

25 ๓๐50

บันไดเวียนทำมมากกว่า 360 องศา



นายสุมิตร เกษะสัจจา

006028

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาค้นคว้าตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

แผนกวิชาศึกษาศาสตร์

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

พ.ศ. 2519

i 18037094

HELICAL STAIR WITH CENTRAL ANGLE MORE
THAN 360 DEGREES

Mr. Sumit Dechasajja

A Thesis Submitted in Partial Fullfillment of the requirements
for the Degree of Master of Engineering
Department of Civil Engineering
Graduate School
Chulalongkorn University

1976

Accepted by Graduate School Chulalongkorn University
in partial fulfillment of the requirement for the degree of
Master of Engineering

Visit Prachuabmoh

.....
(Prof. Dr. Visit Prachuabmoh)

Thesis Committee

Niwat Daranandana
.....Chairman
(Prof. Dr. Niwat Daranandana)

Arun Chaiseri
.....Member
(Prof. Arun Chaiseri)

Vinit Chovichien
.....Member
(Assistant Prof. Dr. Vinit Chovichien)

Suthum Suriyamongkol
.....Member
(Assistant Prof. Dr. Suthum Suriyamongkol)

Thesis Supervisor

Prof. Arun Chaiseri

Thesis Title

Helical stair with central angle more than
360 degrees.

By

Mr. Sumit Dechasajja

Department

Civil Engineering

หัวข้อวิทยานิพนธ์ บันไดเวียนท่ามมากกว่า 360 องศา
ชื่อ นายสุมิตร เกษะสัจจา แผนกวิชา วิศวกรรมโยธา
ปีการศึกษา 2519

บทคัดย่อ

ในการวิเคราะห์บันไดเวียนชนิดแน่นที่ปลายทั้งสอง รับน้ำหนักแม่เต็มตลอดบันได คานโค้งแบบขดสปริงซึ่งกำหนดตามเส้นศูนย์แกนของชั้นบันได ถูกสมมุติเป็นโครงสร้างสำหรับ วิเคราะห์บันไดเวียน และวิเคราะห์โดยใช้วิธีค้ำยัสตีนิท ดิฟเฟอเมชัน (CONSISTENT DEFORMATION METHOD) บันไดเวียนขนาดของจริงท่าม 720 องศา ได้ถูกออกแบบ และบันไดเวียนคอนกรีตจำลองครึ่งหนึ่งของจริงได้สร้างขึ้นเพื่อที่จะทดลองหาพฤติกรรม ที่แท้จริงของโครงสร้าง จากการทดลองพบว่า ระยะโก่งในแนวตั้งที่วัดได้มีค่าน้อยกว่าระยะ โก่งในแนวตั้งที่ได้จากการวิเคราะห์ อัตราส่วนน้ำหนักที่พบรอยแตกครั้งแรกเท่ากับ 1.56 เท่าของน้ำหนักประลัยที่คาดหมายไว้ และเท่ากับ 1.9 เท่า ที่ระยะสุดท้ายของการ ทดลองและบันไดยังมีไคพังทะลาย ลักษณะแตกร้าวนี้อาจมาจากโมเมนต์บิด พบว่าเกิดขึ้น ตลอดบันได

Thesis Title Helical stair with central angle more than
 360 degrees.
Name Mr. Sumit Dechasajja Department Civil
 Engineering
Academic Year 1976

ABSTRACT

An analysis method was developed for a helical stair fixed at both ends subjected to uniform loading on the whole staircase. A helicoidal girder, defined along the center line of steps of the staircase was substituted for the structure, and the method of consistent deformation was used in this analysis. A prototype helical stair with central angle at 720 degrees was designed and a half scale reinforced concrete model was constructed and tested to find the actual behavior of the structure. From the experiment the measured vertical deflections were less than that from the analysis. The load factor obtained at the first crack was 1.56 time the anticipated ultimate load. At the final stage of loading, the model still did not collapse and the load factor was 1.9. The model exhibited torsional type of failure on whole the staircase.

ACKNOWLEDGEMENT

Sincere thanks and gratitude, are extended to the Civil Engineering Department and the graduate School, Chulalongkorn University without which this research would have been impossible.

The writer wished to express his heartfelt appreciation to his advisor Professor Arun Chaiseri. Thanks are also due to his Thesis Committee, Professor Dr. Niwat Daranandana, Assistant Professor Dr. Vinit Chovichien, Assistant Professor Dr. Suthum Suriyamongkol.

Finally special thanks are also given to Mr. Chawalit Thummaruksa of the Concrete Products & Aggregate CO., LTD. for his help in lending the testing loads, Mr. Sanan Taotong of Section of construction material research laboratory technical division, Bureau of Public Work, Bangkok Metropolis for his help in lending mechanical dial gauges, Mrs. Kannika Wongsarasurt for English correction and to all those who participated in the experimental work.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	Title page	I
	Thesis Approval	II
	Abstract	IV
	Acknowledgement	VI
	Table of contents	VII
	List of tables	IX
	List of figures	X
	List of symbols	XII
I	INTRODUCTION	1
	1.1 General statement of the problem	1
	1.2 Literature review	1
	1.3 Purpose and Scope of investigation	4
II	ANALYSIS	5
	2.1 Assumptions	5
	2.2 Geometry of the staircase	5
	2.3 Sign Convention	9
	2.4 Compatibility equations	9
	2.5 Evaluation of redundants and internal forces	19
	2.6 Vertical deflections	22
	2.7 Principle of symmetry	25

CHAPTER	TITLE	PAGE
III	DESIGN OF REINFORCEMENT	38
	3.1 Specifications	38
	3.2 Design of Prototype	38
	3.3 Design of Model	43
IV	CONSTRUCTION AND TEST	50
	4.1 Construction	50
	4.2 Measuring device	51
	4.3 Test Procedure	52
V	DISCUSSION AND CONCLUSION	73
	5.1 Discussion of test result	73
	5.2 Conclusions	76
	REFERENCES	77
	APPENDIX	78
	VITA	100

LIST OF TABLES

TABLE	TITLE	PAGE
1	Internal forces due to external load	12
2	Internal forces due to unit value of redundants	13
3	Internal force due to unit vertical load	23
4	Values of moments and forces	31
5	Values of moments and forces by Morgan method	32
6	Values of moments and forces by Bergman method	33
7	Values of moments and forces by Scordelis method	34
8	Values of moments and forces by Holmes method	35
9	Tabulated values of reinforcement of the prototype	45
10	Tabulated values of reinforcement of the model	46
11	Compressive test of concrete cylinders	53
12	Loading Schedule	59
13	Vertical deflection and horizontal dis- placement in radial direction	60
14	Strain measurement	61
15	Comparative strain	72

LIST OF FIGURES

FIGURE	TITLE	PAGE
1	Perspective sketch of helicoidal girder	6
2	Positive direction for internal forces	6
3	Positive direction of redundants of a left hand helicoidal girder	7
4	Positive direction of redundants of a right hand helicoidal girder	8
5	Dimension of Prototype Helical stair	21
6	Horizontal projection of Helical stair	27
7	Positive direction of redundants and stress resultants for upper half of the stairs	28
8	Curve for moments and Torsion	36
9	Curve for shears and Thrust	37
10	Detail of reinforcement at the bottom face for lower half of the staircase	47
11	Detail of reinforcement at the top face for lower half of the staircase	47
12 - 13	Section showing reinforcement	48-49
14	Plan of strain and deflection measuring stations	54
15	Form work and support	55
16	Typical measuring devices	55
17	Model under load	56

FIGURE	TITLE	PAGE
18	Arrangement of steel reinforcement in model staircase	56
19	Fixed end at the lower support	57
20	View of the flexural cracks at mid point of center line of the step of the stairs	57
21	View of torsional cracks at the outer side of the stairs	58
22	View of the torsional cracks at the top of the stairs	58
23 - 30	Load - Vertical deflection curves	62-65
31	Horizontal displacement in the radial direction (As measure at the outer side of stairs)	66
32	Horizontal deflection profile in the radial direction along the outer side of stair	67
33	Vertical deflection profile along the center line of step	68
34 - 36	Load - Strain curves	69-71

LIST OF SYMBOLS

- A_1 = total area of longitudinal reinforcement to resist torsion
 A_s = area of tension reinforcement
 A_t = area of one leg of a closed stirrup resisting torsion within a distance S
 A_v = area of shear reinforcement within a distance S
 b = width of stair section
 d = distance from extreme compression fiber to centroid of tension reinforcement
 E = modulus of elasticity of concrete
 E_s = modulus of elasticity of steel
 f_c^f = cylinder crushing strength of concrete
 f_y = yield strength of steel reinforcement
 G = modulus of shear
 h = total depth of stair section
 H = horizontal redundant force at mid span
 H_t = effective height of the stairs
 I_r = second moment of area of waist section about the horizontal axis = $\frac{1}{12} bh^3$
 I_s = second moment of area of waist section about the axis normal to the slope of the stairs = $\frac{1}{12} hb^3$
 J = polar moment of inertia = $\frac{bh^3}{16} \left[\frac{16}{3} - 3.36 \frac{h}{b} \left(1 - \frac{h^4}{12d^4} \right) \right]$
 M_r = vertical moment (moment about horizontal axis in radial direction)



- M_s = lateral moment (moment about the axis normal to the slope of the stairs)
- M_t = Torsional moment
- M_u = ultimate moment of the section
- M_v = redundant moment acting in a tangential plane at mid span
- n = ratio of moduli = $\frac{E_s}{E}$
- F_b = balanced steel ratio
- Q_r = horizontal shearing force in radial direction
- Q_s = shearing force across the waist of the stairs
- Q_t = axial force in the direction tangent to the helix center line
- R_i = internal radius of the stairs
- R_o = external radius of the stairs
- R_1 = radius of center line of load = $\frac{2}{3} \frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}$
- R_2 = radius of center line of step = $\frac{1}{2} (R_o + R_i)$
- S = shear or torsion reinforcement spacing in a direction parallel to the longitudinal reinforcement
- v_c = nominal permissible shear stress carried by concrete
- v_{tc} = nominal permissible torsion stress carried by concrete
- v_{tu} = nominal total design torsion stress
- v_u = nominal total design shear stress
- x = shorter overall dimension of a rectangular part of a section

- x_1 = shorter center-to-center dimension of a closed rectangular stirrup
- y = longer overall dimension of a rectangular part of a section
- y_1 = longer center-to-center dimension of a closed rectangular stirrup
- θ = angle measured from the lower support
- θ_1 = angle measured from the mid point of center line of step of the helix
- α = slope made by tangent to helix center line with respect to horizontal plane
- β = angle measured from the lower support to the applied unit vertical load
- ϕ = total arc subtended by helix as seen in plane