



TEACHING RESOURCE FOR STRUCTURAL STEEL DESIGN



Institute for Steel Development and Growth, Kolkata

FOREWORD

The resource material for both teaching and professional use of structural steel, contained in this volume has far-reaching implications for the ongoing as well as upcoming developments of Civil Infrastructure in India. The country has as yet a huge deficiency of infrastructure, but the problem has been receiving increasing attention over the last few decades. The construction industry has a big role to play in reducing the deficiency, and, this brings into focus the construction materials. The two hitherto major structural materials, namely steel and concrete have been at the center stage over the last century, and, despite reservations borne out of sustainability concerns, which are indeed being addressed, no drastic change of scenario seems to be on the cards in the immediate future. In fact, with the buildings growing skywards, and longer span bridges being deployed increasingly, steel will come comparatively into greater demand.

The consumption of steel in structures till recently had been mostly in the railways and the industrial sector. In an overall sense, it can be said that the many advantages of steel as a structural material have been exploited only in a limited way due to some misplaced reasoning, but also clearly, the skillsets for meeting the demands on the deployment of steel in structural engineering do not present a bright scenario. The starting point to allay this situation is to raise the status of education related to the subject of steel structures.

To briefly look at the history, this writer can say from personal knowledge that design of steel structures was taught in bachelor's degree level courses in engineering in the 1950s/60s in many engineering colleges in the country, but the number of teaching units has decreased somewhat with the years. The first Indian text on the subject was produced in the 1960s by two Professors at the University of Roorkee, Dr.A.S.Arya and Dr.J.L.Ajmani, and came as a welcome resource to all concerned - students, teachers as well as design professionals.

In the late 90s, INSDAG was established with the objective of promoting the growth and appropriate usage of steel in civil infrastructure. Besides their many activities towards this objective, awareness creation and dissemination of relevant knowledge about steel and its application were important thrust directions. A flagship activity pursued was the preparation of *Teaching Resource Material* and its dissemination amongst teachers to enable better teaching of the subject. A team consisting of the well-known academic from IIT Madras, Dr. K. Kalyanaraman and his colleagues, in association with Anna University-Chennai

and SERC- Madras, took up this task under the guidance of Dr. R. Narayanan an eminent expert with decades of teaching experience in the UK, US, and India. The resource material was published in 2001. *Limit State Method of Design* was introduced, replacing the *Working State Method*. In the absence of Indian codes not covering the *Limit State Method* during that time, references of foreign codes were incorporated.

A survey carried out by the team about the teaching of steel structures in Engineering Institutions revealed a number of shortcomings. The situation today may perhaps be better but not to a great extent. A major change that has come about since then is that the Indian standard IS 800 has been revised in 2007, and, has now included the *Limit States* approach. This version was incorporated in National Building Code in 2016 (NBC 2016).

This has necessitated the upgrading and revision of the *teaching resource* material published earlier. Clauses of the foreign codes have been replaced by Indian codes. Some chapters have been re-arranged. Wherever relevant, the text relates to IS 800 – 2007/ NBC 2016, though other latest literature has been referred too. There is enhanced coverage of composite construction whose use is becoming more popular. The Chapters contained in this volume have been drafted by Prof. M. K. Madhavan of IIT Hyderabad and his team. The write-up is very well prepared, with good illustrations, and reflects the expertise of the team.

This writer wishes to compliment Director General, Sri P.K.Mishra and his team led by Sri M.M.Ghosh at INSDAG for their efforts in furthering this vitally important thrust area of education to enable upgradation of the design and construction of steel structures, and to thus promote the use of appropriate utilization of steel in the country. Further, this is to record appreciation of the work of Prof. Madhavan and his team for their meticulous efforts. Their work is a great service to the profession. Teachers, students and young professionals should expect to benefit from the addition of this volume.

PREM KRISHNA

Chief Guest



DR. PREM KRISHNA

Born March 1938, Dr. Prem Krishna obtained his early degrees from the University of Roorkee - BE(Civil) in 1959, ME(Structures) in 1961. He obtained his Doctorate from Imperial College, London in 1964. Dr. Prem Krishna joined the faculty in Civil Engineering at the University of Roorkee in 1965 and retired therefrom in 1998. He also had teaching assignments at the University of Illinois, Urbana, USA, and the Imperial College of London, UK (1968-70).

Professor Prem Krishna's specialisations included steel structures, long span cable-supported roofs and bridges, besides wind engineering. He taught the subject of Steel structures at different levels for many years, apart from R&D in the subject.

He started R&D work in the field of Wind Engineering in 1978. His efforts apart from those from other researchers have enabled the Country in achieving greater capacity to tackle industrial wind engineering problems. Dr. Krishna took the initiative to organize the first Asia-Pacific Symposium on Wind Engineering at the University of Roorkee in 1985 – this has since become a four-yearly conference, revolving amongst the AP economies. Professor Prem Krishna along with a few other colleagues set up the Indian Society of Wind Engineering in 1993 to create a platform for interaction between engineers and scientists interested in the area of wind. He served as its first President for seven years. The ISWE organized successfully the 9th International Conference on Wind Engineering at Delhi in 1995.

Important Professional Memberships/Positions

- *Fellow (1987--) and Vice – President (2008-2013) , Indian National Academy of Engineering
- *Founder President, Indian Society of Wind Engineering (1993-2000)
- * President, International Association for Wind Engineering -IAWE (1991-95)
- *Chairman, Research Council, CBRI, Roorkee (2010 – 2017)

Awards / Honours

- *IAWE Presidential Award for career-long contributions to wind engineering, 2021 (only received to date by three persons internationally)
- *Distinguished Alumnus Award, 2012, IIT Roorkee
- * Life-time Achievement Award by the ISWE, celebrating 20 years of its establishment.

Speaker



PROF (DR) MAHENDRAKUMAR MADHAVAN

Mahendrakumar Madhavan is a Professor in the Department of Civil Engineering and the Dean of Alumni and Corporate Relations at IIT Hyderabad. He leads the structural steel research group, focusing on sustainable construction practices globally. With a Ph.D. from the University of Alabama at Birmingham and a master's from the National University of Singapore, he previously worked as a Structural Engineer in the USA. Prof. Madhavan is a Registered Professional Engineer (PE) in Alabama, USA, and a Chartered Structural Engineer (CEng), UK.

His research includes physical testing of structural systems, numerical modeling, and innovative design methods for steel-intensive structures. A prolific author with 70+ international publications, he serves on editorial boards and chairs committees of the American Society of Civil Engineers (ASCE). A Fellow of ASCE and ICE, London, he is the first Indian Fellow of ASCE's Structural Engineering Institute.

INTRODUCTION TO THE TEACHING RESOURCE

The idea for this Project was born out of a lunchtime conversation this writer had with Mr. R.K. Prasannan, Development Commissioner for Iron and Steel, and Mr. M.S. Ramanujam, the Regional Development Commissioner (Ministry of Steel) in late 1998. It became obvious that the low usage of Structural Steel in India was largely attributable to skills shortage in the effective use of this material in construction. The urgent need to reorient the education of student engineers and to retrain the current stock of practising professionals (based on the current state-of-the-art) was clearly identified. It was noted that the British Steel industry, when faced with similar problems of skills shortage in the 1980's, solved it by generating a Teaching Resource to enhance the teaching quality in the Universities, under the expert direction of Professor Patrick Dowling. The present success of the British Steel Industry is generally regarded as a direct consequence.

An Expert Team led by Professor Rangachari Narayanan, Retired Head of the Education and Publications Division, The Steel Construction Institute, England, working in co-operation with Professor V. Kalyanaraman, (Head of the Department of Civil Engineering at IIT Madras), Professor A.R. Santha Kumar, (Dean, Anna University, Chennai) and Dr. S.Seetharaman (Assistant Director, Structural Engineering Research Centre, Chennai), representing Dr. T.V.S.R. Appa Rao, (Director, SERC, Chennai) was entrusted with the task of compiling this Teaching Resource which could be used for the purposes outlined above. Dr. S.R. Mediratta, the Director General of the newly formed Institute for Steel development and Growth (INSDAG) was requested to act as the facilitator. The Team commenced its work in August 1999 with the added strength of three young experts, Dr. Satish Kumar (IIT, Madras), Mr. Arul Jayachandran (SERC) and Mr. R. Senthil (Anna University). Rapid progress of the work was made possible by the willing support given by the young Project Associates, Miss R. S. Priyadarsini, Mr. S. Sambasiva Rao, Mr. G. Venkateswara Rao, Mr. Indranil Banerjee and Miss P. Usha who joined the Team.

Till the late 1960's, Structural Steel Design was based on the "Working Stress Method" all over the world. The more modern "Limit State Design" approach - developed in the early 1970's - is technologically sound and results in significant economy in the completed structures. This is of particular advantage as Steel is a reusable material and is environment-friendly. Moreover, modern Steel Mills have made substantial improvements in the quality of finished steel in recent years. To derive the fullest benefits from this improved steel, the Codes of Practice in the use of Steel will need updating. Unfortunately, the Bureau of Indian Standards has not revised the Indian Codes for Steel Construction to conform to Limit State methods, unlike the Codes for the Structural Use of Concrete. This makes the use of steel in construction an uneconomic proposition. Professor Kalyanaraman of the Indian Institute of Technology Madras had very kindly volunteered to provide the necessary leadership for revising the Codes to modern Standards and the work is in progress.

There are literally hundreds of University Institutions in India teaching courses in Structural Engineering. Being autonomous, all the Universities formulate their own syllabi. The depth and breadth of coverage in Structural Steel Design - as in other subjects - does vary between Institutions. In view of the obsolescence in the teaching of Structural Steel Design referred to in the previous paragraph, all the Universities and

Colleges would need support and assistance to varying degrees in their need for state-of-the-art training material. Retraining of Engineers who are currently employed in Industry and in Design Offices is an added challenge. The urgent need for an up-to-date Teaching Resource, as a reference material for the teachers and trainers, is obvious.

A high-priority task was to upgrade and widen the academic base of Indian University teachers in the subject of Structural Steel Design to the levels prevailing in the Western World, so that they can teach this subject confidently at the Undergraduate Level. With the availability of this support, many motivated young academics would be able to advance even further and develop an infectious enthusiasm for the subject among the students.

In planning this task, the Expert Team identified the following challenges and opportunities.

- Most of the teachers for whom this Resource is intended, have not had ANY education in up-to-date Construction Technology. This situation is not different even in high profile Colleges. The I.S. Codes and the present level of University teaching are out of date by 25 years. Many Masters Degree courses in Structural Engineering (even those organized under Quality Improvement Programmes funded by AICTE) do not include any in-depth coverage of Structural Stability and similar subjects, which are vital for the understanding of behaviour of Steel Structures.
- An overwhelming majority of Colleges do not have any worthwhile collection of up-to-date books, largely on account of their high costs and diminishing budgets. Even if they wanted to, there is no easy way for the Teachers to refer to modern books and enhance their level of competence. (This is not an indictment of the Teachers; nevertheless this leads to unsatisfactory teaching and subsequently to incompetence in the field practice of Structural Engineering.)
- Teachers in most Colleges are overworked. (Many Colleges routinely assign about 25 hours of teaching to very young teachers. Assuming that it takes 2 hours to prepare a lecture and to mark the scripts, they are expected to work 75 hours a week, EVERY WEEK!). The ready availability of a well-researched set of notes will be very helpful to them.
- Discussions with a selection of Engineering Teachers revealed that Structural Steel as a subject is not very popular among senior academics and young and inexperienced Teachers in their early part of their career are forced to teach it.
- The level of research activity in Structural Steel is abysmally low. Only a handful of people are engaged in research and generation of new knowledge. There are – indeed – few Structural Steel-related patents taken out by any Engineer or Scientist working in India.
- There are very few refresher or in-career courses in Structural Steel Design.

Notwithstanding these limitations, the Team felt that they had an opportunity to set things right. With the participation of the best known centres of expertise in India, the

Expert team - with a total relevant experience of over 150 years gained in this country and abroad - is perhaps the best that can be assembled in this country. Some very bright young men and women, with excellent potential to become future leaders in the profession, were recruited as Project Associates. The Team had access to all the relevant books and journals. With these favourable conditions, the Team set out to assemble an up-to-date and technically complete material, which could be used to cover the needs of a typical undergraduate course. We obtained the syllabi from most of the Indian Universities, which helped to guide us to formulate the contents of the Resource. The material generated is user-friendly and does not demand references to many other books, - not available (in India) to the teachers. University Teachers and panels of experts reviewed the drafts before finalisation. Drafts were also published in the web site of INSDAG in instalments to enable University Teachers and other interested persons to review them. The Members of the Expert team hope that the Resource material generated with so much effort and care would help to eliminate an important gap in the training of Structural Engineers in the area of Structural Steel design. Suggestions to improve the contents and constructive comments and criticisms will be gratefully received by the Team.

An exciting aspect of the project was to discover the number of people in India with a lively interest in the developments in the subject. The writer values the many new friends he has made in the course of directing the Project and is grateful to the many academics - too numerous to mention - who devoted their time to review and improve the Project. For those who donated their time so generously to the Project, as well as those who funded it, there could be no greater reward for their efforts than to see the benefits accruing to the next generation of Structural Engineers.

Rangachari Narayanan

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Speaker



PROF (DR) S R SATISHKUMAR

Dr. S.R. Satish Kumar earned his BE (Civil) from the College of Engineering, Pune, in 1987, followed by an MTech in Structural Engineering from IIT Bombay in 1992, and a Doctor of Engineering from Nagoya University, Japan, in 1996. He worked as a research engineer at NKK Corporation, Japan, pioneering seismic design and pseudo-dynamic testing of steel bridge piers for the Japanese Ministry of Construction.

He joined IIT Madras in 1998 and is currently a Professor and Head of the Structural Engineering Laboratory, Department of Civil Engineering. Dr. Satish Kumar teaches Design of Steel Structures, Structural Dynamics, and Earthquake-Resistant Design, and conducts training courses for faculty and consultants.

His research focuses on seismic design and testing, with numerous publications in national and international journals. He has co-authored Teaching Resources for the Design of Steel Structures and contributed significantly to the revision of the Indian Code IS 800.

Speaker



PROF (DR) DIPTI RANJAN SAHOO

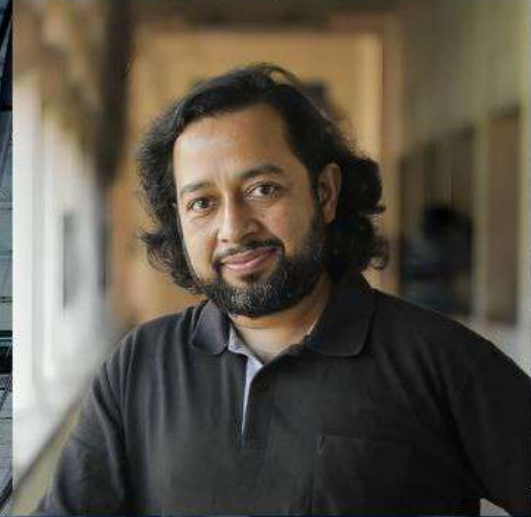
Prof. Dipti Ranjan Sahoo is the Dean (Infrastructure) and Professor in the Department of Civil Engineering at IIT Delhi. He earned his Ph.D. in Civil Engineering from IIT Kanpur in 2008, specializing in earthquake-resistant design, and held academic positions at IIT Bhubaneswar and the University of Texas at Arlington, USA, before joining IIT Delhi in 2010.

His research focuses on earthquake design, hybrid simulation, seismic fragility, passive vibration control, steel-concrete composites, and structural fire engineering. He has over 250 publications, seven patents on earthquake vibration control devices, and has authored the textbook Indeterminate Structural Analysis. He has supervised 150+ students, including 15 Ph.D. candidates.

A recipient of the Shanti Swarup Bhatnagar Prize (2022), Prof. Sahoo is the first Civil Engineer to win this honor in nearly six decades. He is an elected Fellow of INAE, ICE (UK), IEI, and ISET, and has received multiple awards, including the INAE Young Engineer Award and SERB Young Scientist Award.

He serves on editorial boards of leading journals, including the International Journal of Steel Structures, and has contributed as an expert to national projects on seismic compliance and prefab structures. Prof. Sahoo has also coordinated workshops and courses under GIAN, SPARC, and TEQIP schemes.

Speaker



PROF (DR) SIDDHARTHA GHOSH

Prof. Siddhartha Ghosh is a distinguished academic in the Department of Civil Engineering at IIT Bombay, where he serves as the JK & MJ Mehta Chair Professor and was Dean (Educational Outreach). He earned his Ph.D. from the University of Michigan, USA, and holds MTech and BE degrees from IIT Kanpur and Jadavpur University, respectively.

His research focuses on structural safety, resilience, risk and reliability, life-cycle management, and the design of lightweight structures. Prof. Ghosh has contributed significantly to the development of structural steel and tensile membrane structures in India, authoring numerous publications and leading projects such as the development of Osdag, a software for structural steel design.

An active member of BIS code committees and several international organizations, he has led projects on sustainable rural connectivity and infrastructure resilience, with support from global and national sponsors. Prof. Ghosh also serves on various advisory committees, including the Ministry of Steel and the Atomic Energy Regulatory Board.

Speaker & COORDINATOR



PROF (DR) P C ASHWIN KUMAR

Dr. P. C. Ashwin Kumar serves as an Assistant Professor in the Department of Earthquake Engineering at the Indian Institute of Technology (IIT) Roorkee. He holds a Master's degree from IIT Madras and a PhD from IIT Delhi. His expertise includes steel structure design, passive energy dissipation, retrofitting of deficient structures, fracture mechanics, and composite structures.

Before joining IIT Roorkee, Dr. Kumar worked with WSP India and EDR Consultancy Pvt. Ltd., designing steel and RCC buildings for projects in India and the Middle East. He has published extensively on topics such as steel braced frames, fracture mechanics of Indian structural steel, retrofitting RCC frames with conventional braces, and post-installed anchors for steel retrofitting.

Dr. Kumar supervises nine PhD students working on diverse topics related to steel structures. He is the Secretary of the Indian Society of Earthquake Technology (ISET) and previously served as the Associate Dean of Infrastructure at IIT Roorkee for three and a half years. Additionally, he initiated the Structural Steel Education Forum (SSEF) at IIT Roorkee to promote education in steel structure design.

Speaker & COORDINATOR



MR. MANAS M GHOSH

MANAS M GHOSH obtained his Bachelors in Civil Engineering from Jadavpur University, Kolkata in 1986. He joined Simon Carves India Limited (a premier Turnkey Contractors and Engineering Consultancy firm) in the Structural Engineering design department. There he was involved in designing Steel structures for steel plants and chemical plants. Simultaneously he embarked on further studies and completed his Masters in Business Administration (MBA) in Finance from Jadavpur University in 1990 in their 3 years evening course.

Mr Ghosh then joined Nicco Corporation Limited (Project division) in 1991. He then shifted to Tata Korf Engineering Services Limited (a company promoted by Tata Steel) in mid-1993 in Structural Engineering Designs. He joined Institute For Steel Development & Growth (INSDAG) in December 2002 and is involved in Structural Steel Design and project execution. He is retained as a Consultant in INSDAG after his superannuation.

Mr. Ghosh is a Chartered Engineer and a Member of The Institute of Engineers (India). He is also the Fellow of Indian Institute of Structural Engineers (IASTRUCTE), New Delhi.

INTRODUCTION TO LIMIT STATES

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