1. MATERIAL STRENGTHS AND STRESS-STRAIN RELATIONSHIPS

1.1 GRADES OF CONCRETE

The following six grades of concrete can be used for reinforced concrete work as specified in Table 2 of the Code (IS : 456-1978*):

M 15, M 20, M 25, M 30, M 35 and M 40.

The number in the grade designation refers to the characteristic compressive strength, f_{ck}, of 15 cm cubes at 28 days, expressed in N/mm²; the characteristic strength being defined as the strength below which not more than 5 percent of the test results are expected to fall.

*Code of practice for plain and reinforced concrete (*third revision*).

1.1.1 Generally, Grades M 15 and M 20 are used for flexural members. Charts for flexural members and tables for slabs are, therefore, given for these two grades only. However, tables for design of flexural members are given for Grades M 15, M 20, M 25 and M 30.

1.1.2 The charts for compression members are applicable to all grades of concrete.

1.2 TYPES AND GRADES OF REINFORCEMENT BARS

The types of steel permitted for use as reinforcement bars in *4.6* of the Code and their characteristic strengths (specified minimum yield stress or 0·2 percent proof stress) are as follows:

Type of Steel	*Indian Standard*	*Yield Stress or 0·2 Percent Proof Stress*
Mild steel (plain bars)	IS : 432 (Part I)-1966*	26 kgf/mm² for bars up to 20 mm dia 24 kgf/mm² for bars over 20 mm dia
Mild steel (hot-rolled deformed bars)	IS : 1139-1966†	
Medium tensile steel (plain bars)	IS : 432 (Part I)-1966*	36 kgf/mm² for bars up to 20 mm dia 34·5 kgf/mm² for bars over 20 mm dia up to 40 mm dia 33 kgf/mm² for bars over 40 mm dia
Medium tensile steel (hot-rolled deformed bars)	IS : 1139-1966†	
High yield strength steel (hot-rolled deformed bars)	IS : 1139-1966†	42·5 kgf/mm² for all sizes
High yield strength steel (cold-twisted deformed bars)	IS : 1786-1979‡	415 N/mm² for all bar sizes 500 N/mm² for all bar sizes
Hard-drawn steel wire fabric	IS : 1566-1967§ and IS : 432 (Part II)-1966‖	49 kgf/mm²

NOTE—SI units have been used in IS: 1786-1979‡; in other Indian Standards, SI units will be adopted in their next revisions.

*Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part I Mild steel and medium tensile steel bars (*second revision*).

†Specification for hot rolled mild steel, medium tensile steel and high yield strength steel deformed bars for concrete reinforcement (*revised*).

‡Specification for cold-worked steel high strength deformed bars for concrete reinforcement (*second revision*).

§Specification for hard-drawn steel wire fabric for concrete reinforcement (*first revision*).

‖Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part II Hard drawn steel wire (*second revision*).

Taking the above values into consideration, most of the charts and tables have been prepared for three grades of steel having characteristic strength f_y equal to 250 N/mm², 415 N/mm² and 500 N/mm².

1.2.1 If the steel being used in a design has a strength which is slightly different from the above values, the chart or table for the nearest value may be used and the area of reinforcement thus obtained be modified in proportion to the ratio of the strengths.

1.2.2 Five values of f_y (including the value for hard-drawn steel wire fabric) have been included in the tables for singly reinforced sections.

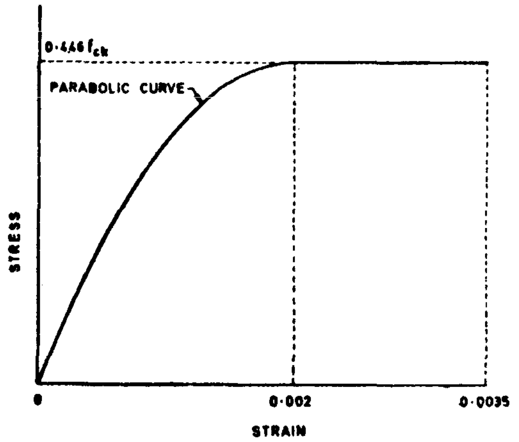

FIG. 1 DESIGN STRESS-STRAIN CURVE FOR CONCRETE

1.3 STRESS-STRAIN RELATIONSHIP FOR CONCRETE

The Code permits the use of any appropriate curve for the relationship between the compressive stress and strain distribution in concrete, subject to the condition that it results in the prediction of strength in substantial agreement with test results [*37.1*(c) of the Code]. *An acceptable stress-strain curve* (see *Fig. 1*) *given in Fig. 20 of the Code will form the basis for the design aids in this publication. The compressive strength of concrete in the structure is assumed to be* $0{\cdot}67\,f_{ck}$. *With a value of 1·5 for the partial safety factor* γ_m *for material strength (35.4.2.1 of the Code), the maximum compressive stress in concrete for design purpose is* $0{\cdot}446\ f_{ck}$ (see *Fig. 1*).

1.4 STRESS-STRAIN RELATIONSHIP FOR STEEL

The modulus of elasticity of steel, E_s, is taken as 200 000 N/mm² (*4.6.2* of the Code). This value is applicable to all types of reinforcing steels.

The design yield stress (or 0·2 percent proof stress) of steel is equal to f_y/γ_m. With a value of 1·15 for γ_m (*35.4.2.1* of the Code), the design yield stress f_{yd} becomes $0{\cdot}87\,f_y$. *The stress-strain relationship for steel in tension and compression is assumed to be the same.*

For mild steel, the stress is proportional to strain up to yield point and thereafter the strain increases at constant stress (*see* Fig. 2). For cold-worked bars, the stress-strain relationship given in Fig. 22 of the Code will

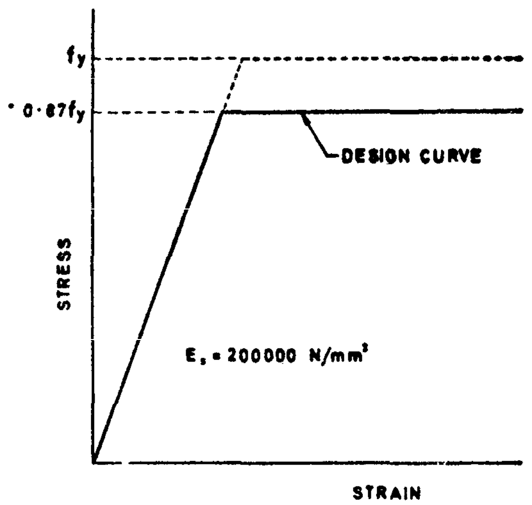

FIG. 2 STRESS-STRAIN CURVE FOR MILD STEEL

be adopted. According to this, the stress is proportional to strain up to a stress of $0{\cdot}8\ f_y$. Thereafter, the stress-strain curve is defined as given below:

Stress	*Inelastic strain*
$0{\cdot}80\,f_y$	Nil
$0{\cdot}85\,f_y$	0·000 1
$0{\cdot}90\,f_y$	0·000 3
$0{\cdot}95\,f_y$	0·000 7
$0{\cdot}975\,f_y$	0·001 0
$1{\cdot}0\,f_y$	0·002 0

The stress-strain curve for design purposes is obtained by substituting f_{yd} for f_y in the above. For two grades of cold-worked bars with 0·2 percent proof stress values of 415 N/mm² and 500 N/mm² respectively, the values of total strains and design stresses corresponding to the points defined above are given in Table A (*see* page 6). The stress-strain curves for these two grades of cold-worked bars have been plotted in Fig. 3.

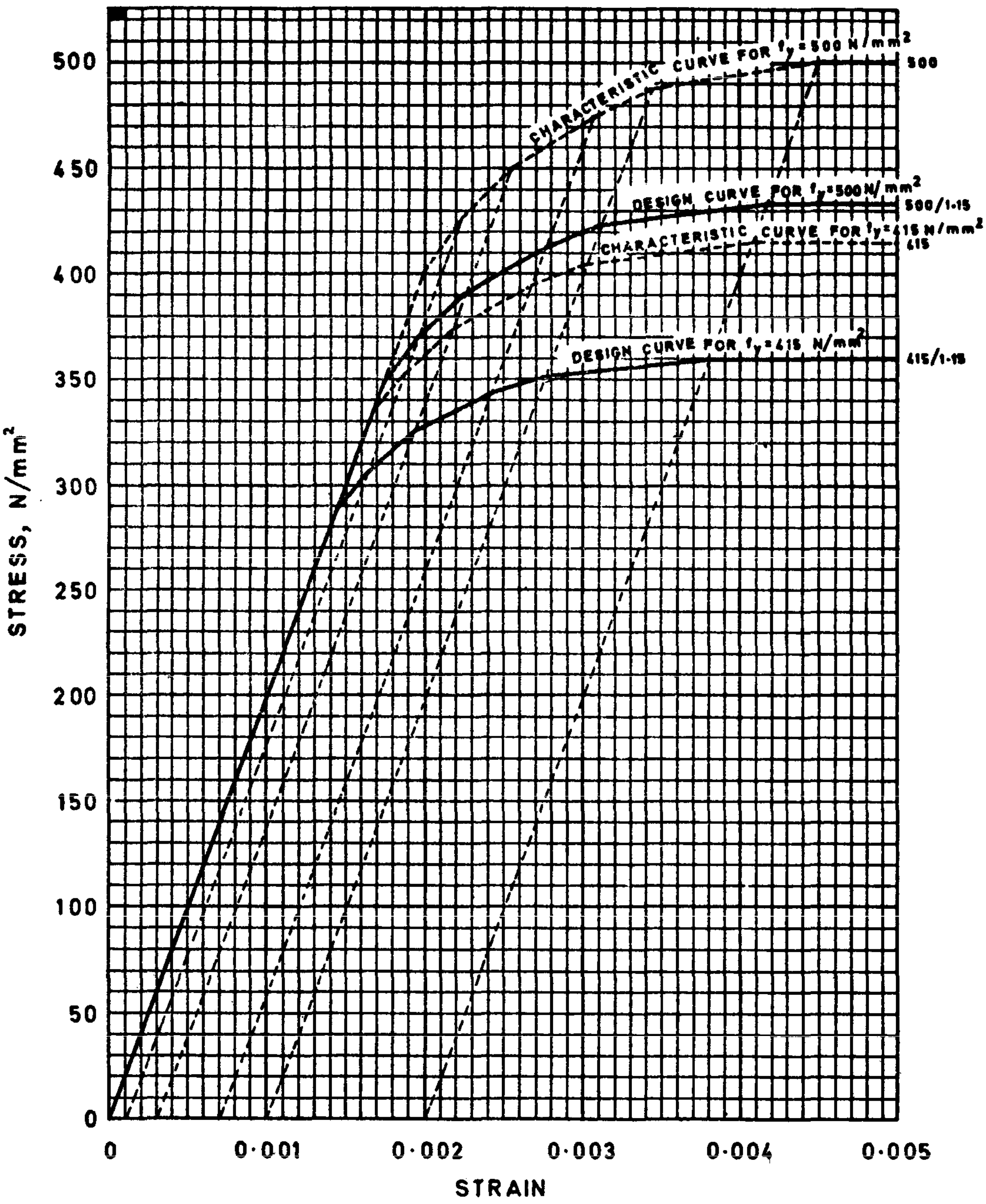

FIG. 3 STRESS-STRAIN CURVES FOR COLD-WORKED STEELS

TABLE A SALIENT POINTS ON THE DESIGN STRESS-STRAIN CURVE FOR COLD-WORKED BARS

(*Clause 1.4*)

Stress Level	f_y = 415 N/mm²		f_y = 500 N/mm²	
	Strain	Stress	Strain	Stress
(1)	(2)	(3) N/mm²	(4)	(5) N/mm²
0·80 f_{yd}	0·001 44	288·7	0·001 74	347·8
0·85 f_{yd}	0·001 63	306·7	0·001 95	369·6
0·90 f_{yd}	0·001 92	324·8	0·002 26	391·3
0·95 f_{yd}	0·002 41	342·8	0·002 77	413·0
0·975 f_{yd}	0·002 76	351·8	0·003 12	423·9
1·0 f_{yd}	0·003 80	360·9	0·004 17	434·8

NOTE — Linear interpolation may be done for intermediate values.