Introductory remarks to theme II

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Einführende Bemerkungen zum Thema II

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The second session of this Symposium deals with "Simple Design Procedures for Concrete Columns". Before considering the technical contributions it is desirable to define the term "Simple Design Procedures". I shall arbitrarily define a simple design procedure as one which can be carried out economically by the design engineer.

A 40 cm square column 8 meters high in a braced frame building will cost about $175 to build. Of this sum, about $8 will go to the consulting engineer to pay for the structural analysis, design, drawing specification writing and inspection related to this member. The portion of this design fee which can be spent on calculating slenderness effects and selecting the column cross section is enough to pay for about 10 to 15 minutes of actual design time. By my definition, any design procedure which requires more design time is not a "simple design procedure".

Since the cost of a bridge pier is much greater, more time can be spent on its design and hence the "simple design procedure" for a bridge pier can and probably should be much more complex than the simple design procedure for a building column.

In an essay on structural design, the late Professor Hardy Cross stated:

> "Analytical procedures in mechanics should be so simple and flexible that they may give quickly either a quantitative or a qualitative method of thinking. They should draw a picture of a structure in action. Great builders for thousands of years have necessarily formed in their minds some such pictures. ...
>
> For formal analysis, methods may be used that are not primarily methods of thinking at all. These are often very formalistic, like a sausage grinder. If certain

numerical data are fed into one end of the analysis and a crank is turned, a lot of little sausages -- moments, reactions, stresses, movements -- come inevitably out of the other end of the machine. It works quite smoothly; in fact it works with deceiving smoothness. Because the sausages seem uniform and regular it is often assumed that the meat cannot be spoiled."

The Introductory Report for this session touched on a number of topics, some of which were elaborated on by the participants in this session and by the papers in the preliminary report:

1. Slender Columns

The majority of the contributions deal with some aspect of the behavior or design of slender columns.

(a) Cross-Sectional Stiffness, EI

The submissions by Oelhafen and by Drysdale, Sallem and Tan compare the ACI Code Equations for EI to those back-computed from the theoretical buckling loads of slender columns. Both authors find that the ACI equations become excessively conservative as the eccentricity e/h decreases and as the slenderness ℓ/r increases. Irle, Schäfer and Schäfer propose an equation for EI which is a function of e/h and ℓ/r.

The procedure for calculating EI proposed by Professor Menn comes closest to satisfying Hardy Cross's requirement that analytical procedures should "draw a picture of a structure in action" and for this reason it is valuable. Menn proposes that EI be calculated from the moment and curvature that exist at the onset of simultaneous yielding of the compression and tension reinforcement. This stage in the behavior corresponds to a major decrease in the stiffness of the cross-section and hence corresponds to a turning point in the life of the column. Creep of concrete or lightweight concrete can be accounted for in this model by modifying the concrete stress-strain curve used in computing the moment at this stage of loading. On the other hand, this procedure leads to a constant EI for a given cross-section and time and hence should tend to become conservative as e/h decreases and ℓ/r increases.

Kammenhuber and Dimitrov consider the effect of non-uniform EI values on the stability of slender columns.

Sparowitz presents a graphical solution of the strength of slender columns.

(b) Effects of Sustained Loads

The effects of sustained loads on the EI values for slender columns are discussed by Oelhafen, Menn, and Drysdale et. al. Drysdale, Sallam and Tan suggest that the creep effect should be expressed as a function of the ratio of the sustained load to the short time capacity under pure axial load rather than as a function of the ratio of the sustained load moment to the total load moment or sustained load to ultimate load. This concept has certain attractive features since it would reduce the strength of columns with low e/h ratios which are most apt to be affected by creep to a greater degree than it affects the EI for columns at large e/h.

(c) Biaxially Loaded Slender Columns

Six submissions dealt with various aspects of the analysis and design of biaxially loaded slender columns. The calculation of the final eccentricity of a rectangular column with biaxial eccentricity is discussed by Okada, Kojima and Hirosawa. Buck, Benkert, Schröder and Reis discuss a similar problem.

Gardner and Abdel-Sayed present cross-section interaction diagrams that relate load, eccentricity and curvature for bending about one axis and the 45 degree axis and show how these may be used to design slender columns.

Chen and Shoroka discuss the equivalent moment factor, C_m, for biaxially loaded slender columns. A significant portion of the conservatism they observe in the ACI code procedures for such columns is probably due to the conservatism of the ACI EI equation discussed earlier by Oelhafen or Drysdale.

Menegotto and Pinto present a computer analysis of slender biaxially loaded columns. In a second contribution they discuss the practical but here-to-fore neglected case of a rectangular column subjected to different moment diagrams in the two directions in which the points of maximum moment do not coincide.

(d) Other Topics Concerning Slender Columns

Petersen described a design office computer program which used numerical integration of moment curvature diagrams to design statically determinate columns in mill buildings. Oelhafen described a step-by-step solution of the strength of slender columns which has been programmed for mini-computers.

2. Other Aspects of Column Design

In their submission Yamada and Kamamura discussed the shear strength of columns.

Kammenhuber discussed the need for using both load and material safety factors in the design of slender columns.

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