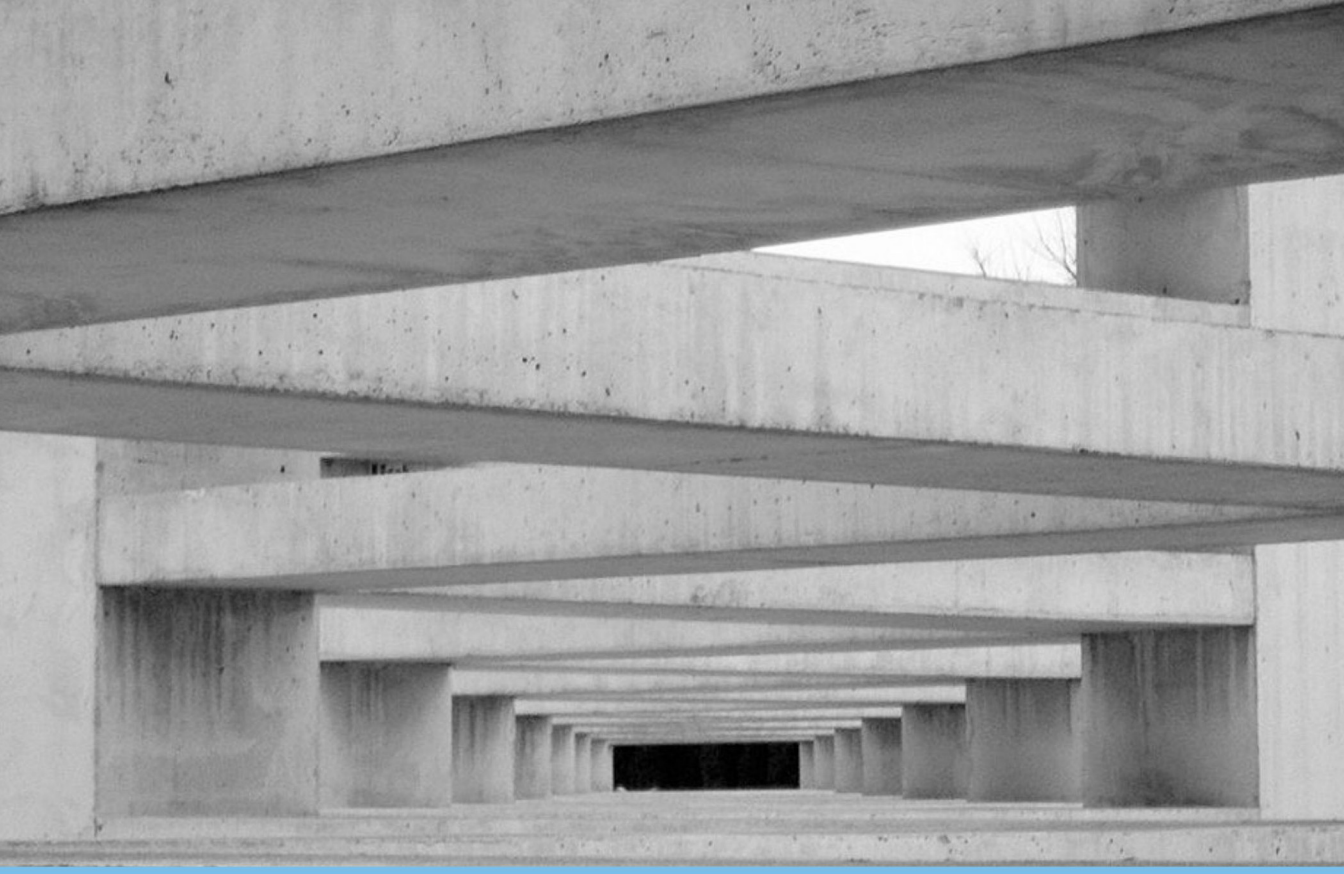

Limit State Design of Concrete Structures

Ramchandra
Virendra Gehlot

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LIMIT STATE DESIGN OF
CONCRETE STRUCTURES

(As per IS: 456-2000)

A Text-Book of Reinforced Concrete Structures (S.I. System of units)

[For under-graduate and post-graduate students]

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The author highly acknowledges Bureaue of the Indian Standards for reproducing in this book some of the 'Tables and Clauses' from the Indian Standard Specifications.

It is desirable that for complete detail, reference be made to the latest versions of the Standards which are available from Indian Standards Institution, Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi-1, or from its branch offices at Bombay, Calcutta, Kanpur and Madras.

SYSTEM INTERNATIONAL d' UNITES (SI-System of Units)

In order to avoid the conversion of results obtained by engineers working with the foot-pound second system (gravitational) of units in terms of centimetre-gram second absolute system of units used by the scientists, a need of common system of units was realised. The General Conference on Weights and Measures held at Paris is 1960 finalised the System International *d*' Unites (SI). It is an absolute system of units. The mass is considered as fundamental unit and not the force. ISI has included a comment of transition in IS 3616-1966. 'Recommendation on the International System (SI) Units' that this system has begun to replace older systems of units in several branches of science and technology. The SI is a universal system of units and it has been adopted in France as a legal system and it is likely to become common in many countries. SI Units have the following six basic units.

1. Units of length (metre, m)

The length equal to 1,650,763.73 wave lengths, in vacuum, of the radiation corresponding to the transition between $2p^{10}$ and $5d^5$ levels of the krypton n atom of mass 86 is known as *one metre*.

Linear distances are expressed in metres and multiples or division of 10^3 of metres (i.e., one kilo-meter (km) = 10^3 m, one metre (m) = 1m, and one millimetre (mm) = 10^{-3} m.

2. Unit of mass (kilogram, kg)

The mass of planium-iridium cylinder deposited at the International Bureau of Weights and Measures and declared as the international prototype of the kilogram by the First General Conference of Weights and Measures is called as *one kilogram*.

3. Units of time (second, s)

1131, 566, 925, 974.7 of the length of the tropical year for 1900, the year commending at 1200 hours universal time on the first day of January, 1900 is termed as *one second*.

Units of electric current (Ampere, A)

The constant current which flows in two parallel straight conductors of infinite length of negligible circular cross-section and placed at a distance of one metre from each other in vacuum producing a force 2 x 10^{-7} Newtons per metre length between the conductors is defined as *one ampere*.

Unit of thermo-dynamic temperature (degree Kelvin, °K)

The degree interval of the thermo-dynamic scale on which the temperature of triple point of water is 273.16 degrees, is known as *one degree Kelvin*.

For temperatures, conventional degrees centigrade (°C) may be used, since, temperature changes are concerned rather than absolute temperatures.

Units of luminous intensity (candela, cd)

One sixtieth of luminous intensity normally emitted by one centimetre square of integral radiator (black body) at the temperature of solidification of platinum is called as *one candela*.

The SI units make the use of multiples and sub-multiples 1000 *times* or 1/1000 *times* the unit quantity and in powers of 10^3 (*kilo*) or 10^{-3} (*milli*) in respect of still larger and smaller quantities respectively. The length are measured usually in kilometre (1 km = 1000 m), metre and millimetre (1 mm = 10^{-3} m). The symbols of units are not to be suffixed with "*s*" for plural.

The force is a derived quantity and physical law connecting the quantity of the fundamental quantities or previously obtained derived quantities is force = mass x acceleration (i.e., 1 m per sec^2) in a unit mass of 1 kg. Its unit is Newton (N). Though, the Newton is a small unit, a still larger unit kN may be used. The intensity of force (viz., stress) due to 1 Newton over a unit area of one metre square is known as one *pascal*. It is denoted by symbol, Pa (1 Pa = 1 N/m^2 and 10^6. Pa = 1 N/mm^2, viz., 1 MPa = 1 N/mm^2).

The unit of force, (the Newton N), is the force required to give unit acceleration (1m/sec^2) to unit mass (1 kg).

In terms of Newtons, the common force units in the foot-pound-second system (with g = 9.81 m/sec^2) are [1 lb-wt = 4.45 Newtons (N), 1 ton-wt = 9.96 x 10^3 Newtons (N)].

It is used for the external loads and the internal forces such as shear force. Bending moment and toques are expressed in Newton-metres (N-m).

Stress is also an important unit. In the foot-pound system, stresses are commonly expressed in lb-wt/in^2 and $tons/in^2$. In the SI system, there take the values [1 lb-wt/in^2 = 6.89 x 10^3 N/m^2 = 6.89 kN/m^2 and 1 ton-wt/in^2 = 15.42 x 106 N/m^2 = 15.42 Mn/m^2].

Yield stresses of the common metallic materials are in the range [200 MN/m^2 to 750 MN/m^2]. Young's modules for steel,

$E_{STEEL} = 30 \times 10^6$ lbs–wt/in^2 = 207 gN/m^2 = 2.07×10^5 N/mm^2

Working and yield stresses are expressed in MN/m^2 or N/mm^2.

SI system of units have many advantages. The units are very handy. The burden of non-decimal coefficients in foot-pound second system is avoided. It has relatively large main units in contrast to centimetre-gram-second system. At the same time, it is closely related to centimetre-gram-second system of units. In practice, it results in perfectly reasonable number when the value of g = 10 m/sec^2 is used instead of 9.806 m/sec^2.

In general, decimal multiples in the SI-system are taken in units of 103. For prefixes, followings are mostly used [(kilo k 10^3), (mega M 10^6) and (giga G 10^9)].

In addition to six basic units, following basic SI units are also relevant.

Force	Newton (N)	kg-m/sec^2
Work, energy	Joule (J)	kg.m^2/sec^2 = N-m
Power	Watt (W)	kg.m^2/sec^3 = J/se
Frequency	Hertz (Hz)	cycle per second

References

1. Professor V.S. Mokashi, Visvesvaraya Regional College of Engineering, Nagpur in his paper titled as International System (SI) Units and their Application to Engineering, India, Vol. 19, March 1970 has highlighted the advantages and discussed SI units. A reference has been made to this paper.
2. John, Case and A.H. Chilver, Strength of Materials and Structures' An Introduction to the Mechanics of Solids and Structures, Published by ELBS (English Language Book Society Edward Arnold), 1971.

PREFACE (Third Edition)

On receiving suggestions from some of the students and few of the friends, teaching this subject in the various engineering institutions, the words 'Elements of' have been deleted from the title of this book. Where as, the remaining title 'Limit State Design of Concrete Structures' has been retained in this third edition. It is also essential to mention Concrete Structures as a new book with title 'Limit State of Design of Steel Structures' is likely to come soon.

Many terms, related with this subject have been defined additionally with more emphasis keeping in view, the draft for approval for IS: 800 (revised code of practice, which one is yet to be issued) and terms (e.g., Actions for loads and load effects for the internal forces) which have been introduced by the Euro-codes, have been associated with the text of this book.

Inspite of careful reading of the manuscript, typographical and computational errors might have left in. The authors shall be highly obliged to all those who will point-out such errors.

Authors are thankful to their colleagues and friends for their liking and sending useful suggestions. Authors are also thankful to publishers of this book M/s Scientific Publishers (India), Jodhpur, for preparing make-up and printing this book in the latest technology and bringing out the same in a nice get-up and short-time. Authors express sincere thanks for Shri Rajesh Ojha for his efforts to bring third edition also in short times.

Suggestions from the students and affectionate teachers of various. Institutions shall be highly appreciated

Ramchandra
Virendra Gehlot

PREFACE (First Edition)

In this book, the author with his long teaching experience in the subject has made efforts to present the subject matter in a way which lays emphasis on the fundamentals, keeping in view the difficulties experienced by the students. Every basic concept, fundamental method, equation or theory of interest to the student of reinforced concrete design has been described in a simplified manner. S.I. system of units and new code IS: 456-1978 have been used entirely in the text. The various provisions of IS: 456-1978 and concepts of 'Limit State Design' have been nicely introduced to design the reinforced concrete structures and the structural members. This book will be found useful to undergraduate and post-graduate students.

The complete text in this book has been divided in **seven parts**. [Part I: Introduction, Part II: Loads and stresses, Part III: Design of beams (singly reinforced, doubly reinforced, flanged and continuous), Part IV: Design of slabs (spanning in one and two directions, circular and flat slabs), Part V: Design of columns, (Short and long), Part VI: Design of footings, (independent and combined) and Part VII: Design of other concrete structures (stairs, retaining walls, domes and lintels).

A number of design problems has been solved to illustrate the theory and practice. The chapters have been so arranged that it facilitates self-understanding of the subject during the study. In addition to the limit state of serviceability has also been described in detail. The readers will appreciate the presentation of the concept of redistribution of moments.

Inspite of careful scrutiny of the manuscript, it is possible that some computational errors are still left. The author shall be highly obliged to all those who will bring these errors in his notice.

The author is thankful to his colleagues for their suggestions, to the publishers M/s Standard Book House (Shri Rajinder Kumar Jain and Shri Sandeep Jain) for composing this book by latest technology of laser print and for bringing out the same in a ice get up and short time and to Shri Kanhaiya Lal for preparing the drawings of the author's this and various other books.

Suggestions from the students and affectionate teachers of various Institutions shall be highly appreciately.

September, 1, 1990 **DR. RAMCHANDRA**

CONTENTS

PART - VII
DESIGN OF OTHER CONCRETE STRUCTURES