at a distance of  $0.416 x_0$  (which has been rounded off to  $0.42 x_0$  in the code) from the extreme compression fibre; and the total force of compression is  $0.36 f_{ck} bx_0$ . The lever arm, that is, the distance between the centroid of compressive force and centroid of tensile force is equal to  $(d-0.416 x_0)$ . Hence the upper limit for the moment of resistance of a singly reinforced rectangular section is given by the following equation:

$$M_{\text{u,lim}} = 0.36 f_{\text{ck}} bx_{\text{u,max}} \times (d - 0.416 x_{\text{u,max}})$$

Substituting for  $x_{u,max}$  from Table B and transposing  $f_{ck}$   $bd^2$ , we get the values of the limiting moment of resistance factors for singly reinforced rectangular beams and slabs. These values are given in Table C. The tensile reinforcement percentage,  $p_{t,lim}$  corresponding to the limiting moment of resistance is obtained by equating the forces of tension and compression.

$$p_{t,\text{lim}} bd (0.87 f_y) = 0.36 f_{ck} bx_{u,\text{max}}$$

Substituting for  $x_{0,\text{max}}$  from Table B, we get the values of  $p_{1,\text{lim}}$   $f_y/f_{ck}$  as given in Table C.

TABLE C LIMITING MOMENT OF RESISTANCE AND REINFORCEMENT INDEX FOR SINGLY REINFORCED RECTANGULAR SECTIONS (Clause 2.3)						
fy. N/mm*	250	415	500			
Mostim for bd*	0-149	<b>⊍</b> 138	0.133			
Pt-lim fy	21-97	19-82	18.87			

The values of the limiting moment of resistance factor  $M_{\odot}/bd^3$  for different grades of concrete and steel are given in Table D. The corresponding percentages of reinforcements are given in Table E. These are the maximum permissible percentages for singly reinforced sections.

# TABLE D LIMITING MOMENT OF RESISTANCE FACTOR M<sub>u,lim</sub>/bd\*, N/mm\* FOR SINGLY REINFORCED RECTANGULAR SECTIONS (Clause 2.3)

fy. N/mm <sup>x</sup>			
250	415	500	
2-24	2.07	2:00	
3-73 4-47	3·45 4·14	3.33	
	250 2-24 2-98 3-73	250 415 2-24 2-07 2-98 2-76 3-73 3-45	

TABLE E MAXIMUM PERCENTAGE OF TENSILE REINFORCEMENT Pt. Illm FOR SINGLY REINFORCED RECTANGULAR

(Clause 2.3)

fek, N/mm*	fy, N/mm <sup>a</sup>			
	250	415	500	
15	1-32	0-72	0.57	
15 20 25 30	2:20	1-19 1-43	0-94 1-13	

#### 2.3.1 Under-Reinforced Sections

Under-reinforced section means a singly reinforced section with reinforcement percentage not exceeding the appropriate value given in Table E. For such sections, the depth of neutral axis  $x_u$  will be smaller than  $x_{u,\max}$ . The strain in steel at the limit state of collapse will, therefore, be more than  $\frac{0.87 \, f_y}{E_s} + 0.002$  and, the design stress in steel will be  $0.87 \, f_y$ . The depth of neutral axis is obtained by equating the forces of tension and compression.

$$\frac{p_t \, bd}{100} \, (0.87 \, f_y) = 0.36 \, f_{ek} \, b \, x_u$$

$$\frac{x_u}{d} = \left(\frac{p_t}{100}\right) \, \frac{0.87 \, f_y}{0.36 \, f_{ek}}$$

The moment of resistance of the section is equal to the product of the tensile force and the lever arm.

$$M_{0} = \frac{p_{1}}{100} \frac{bd}{(0.87 f_{2})} (d - 0.416 x_{0})$$

$$= 0.87 f_{2} \left(\frac{p_{1}}{100}\right) \left(1 - 0.416 \frac{x_{0}}{d}\right) bd^{2}$$
Substituting for  $\frac{x_{0}}{d}$  we get

$$M_a = 0.87 f_r \left(\frac{P_1}{100}\right) \times \left[1 - 1.005 \frac{f_r}{f_{ch}} \left(\frac{P_1}{100}\right)\right] b d^a$$

2.3.1.1 Charts 1 to 18 have been prepared by assigning different values to  $M_u/b$  and plotting d versus  $p_t$ . The moment values in the charts are in units of kN.m per metre width. Charts are given for three grades of steel and two grades of concrete, namely M 15 and M 20, which are most commonly used for flexural members. Tables 1 to 4 cover a wider range, that is, five values of  $f_r$  and four grades of concrete up to M 30. In these tables, the values of percentage of reinforcement  $p_t$  have been tabulated against  $M_u/bd^2$ .

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Subramanya K N,Hui-Ming Wee,Mario Orlando Oliveira

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Advances in Civil Engineering and Infrastructural Development Laxmikant Madanmanohar Gupta, Maya Rajnarayan Ray, Pawan Kumar Labhasetwar, 2020-11-13 This book comprises selected proceedings of the International Conference on Recent Advancements in Civil Engineering and Infrastructural Developments ICRACEID 2019 The contents are broadly divided into five areas i smart transportation with urban planning ii clean energy and environment iii water distribution and waste management iv smart materials and structures and v disaster management. The book aims to provide solutions to global challenges using innovative and emerging technologies covering various fields of civil engineering The major topics covered include urban planning transportation water distribution waste management disaster management environmental pollution and control environmental impact assessment application of GIS and remote sensing and structural analysis and design Given the range of topics discussed the book will be beneficial for students researchers as well industry professionals Advances in Civil Engineering Rao Martand Singh, K. P. Sudheer, Babu Kurian, 2020-09-21 This volume comprises select peer reviewed papers presented at the international conference Advanced Research and Innovations in Civil Engineering ARICE 2019 It brings together a wide variety of innovative topics and current developments in various branches of civil engineering Some of the major topics covered include structural engineering water resources engineering transportation engineering geotechnical engineering environmental engineering and remote sensing The book also looks at emerging topics such as green building technologies zero energy buildings smart materials and intelligent transportation systems Given its contents the book will prove useful to students researchers and professionals working in the field of civil 2024-25SSC JE Civil Engineering YCT Expert Team , 2024 25SSC JE Civil Engineering Study Material engineering

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Rao, K. Ramanjaneyulu, 2018-08-01 This book is a collection of select papers presented at the Tenth Structural Engineering Convention 2016 SEC 2016 It comprises plenary invited and contributory papers covering numerous applications from a wide spectrum of areas related to structural engineering It presents contributions by academics researchers and practicing structural engineers addressing analysis and design of concrete and steel structures computational structural mechanics new building materials for sustainable construction mitigation of structures against natural hazards structural health monitoring wind and earthquake engineering vibration control and smart structures condition assessment and performance evaluation repair rehabilitation and retrofit of structures Also covering advances in construction techniques practices behavior of structures under blast impact loading fatigue and fracture composite materials and structures and structures for non conventional energy wind and solar it will serve as a valuable resource for researchers students and practicing engineers Reinforced Concrete Design Santanu Bhanja, 2024-06-26 Reinforced Concrete Design RC is performed mostly by the limit state method throughout the world This book covers the fundamental concepts and principles of RC design developing the topics from the basic theories and assumptions Building upon the possible revisions to the mother code of concrete in India IS 456 2000 it explains the RC design provisions of IRC 112 2020 which are in line with international standards In addition to strength design serviceability and ductility design are also covered Features Highlights the basic philosophy of RC design and behaviour of the sections up to and beyond limit state Clarifies limit state theory from the basic assumptions provided in relevant Indian and international standards IS 456 IRC 112 and Eurocode 2 Includes design aids or tools for standard and high strength concrete up to M90 grade as per different codes of practice Explains the concept of ductility of reinforced concrete sections subjected to flexure with or without axial loads from fundamental principles Covers fundamentals on serviceability requirements in reinforced concrete structures Illustrates the design methodology of shear walls and includes design aids developed using basic principles as per relevant codes of practice Explains reinforced concrete design provisions as per latest national and international standards and these are expected to be in line with those to be included in the forthcoming revision of IS 456 This book is aimed at graduate students researchers and professionals in **UPSSSC JE Civil Engineering (Paper II) | Concerned** civil engineering construction engineering and concrete Subject : Civil and Structural | 10 Full-length Mock Tests (1200+ Solved Questions) EduGorilla Prep Experts, 2022-08-03 Best Selling Book in English Edition for UPSSSC JE Civil Engineering Paper II Exam with objective type questions as per the latest syllabus given by the UPSSSC Compare your performance with other students using Smart Answer Sheets in EduGorilla s UPSSSC JE Civil Engineering Paper II Exam Practice Kit UPSSSC JE Civil Engineering Paper II Exam Preparation Kit comes with 10 Full length Mock Tests with the best quality content Increase your chances of selection by 14X UPSSSC JE Civil Engineering Paper II Exam Prep Kit comes with well structured and 100% detailed solutions for all the questions Clear exam with good grades using thoroughly Researched Content by experts MPPEB Sub

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