



Error involved in isolating one floor of a building frame for design purposes  
by Pete Boyaci

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering  
Montana State University  
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**Abstract:**

This thesis presents an investigation of the errors made in calculating the design moments of the beams in a continuous frame, when this frame is analyzed in accordance with article 702 of the American Concrete Institute (A.C.I.) specifications which is followed in the designs of multiple story building frames.

In Part I of this thesis the analysis of the frame is based on the A.C.I. specifications where every floor is treated independently, as if it were a complete structure in itself. Thus, the design moments for the beams of the frame are determined.

In Part II the frame is analyzed as a single unit and the effects of all loading combinations are included in the design moments for the beams. The comparison of the moments obtained in Part I, where each floor is treated as an isolated unit, to the moments obtained in Part II, where the frame is treated as a unit, reveals the errors made when analysis is based on the A.C.I. specifications.

The results of the two parts show discrepancies up to twenty percent in the design moments. The frame proves to be underdesigned if analyzed according to the A.C.I. code.

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OF A BUILDING FRAME  
FOR DESIGN PURPOSES

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PETE BOYAGI

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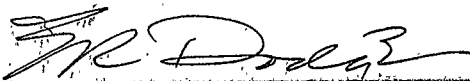
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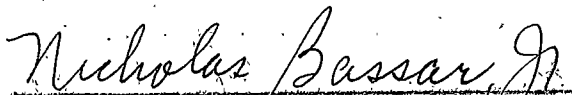
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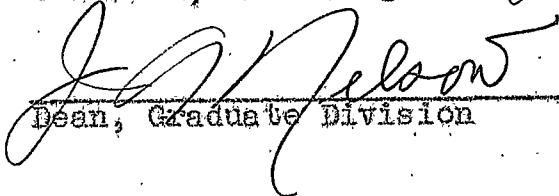
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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENT. . . . .	2
LIST OF TABLES. . . . .	5
ABSTRACT. . . . .	8
INTRODUCTION	
Object . . . . .	9
History. . . . .	9
Importance . . . . .	11
PROCEDURE	
Part I	
Specifications. . . . .	13
Outline of Procedure Followed . . . . .	15
Design of Slabs . . . . .	15
Design of Columns . . . . .	18
Design of Beams . . . . .	21
Stiffness Factors. . . . .	21
Distribution Factors . . . . .	22
Fixed End Moments. . . . .	24
Moment Distribution. . . . .	25
Part II	
Analysis of the Frame as a Single Unit. . . . .	39
Approach. . . . .	39

TABLE OF CONTENTS

	Page
CONCLUSIONS . . . . .	61
LITERATURE CITED AND CONSULTED. . . . .	64

LIST OF TABLES

TABLE NO.	DESCRIPTION	Page
I	Design of Roof Slabs S1 and S2 . . .	16
II	Design of Slabs S1 and S2 for Floors 1, 2 and 3 . . . . .	17
III	Design of Columns C1 through C8. . .	19
IV	Design of Columns C9 through C16 . .	20
V	Fixed End Moments for Maximum Condi- tions. . . . .	26
VI	Moment Distribution for Isolated Roof . . . . .	28
VII	Moment Distribution for Isolated 3. Floor, Part a. . . . .	29
VIII	Moment Distribution for Isolated 3. Floor, Part b. . . . .	30
IX	Moment Distribution for Isolated 2. Floor, Part a. . . . .	31
X	Moment Distribution for Isolated 2. Floor, Part b. . . . .	32
XI	Moment Distribution for Isolated 1. Floor, Part a. . . . .	33
XII	Moment Distribution for Isolated 1. Floor, Part b. . . . .	34
XIII	Balanced Moments for Frame, Loaded Span AB. . . . .	40
XIV	Balanced Moments for Frame, Loaded Span BC. . . . .	41
XV	Balanced Moments for Frame, Loaded Span CD. . . . .	42

LIST OF TABLES

TABLE NO.	DESCRIPTION	Page
XVI	Balanced Moments for Frame, Loaded Span EF. * * * * *	43
XVII	Balanced Moments for Frame, Loaded Span FG. * * * * *	44
XVIII	Balanced Moments for Frame, Loaded Span GH. * * * * *	45
XIX	Balanced Moments for Frame, Loaded Span KL. * * * * *	46
XX	Balanced Moments for Frame, Loaded Span LM. * * * * *	47
XXI	Balanced Moments for Frame, Loaded Span MN. * * * * *	48
XXII	Balanced Moments for Frame, Loaded Span PR. * * * * *	49
XXIII	Balanced Moments for Frame, Loaded Span RS. * * * * *	50
XXIV	Balanced Moments for Frame, Loaded Span ST. * * * * *	51
XXV	Final Moments when Frame is Treated as a Single Unit * * * *	52
XXVI	Final Moments when Frame is Treated as a Single Unit * * * *	53
XXVII	Final Moments when Frame is Treated as a Single Unit * * * *	54
XXVIII	Final Moments when Frame is Treated as a Single Unit * * * *	55
XXIX	Final Moments when Frame is Treated as a Single Unit * * * *	56

LIST OF TABLES

TABLE NO.	DESCRIPTION	Page
XXX	End Moments for Maximum Positive Conditions * * * * *	57
XXXI	End Moments for Maximum Positive Conditions * * * * *	58
XXXII	Error in Isolating One Floor of a Frame * * * * *	59



### ABSTRACT

This thesis presents an investigation of the errors made in calculating the design moments of the beams in a continuous frame, when this frame is analyzed in accordance with article 702 of the American Concrete Institute (A.C.I.) specifications which is followed in the designs of multiple story building frames.

In Part I of this thesis the analysis of the frame is based on the A.C.I. specifications where every floor is treated independently, as if it were a complete structure in itself. Thus, the design moments for the beams of the frame are determined.

In Part II the frame is analyzed as a single unit and the effects of all loading combinations are included in the design moments for the beams. The comparison of the moments obtained in Part I, where each floor is treated as an isolated unit, to the moments obtained in Part II, where the frame is treated as a unit, reveals the errors made when analysis is based on the A.C.I. specifications.

The results of the two parts show discrepancies up to twenty percent in the design moments. The frame proves to be underdesigned if analyzed according to the A.C.I. code.

## INTRODUCTION

### Object

The primary objective of this paper is to investigate the percentage error involved in isolating one floor of a continuous building frame and treating every floor independently. The application of the moment distribution concept provided the most direct and convenient method in determining this error.

### History

The multiple story building has been utilized for many years in the building history, and was the most successful solution of the centralization problem and, at the same time, the best use of high-priced land.

History reveals that the building materials used, from the time our ancestors emerged from caves to the present, played definitely the most important role in construction. From the branches and leaves to structural steel and reinforced concrete, from art and experience to modern methods of analyzing a structure, the years that elapsed were a challenge to creative minds.

The building materials used thousands of years ago like stone, brick, wood and many others -- then in a primitive form -- are still used.

The development of the converter by Henry Bessemer

in England, and of the open-hearth furnace by William Siemens in America between 1860 and 1870, made possible the production of a material whose properties could be properly controlled and could be cast and rolled into desired shapes. The new material, known as steel, is one of the greatest achievements in building history. Steel has contributed a material that enables not only speed, strength, rigidity and lightness of erections, but also rapidity of demolition. Another material, equally important, was used by the Egyptians and Romans<sup>1</sup> early in the history of construction, in a massive form and in the nineteenth century reinforced with steel, was adapted as one of the major building materials. This material is known as "concrete", and with steel in the body of the concrete, known as "reinforced concrete".

As far as design is concerned, in the early years art and experience replaced computations. The Post and Lintel construction<sup>2</sup> that was started in Egypt and Persia became the most widely used method of construction. Later, the simple supported beam idea, based on the post and lintel started to grow. Multiple story buildings were

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1. "Materials and Methods of Architectural Construction," by C. M. Gay and H. Parker, published by John Wiley and sons, Inc., N.Y. p. 27

2. Ibid p. 3

based on these simple supported beam principles and the statically determinate analysis.

In the year 1915, George A. Maney developed the widely known Slope Deflection Method which provided an economical design, compared to the previous ones, with the required theoretical analysis of the statically indeterminate frame. However, the tedious design, requiring the solution of numerous simultaneous equations, was too complicated compared to the analysis of determinate structures. A new technique, based on previous theories, like the Theory of Relaxation, was introduced by Hardy Cross in 1932. This new technique, known as "The Moment Distribution" was adopted by the engineers.

Then the American Concrete Institute, with numerous assumptions, made the analysis of a reinforced concrete frame comparatively shorter, and the A.I.S.C. reduced the work involved in steel design.

#### Importance

Article 702 of the A.C.I. specifications states "The live load may be considered to be applied only to the floor under consideration, and the far ends of the columns may be assumed as fixed."

The importance of this thesis is to investigate how much error is involved in the analysis of a frame if the

frame is designed according to this Article 702 of the specifications

## PROCEDURE

### Part I

A plan view of a continuous reinforced concrete frame is shown in Fig. 1. The section I-I of this frame is to be analyzed according to A.C.I. specifications.

#### Given loads:

Live load for Roof, 50 pounds per square foot

Live load for all other floors, 150 pounds per square foot

#### Specifications

The 28 day ultimate strength of concrete is 2500 pounds per square inch

Two way slabs are to be used in the analysis.

#### Outline of the Procedure followed

- A. The thickness of the slabs is determined
- B. Columns are designed
- C. Beams are designed.

In Fig. 2 all joints are lettered; columns and beams are numbered and they will be referred to in this manner.

#### Design of slabs

The design of slabs for roof and all other floors is shown in Tables I and II. The two governing factors that have to be given consideration in the design are as follows:

- a. The minimum thickness to satisfy deflection

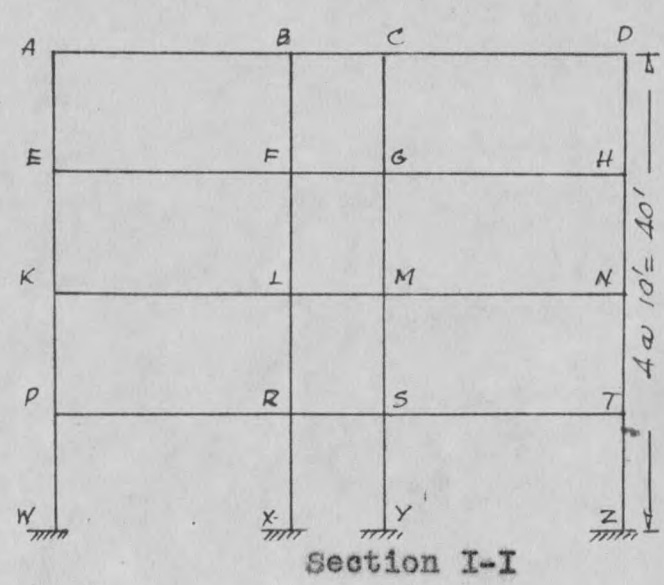
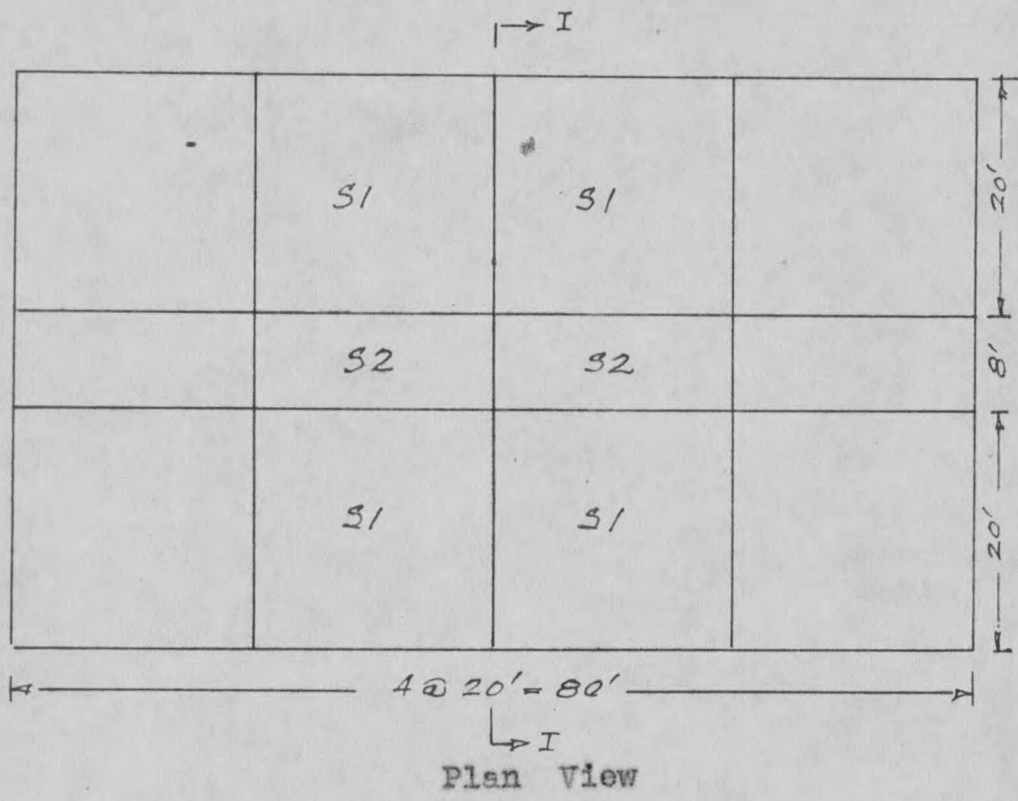


Fig. 1 Plan View and Section I-I of the Frame to be Analyzed.

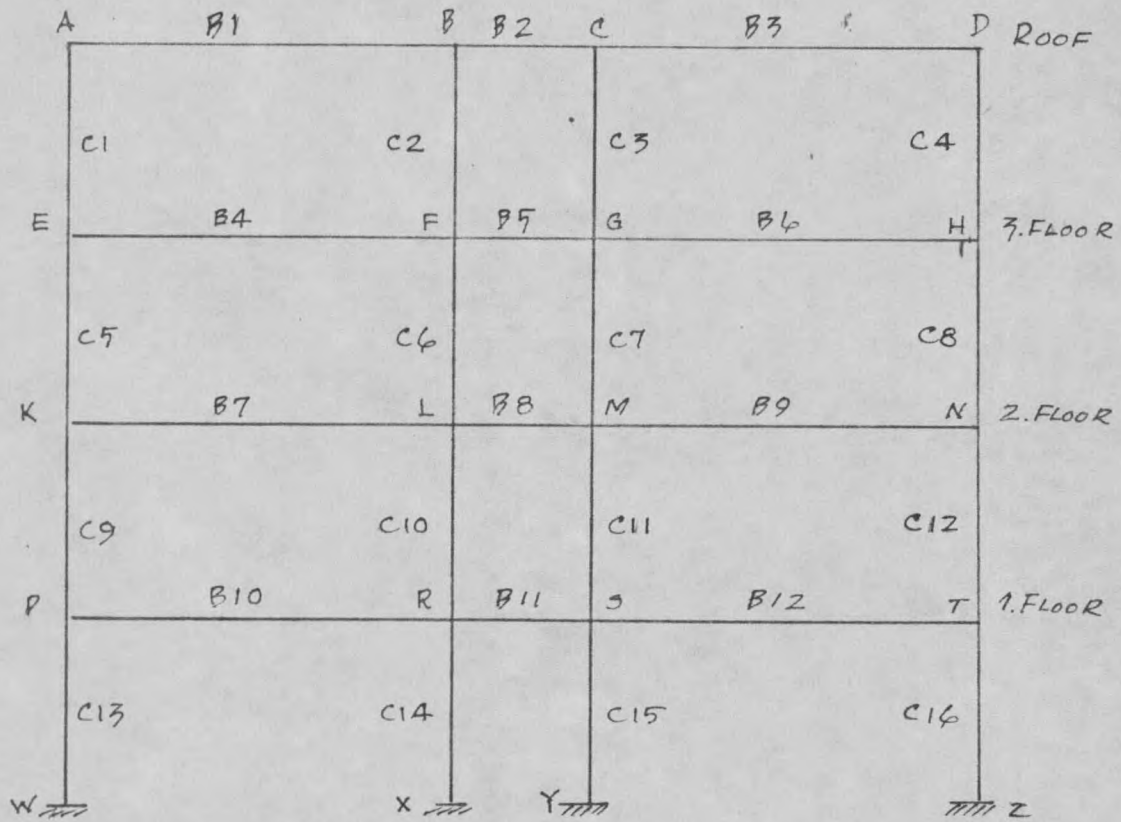


Fig. 2 Identification of the Members to be Analyzed.



TABLE I: DESIGN OF ROOF SLABS S1 & S2.

S1	S2
<p>L.L. = 50 psf                      D.L. = 70 psf assumed  <math>W = 120 \quad S = 20' \quad m = 1</math>  <math>t = [20 + 20 - \frac{N}{10}] \frac{12}{72} \sqrt[3]{\frac{2500}{3000}}</math>                      where <math>N = 60'</math>  <math>t = 5.33 \text{ in.}</math></p>	<p>L.L. = 50 psf                      D.L. = 50 psf  <math>W = 100 \quad S = 8 \quad m = .4</math>  <math>t = [8 + 20 - \frac{N}{10}] \frac{12}{72} \sqrt[3]{\frac{2700}{3000}}</math>                      where <math>N = 56'</math>  <math>t = 3.54 \text{ in.}</math></p>
<p>Moment coefficients  <math>C_1</math> coef. for Neg. Mom. at disc. Edge  <math>C_2</math> " " " " " Cont. "  <math>C_3</math> " " Pos. " " Midspan  <math>M = CWS^2</math>  <math>M_1 = 12.10 \text{ in. kips}</math>  <math>M_2 = 23.40 \text{ " "}</math>  <math>M_3 = 17.80 \text{ " "}</math>                      Design Mom = 16.47 in kips  <math>d = \sqrt{\frac{M}{Kb}} = 2.42 \text{ in.}</math>                      Use <math>t = 5.5 \text{ inches}</math></p>	<p>Moment coefficients  <math>C_1</math> coef. for Neg. Mom. at Cont. Edges  <math>C_2</math> " " Pos " " Midspan  <math>M = CWS^2</math>  <math>M_1 = 2.54 \text{ in. kips}</math>  <math>M_2 = 1.92 \text{ " "}</math>                      Design Mom = 0.947 in. kips  <math>d = \sqrt{\frac{M}{Kb}} = 1.85 \text{ in.}</math>                      Use <math>t = 4 \text{ inches.}</math></p>

TABLE II: DESIGN OF SLABS S1 & S2 FOR FLOORS 1, 2, & 3.

S1	S2
L.L. = 150 psf D.L. = 75 psf assumed $W = 229 \quad S = 20 \quad m = 1$ $t = 5.33''$	L.L. = 150 psf D.L. = 50 psf assumed $W = 200 \quad S = 8 \quad m = .4$ $t = 3.54 \text{ in.}$
Moment coefficients $C_1$ coef. for Neg. Mom. at disc. Edge $C_2$ " " " " " Cont. " $C_3$ " " Pos. " " Midspan  $M = cws^2$ $M_1 = 23.20 \text{ in. kips}$ $M_2 = 44.50 \text{ " "}$ $M_3 = 34.50 \text{ " "}$ Design Mom = 51,360 in. pou. $d = \sqrt{\frac{M}{Kb}} = 3.33 \text{ in.}$  Use $t = 5.5 \text{ in.}$	Moment coefficients $C_1$ coef. for Neg. Mom. at cont. edge $C_2$ " " Pos " " Midspan  $M = cws^2$ $M_1 = 5.08 \text{ in. kips}$ $M_2 = 3.84 \text{ " "}$ Design Mom = 18,220 in. pou. $d = \sqrt{\frac{M}{Kb}} = 2.52 \text{ in.}$  Use $t = 4 \text{ in.}$

requirements of the specifications

- b. The minimum thickness to satisfy the design moment requirements.

The design moments shown in the tables for the slabs are obtained in accordance with the specifications. The maximum moments for two adjacent slabs are computed based on the moment coefficients given by the A.C.I. code. These moments are balanced assuming that the supporting beam between the two adjacent slabs takes one-third of the unbalanced moment and the remaining two-thirds balanced based on the stiffness of the slabs.

#### Design of Columns:

With the determined thickness of slabs a very close approximation of the loads on the columns of the frame is made. These loads and the design of the columns are shown in Tables III and IV. All columns are designed based on axial loading conditions. The dimensions of columns C1 through C4 are determined by the 120 square inches minimum area requirement of the specifications. The dimensions of columns C5 through C16 after being determined, based on the loads, are arbitrarily increased two inches in each direction to satisfy the bending moments. The design, though not a thorough one, is satisfactory for the purpose. The mere object being to determine the stiffness of the columns needed in the analysis.









































































































