ANALYSIS AND DESIGN OF TRANSVERSE, STAGGERED WALL-BEAMS

by

DILIP G. NAMJOSHI

B. E. (HONORS) Civil Engineering, 1969

S. P. College of Engineering, The University

of Bombay, India

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements of the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1972

Approved by

Stuart E Swartz

MAJOR PROFESSOR

TABLE OF CONTENTS

GENERAL NOMENCLATURE

A = area

A_g = gross sectional area of concrete

A_s = area of main steel reinforcement

A_u = area of upper framing flange

b = width of upper framing flange

C = total compressive force

d^0 = effective depth of the beam

d = overall depth of the beam

E_c = modulus of elasticity for concrete

E_s = modulus of elasticity for steel

f = arm of the primary couple

I_x = moment of inertia of the beam at any section x

I_u = moment of inertia of UFF

LFF = lower framing flange

L = length

M^0 = external bending moment

M' = primary couple

M'' = moment in UFF

m = bending moment for T = 1

n = modular ratio E_s/E_c

N = $M'_{(max)}/f$

P_T = axial force due to T

p = axial force, P_T when T = 1

T = total tensile force

UFF = upper framing flange

V = shear force

V_u = ultimate shear force

v_u = ultimate shear stress

v_c = Allowable shear stress

W = load

x = dimensionless number

$\alpha = \left(\frac{\text{width of an opening}}{L}\right)$

$\gamma = \left(\frac{\text{distance of an opening center line from left support}}{L}\right)$

ϕ = capacity reduction factor

ϕ_1 = slope at the left end of the beam

ϕ_2 = slope at the right end of the beam

INTRODUCTION

Wall-beams - staggered and transverse are used in a new structural framing system which can be used in the design of high-rise reinforced concrete buildings. The conventional structural framing systems used today are flat plate and shear wall. The wall-beam system is an attractive and possibly economical alternative to the present framing systems. Although the system was originally conceived for structural steel construction (1)*, the basic concepts can be applied to reinforced concrete buildings also.

The wall-beam system was introduced by Portland Cement Association, Skokie, Illinois (2). The system was the result of efforts made to find an efficient way to resist wind load and yet have a design which is economical and flexible.

This report discusses the architectural and structural concepts involved in the new system. The theory and analysis are presented to introduce the new system. A design example of a typical wall-beam in a high-rise building using a wall-beam system is also presented in this report.

The wall-beam, as a principal component of the wall-beam framing system is discussed in the report. The detailed study of the wall-beam framing system as a whole is very complicated. However, the study of an isolated wall-beam, along with its analysis and design is useful in giving an introductory idea to the new framing system.

---

*Numbers in parentheses refer to items listed in Bibliography.

REVIEW OF LITERATURE

The Departments of Architecture and Civil Engineering, Massachusetts Institute of Technology prepared a report (1) which introduced a new concept in structural steel framing systems. The report showed that for high-rise structural steel buildings a reduction in overall cost could be achieved. The reduction in the cost of the structure was possible because the system offered an efficient way to resist the wind load. The new system consisted of story-high Pratt-type trusses with staggered locations on each floor level. The report stated that if the new framing system is used, 50% of the structural steel can be saved as compared to the conventional system of braced frames. This system does not affect the planning flexibility of a structure.

The Portland Cement Association, Skokie, Illinois conducted research (2) to determine the applicability of the new framing system to reinforced concrete buildings. The research included an analysis and a design of a concrete wall-beam with rectangular web openings. An experimental investigation was also conducted on a half scale model of a wall-beam.

The Portland Cement Association then developed a digital computer program for the analysis and design of the wall-beam framing system for use on the IBM 1130 computer (3).

ARCHITECTURAL DESIGN

High-rise residential buildings and commercial buildings are an essential part of the major cities in the U.S. The wall-beam system can be effectively used in many types of high-rise structures such as apartments having permanent interior partitions, student dormitories, hotels, etc.

It is a difficult task to explore the architectural implications of the wall-beam framing system in completely general terms. Apartment planning and construction are governed by state regulations or local city regulations. Therefore, a typical apartment building which is somewhat idealized is considered here to demonstrate the merits of this new system. The wall-beam system is suitable primarily for a rectangular plan of an apartment building but it can also be effectively used in other types of plans such as cruciform, Y-shape, broken rectangle etc. as long as the clear spans of the wall-beams extend from outside to outside of the building.

The building illustrated in Fig. 1. has the floor slabs with continuous 12'0" spans (since the slabs are either supported or suspended at 12 - ft. intervals) and 24'0" spaces between two adjacent wall-beams on any floor level.

Within certain limitations the wall-beam system provides for very flexible planning of an apartment unit if the basic requirements are not violated. Many variations are possible in a wall-beam building layout to accomodate desired features of the architectural planning. In each layout, the wall-beams occur at every second floor on each