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# Development of a design method for multi-story structures, February 1967

J. H. Daniels

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**PROGRESS REPORT NO. 1**

**PROJECT 338**

**"DEVELOPMENT OF A DESIGN METHOD FOR  
MULTI-STORY STRUCTURES UTILIZING  
COMPOSITE BEAMS".**

**Submitted to the**

**American Iron And Steel Institute**

**J. Hartley Daniels**

**Lehigh University  
Department of Civil Engineering  
Fritz Engineering Laboratory Report 338-1**

**February 1967.**

## INTRODUCTION

The research project "Development of a Design Method For Multi-Story Structures Utilizing Composite Beams" was initiated at Fritz Engineering Laboratory on July 1, 1966. The American Iron and Steel Institute is sponsoring this project through a doctoral fellowship awarded jointly to J. Hartley Daniels and Lehigh University. The scope of the research to be undertaken under this fellowship was outlined in the original research proposal. This proposal was submitted to the AISI during May 1966 in support of an application for a Doctoral Fellowship in Structural Engineering.

## SCOPE OF RESEARCH

The proposal to the AISI essentially described five related areas of study which when completed will form the basis for a plastic design method for multi-story frames composed of steel-concrete beams and steel columns. The five areas of study can be summarized as follows:

1. The development of a plastic design method suitable for the design of unbraced multi-story frames consisting of steel beams and steel columns.
2. Investigation of the possibility of including the strength of part of the floor system to assist the building frame in carrying gravity and wind loads.

3. A study of the influence of sway deflection behavior of unbraced multi-story frames on their design.
4. A study of the effect of composite beams on rigid frame action, especially with respect to the behavior of negative moment regions.
5. The development of a plastic design method suitable for the design of unbraced multi-story building frames consisting of composite steel-concrete beams and steel columns.

COMPLETED RESEARCH AND RESEARCH IN PROGRESS

This project is an extension of a study which began during the Summer of 1965. That study led to the development of the sway subassemblage method of design for unbraced multi-story frames (utilizing non-composite beams) which are subjected to combined gravity and wind loads.<sup>1,2\*</sup> The sway subassemblage method is further described in References (3) and (4).

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\*References cited at the end of this progress report.

The assumptions on which the sway subassemblage method is based have been extensively examined and exact equations have been developed for determining the initial restraining coefficients of frames up to 3 bays in width. Approximate but nearly exact equations have been derived for frames over 3 bays wide. It has been found that the collapse load of a frame subjected to combined loads, being highly dependent on the sway deformations produced, is sensitive to the values of the initial restraining coefficients. The equations derived in Report 273,37 were over simplified so that initial restraining coefficients could easily be determined from hand computations. However, the assumptions on which they were based resulted in only approximate predictions of the collapse load. The exact equations require assistance from an electronic computer in their solution but result in a more accurate prediction of the collapse load.

A study is now in progress which may allow the inclusion of column shortening effects in the sway subassemblage design method. Previous investigators have shown that column shortening will influence the collapse load of taller frames.<sup>5</sup>

As a result of the above studies, part (1)\* is essentially complete. Designs for gravity loads only will control the selection of beams and columns in the upper stories of a frame. Design for combined loads will govern member selection in the remaining stories.

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\* Numbers in brackets refer to the five areas of study summarized on pages one and two.

The sway subassemblage method is suitable for the combined loading case.

The investigations described in parts (2) and (4) are inter-related. Although (2) is concerned with the strength of the floor system (in this case, composite Tee beams) to assist the frame in carrying gravity loads, (4) is mainly concerned with the strength of the composite beams to resist wind loads, and in particular, the behavior of composite Tee beams which are subjected to concentrated moments. Although investigations in each of (2) and (4) could lead to major research projects the research at this time was limited initially to studies related to the sway subassemblage design method.

A research program just completed in Fritz Laboratory involved the testing of four two-span continuous composite steel-concrete T-beams. Each continuous beam was first tested under fatigue loading to a specified number of load applications. The maximum load level was approximately the service load of each beam. This study concerned the fatigue behavior of the stud shear connection and has been reported in Ref. (6). At the conclusion of the fatigue tests sufficient shear connection remained to develop the ultimate strength of the beams.

Each continuous beam was then tested statically to its ultimate load capacity. These tests have been reported in Ref. (7) and the results form the basis of the studies summarized in part (2). They show that simple plastic theory can be used to predict the ultimate load capacity of continuous composite beams subjected to vertical loads. A by product of this investigation was the need for further studies of the local buckling behavior of continuous composite beams near the interior supports.

Under a combined loading condition the beams in a multi-story frame are subjected to a different distribution of moments than when they come under gravity loads alone. Horizontal shears in the columns above and below a beam cause concentrated moments to be applied at the beam to column joints. Under a sufficiently high joint moment the beams framing into the joint can be subjected to positive moment on one side of the joint and negative moment on the other.

The study summarized in part (4) will include a small test program to determine how the joint moment is distributed to the beams on either side, what strengths can be developed in the composite beams at the joint and the influence of slab reinforcement in the neighbourhood of the joint on the strength and stiffness of the beams. The information obtained from such an investigation will then be used directly in the sway subassemblage method.

The steel test specimens to be used in this investigation have been fabricated (See Fig. 1) and plans are being prepared for the forming and pouring of the slabs. Testing will get underway approximately April 1.

RESEARCH TO BE COMPLETED

Parts (3) and (5) of the study summarized on page two remain to be completed.

Part (3) will require comparative designs of unbraced multi-story frames with and without composite beams. The sway subassemblage method will be used, suitably modified to include composite beams. The frames used in this study will be frames "B" and "C" discussed in Ref. 1. The beams in frames B and C will be assumed to have four inch slabs connected to them to form composite T-beams when performing the composite designs.

The completed studies outlined in parts (1) to (4) will be used as the basis for a description in part (5) of the design method to be used for unbraced multi-story frames utilizing composite beams.

ACKNOWLEDGMENTS

This study is part of a general investigation "Plastic Design of Multi-Story Frames" currently being carried out at Fritz Engineering Laboratory, Department of Civil Engineering, Lehigh University. L. S. Beedle is Acting Chairman of the Department and Director of the Laboratory. This project is financed by the American Iron and Steel Institute and Lehigh University.

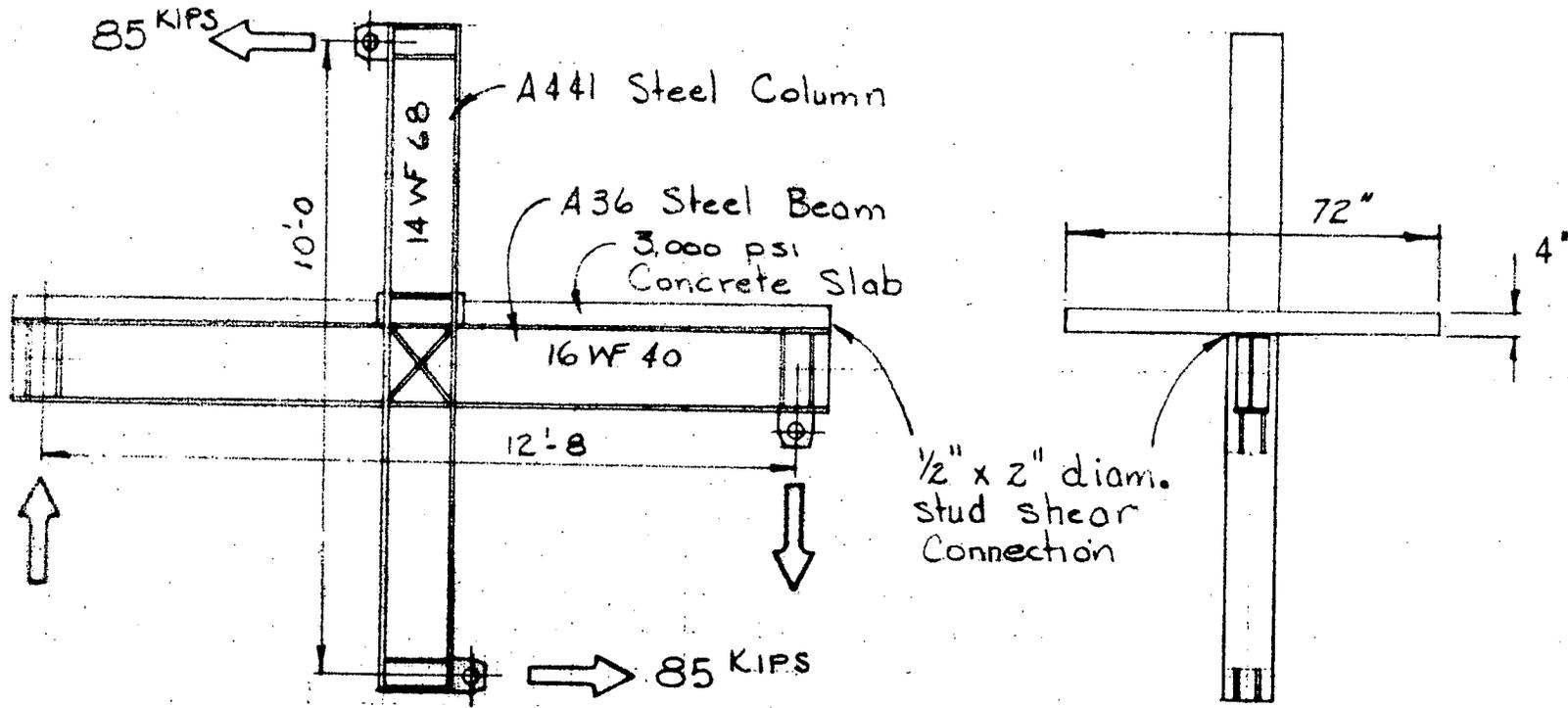


FIG. 1 TEST SPECIMEN DETAILS

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