings for Assessment of Damages caused by Earthquake and Suggesting Remedial Measures (Sponsor : KRIBHCO, Surat), 2003
9. Earthquake Behaviour of Masonry and Prefabricated Buildings (Sponsor : DST, New Delhi), 2002.
10. Development and Repair of RC Near Surface Depositories for Disposal of Radioactive Wastes (Sponsor: BARC, New Delhi), 2002.

11. Investigating Earthquake resistance of Three Multi-storeyed Buildings of Sahara India at Lucknow and Recommending Seismic Retrofitting Measures (Sponsor : SICCL, Lucknow,), 2002
12. Repair & Rehabilitation of earthquake Damaged Health Care Buildings (Sponsor: Govt. of Gujarat), 2002
13. S & T Support for Survey, Repair and Rehabilitation of Buildings of Earthquake Affected Areas of Garhwal Including Establishment of Building Centres (Sponsor : UP, PWD), 1999
14. Reclamation of Abandoned Flyash Ponds for Human Settlements (Sponsor : TIFAC, DST, New Delhi), 1999
15. Engineering and Geotechnical Investigation and Design of Balianala retaining walls (Sponsor : PWD, Nainital), 1998

List of Consultancy Projects

1. Health assessment of RC Chimney & suggesting remedial measures at NTPC, Badarpur (Sponsor: NTPC, Badarpur), Jan. 2004.
2. Vibration monitoring of R&D Centre (CEERI) at Naraina (Sponsor: CEERI Pilani), March 2004.
3. Structural design of School Buildings under Rajiv Gandhi Navodaya Vidhyalaya at Dehradun and Landhora (Sponsor: UP RNN, Lucknow), 2004
4. Advice on seismic design for Gujarat Government Office Buildings, Ahmedabad (Sponsor: SMEC, Ahmedabad), Jan. 2004.
5. Advice on Remedial Measures for Earthquake Damaged Pump Stations & Residential Buildings of SMPL - IOCL in Gujarat (Sponsor: IOCL, Rajkot), Jan. 2004.
6. Distress in Campus School Building at GB Pant University of Agriculture & Technology, Pantnagar (Sponsor: Pantnagar University), July 2004.
7. Third Party Inspection of Road Repaired by Hot Mix Plant at BHEL Hardwar Township (Sponsor: BHEL, Hardwar), Dec. 2004.
8. Third Party Inspection of Water-proofing cement coat on the exterior of buildings at BHEL Hardwar Township (Sponsor: BHEL, Hardwar), Dec. 2004.
9. Third Party Inspection of Grit finish plaster on buildings at BHEL Noida (Sponsor: BHEL, Noida), Mar. 2004.
10. Structural analysis & seismic design of Forest Hospital building at Haldwani (Sponsor: Forest Hospital, Haldwani), March 2004.
11. Remedial measures for distressed Guest House at Neelkanth (Sponsor: UA Tourism, Dehradun), Jan. 2004.
12. Structural design of Office Buildings at Meerut (Sponsor: UP AVP, Lucknow), 2003
13. Structural analysis & seismic design of Mechanical Engineering Block of GB Pant University, Pauri (Sponsor: UPRNN, Lucknow), Jan. 2003.
14. Remedial Measures for Restoration of Damaged Buildings at IOCL, Gandhidham, 2002.
15. Investigation of Damages of IOCL Buildings caused by Earthquake & suggesting measures at IOCL, Rajkot, 2002.
16. Checking of Structural Integrity of Indian Oil Nagar, Noida including pipeline office building at NOIDA, IOCL, New Delhi, 2002.
17. Strengthening measures for repair of PVKL's control room building at Kandla, Jamnagar, 2002.
18. Remedial measures for restoration of damaged buildings of IOCL at Ahmedabad, 2002.
19. Checking of Design Basis with regard to Earthquake forces, IOCL, New Delhi, 2002.

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