S Y N O P S I S

In recent years the problem of predicting strength of reinforced and prestressed concrete members subjected to torsion has gained considerable importance. The investigations reported so far have been limited mainly to plain and reinforced concrete rectangular and flanged sections and prestressed concrete rectangular sections. The data on torsion of flanged prestressed concrete sections are very meagre and the necessity for more data on this type of sections need not be over emphasised.

In this thesis, results of tests of prestressed concrete T sections with and without web reinforcement under pure torsion, combined bending and torsion and combined bending, shear and torsion are reported.

Though the determination of torque carrying capacity of rectangular sections is more or less a closed chapter now, the same cannot be said to be true about flanged sections. Prediction equations based on statistical analysis for ultimate torque have been proposed for plain, reinforced and prestressed concrete sections without web reinforcement. Effect of eccentricity has been taken into account in the prediction equations. The equations predict the cracking and ultimate torque satisfactorily.

Prestressed concrete T beams without web reinforcement tested in combined bending and torsion indicated two types of behaviour. Beams having low M/T ratios failing instantaneously with the formation of the diagonal tension crack have been classified as torsional type of failure. A small bending moment increased the torsional capacity of this category of beams. A theory has been proposed to predict the torsional load which is consistent with this type of behaviour. Beams having high M/T ratios exhibited flexure type of failure with inclined compression zone. This failure is termed as bending mode of failure. Analytical expressions have been derived for the determination of strength in this mode. The procedure incorporates the equilibrium of forces in the inclined plane and the strain compatibility along the failure plane. Compared with test results the calculated values appear to be conservative.

Depending on $2T/Vb_w$ ratio, the failure of flanged prestressed sections with plain web under combined bending, shear and torsion are of two types

1) torsional
2) shear compression.

In torsional mode like the beams tested in bending and torsion, the beams failed simultaneously with the appearance of diagonal tension crack. Beams having low values of $2T/Vb_w$ ratio indicated shear compression mode of failure. For these beams, analysis has been presented for determining

diagonal cracking load as well as ultimate load. Depending on the mode of initiation of diagonal cracks, this caterogy of beams have been classified into two groups :

a) Flexure shear type which originates as an extension of existing flexure crack.
b) Web shear type which forms in the web region practically free from any flexure crack.

For a particular beam with given properties prediction of diagonal cracking load depends on the lower value of the two diagonal cracking loads. Both at diagonal cracking and at ultimate stage, the problem of determining strength has been conceived as that of plain concrete under combined stresses. Analytical expressions for the prediction of ultimate load are based on equilibrium equations and compatibility equations. In general, the theories for the different modes of failures indicate conservative values.

The interaction for beam without web reinforcement between bending and torsion and shear and torsion has been studied and the relationships between them have been proposed.

Strength of prestressed concrete flanged sections with web reinforcement in pure torsion has been considered as the sum of total strength of the concrete section plus the full contribution due to the web reinforcement. Unlike the present practice of attributing only a fraction of the strength of the concrete sections, all the available test

results indicated better correlation when full strength of the section has been taken into account. For prestressed concrete flanged sections with web reinforcement under combined bending, shear and torsion, the torsional stress at failure has been proportionately reduced based on interaction relationship proposed for the prestressed flanged sections without web reinforcement. The results appear to be on the conservative side.

Based on the analysis presented in this thesis a scheme for designing members subjected to combined loading with torsion has been developed. Basic approach consists of determining the concrete contribution to the ultimate strength of the member after reducing torsional stress based on interaction between torsion and shear and then proportioning the web reinforcement for torsion for the remaining portion after assigning a part to the transverse shear. The requirements for both web and longitudinal reinforcement for torsion are explained. The procedure is explained with the help of an example.

An attempt has been made to study stiffness of prestressed flanged sections without web reinforcement from theoretical considerations. The entire analysis for stiffness and strength has been verified with the available test results in the literature.

In total, 46 beams were tested to destruction in this investigation. They were tested as follows :

a) 14 beams in pure torsion.

b) 9 beams in combined bending and torsion.

c) 23 beams in combined bending, torsion and shear.

The main variables in the test programme were

i) level of prestress

ii) eccentricity of prestress

iii) shear span

iv) loading ratio

v) stirrup spacing and

vi) unintentional difference in concrete strength.

Behaviour of beams under different stages of loading and final mode of failure are described in details.

The theory proposed is not meant to lay down a theoretical solution to the problem at hand. It, nevertheless, follows a rational approach, aided by certain assumptions, which are, however, individually and in their places, justified through logical or experimental evidence.

Lastly, a summary of conclusions has been drawn up.