MOBILE STRUCTURES OF SANTIAGO CALATRAVA: OTHER WAYS OF PRODUCING ARCHITECTURE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

ARZU EMEL YILDIZ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF ARCHITECTURE
IN
ARCHITECTURE

JANUARY 2007

Approval of the Graduate School of Applied and Natural Sciences

_____

Prof.Dr. Canan Özgen

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Architecture.

_____

Assoc. Prof. Dr. Selahattin Önür

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Architecture.

_____

Assoc. Prof. Dr. Ayşen Savaş

Supervisor

Examining Committee Members

Prof. Dr. Jale Nejdet Erzen (METU, ARCH) _____

Assoc. Prof. Dr. Ayşen Savaş (METU, ARCH) _____

Assoc. Prof. Dr. Ali İhsan Ünay (METU, ARCH) _____

Assist. Prof. Dr. Berin Gür (METU, ARCH) _____

Inst. Dr. Türel Saranlı (BASKENT UNI., ARCH) _____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name: Arzu Emel Yıldız

Signature:

ABSTRACT

MOBILE STRUCTURES OF SANTIAGO CALATRAVA: OTHER WAYS OF PRODUCING ARCHITECTURE

Yıldız, Arzu Emel
M.Arch., Department of Architecture
Supervisor: Assoc. Prof. Dr. Ayşen Savaş

January 2007, 123 pages

This thesis conceptualizes the term “movement” as a design medium for producing architecture. The Deleuzian discourse which defines “movement” as “mobile section of duration” comprises the theoretical frame of the study. Santiago Calatrava’s architectural thinking and practice constitute the pragmatic ground on which the Deleuzian formulation of movement is constructed. Mobile structures of Calatrava are analyzed to introduce some design tools that are used to utilize “movement” as a design medium. These design tools are “unfolding”, “rising”, and “revolving”, which provide actual movements; rhythm and shape, which provide bodily movements; structural illusion, representation of nature, and “figura serpentinata”, which provide visual movements. Other than these, “virtual movement”, a term borrowed from Greg Lynn, is discussed as another design tool that is related with movement but produces perceptions of immobility rather than implications of mobility. This discussion emphasizes both the employment of movement issue as a design medium in the architectural production and the uniqueness of Calatrava in the way of conceptualizing the matter architecturally.

Keywords: movement, Santiago Calatrava, actual movement, bodily movement, visual movement

ÖZ

SANTIAGO CALATRAVA' NIN HAREKETLİ STRÜKTÜRLERİ: MİMARİYİ ÜRETMENİN DİĞER YOLLARI

Yıldız, Arzu Emel
Yüksek Lisans, Mimarlık Bölümü
Tez Yöneticisi: Doç. Dr. Ayşen Savaş

Ocak 2007, 123 sayfa

Bu tez, "hareket" terimini mimariyi üretmede bir tasarım ortamı olarak tekrar tanımlar. Deleuze' ün "hareket"i "sürenin hareketli kesiti" olarak tanımladığı söylem, çalşmanın kuramsal çerçevesini belirler. Santiago Calatrava' nın teorideki ve pratikteki mimari anlayışı, Deleuze' ün hareket formulasyonlarının üzerine kurulacağı pragmatik temeli oluşturur. Calatrava'nın hareketli strüktürleri, hareketi bir tasarım ortamı olarak kullanmayı sağlayacak araçları ortaya koymak için analiz edilir. Bu tasarım araçları; fiili hareketi sağlayacak "katları açma", "kalkma" ve "dönme"; bedensel hareketi sağlayacak ritim ve şekil; ve optik hareketi sağlayacak strüktürel yanılsama, doğanın tasviri ve "yılan figürü" dür. Bunlardan başka olarak, Greg Lynn' e ait bir terim olan "sanal hareket", hareketle ilgili fakat harektsizlik algısı yaratan bir tasarım aracı olarak tartışılır. Bu tartışma hem hareketin mimari üretimde kullanılan bir tasarım ortamı olduğunu vurgular hem de Calatrava' nın hareketle ilgili mimari düşünce sistemini oluşturmadaki benzersizliğini kanıtlar.

Anahtar Kelimeler: hareket, Santiago Calatrava, fiili hareket, bedensel hareket, optik hareket

To My Parents

ACKNOWLEDGMENTS

I would like to express my special thanks to

my supervisor Assoc. Prof. Dr. Ayşen Savaş for her guidance and support throughout my research;

other members of the examining committee, Prof. Dr. Jale Erzen, Assoc. Prof. Dr. Ali İhsan Ünay, Assist. Prof. Dr. Berin Gür and Inst. Dr. Türel Saranlı for their valuable suggestions and comments;

Güneş Özkal for her support and presence whenever I needed;

and my family members; Feride Yıldız, Durak Yıldız and Zeki Kemal Yıldız for being a part of my life.

TABLE OF CONTENTS

ABSTRACT.....iv
ÖZ.....v
ACKNOWLEDGMENTS.....vii
TABLE OF CONTENTS.....viii
LIST OF FIGURES.....ix
CHAPTER
1. INTRODUCTION.....1
2. ACTUAL MOVEMENT.....13
2.1. Unfolding.....18
2.2. Rising.....25
2.3. Revolving.....30
3. BODILY MOVEMENT.....36
3.1. Channeling through Rhythm.....44
3.2. Channeling through Shape….....50
4. VISUAL MOVEMENT…….....57
4.1. Structural Illusion…….....60
4.2. Representation of Nature…….....67
4.3. Figura Serpentinata…….....74
5. VIRTUAL MOVEMENT…….....85
6. CONCLUSION.....95
BIBLIOGRAPHY.....102
APPENDICES
A. SANTIAGO CALATRAVA_CHRONOLOGICAL BIOGRAPHY.....108
B. SANTIAGO CALATRAVA_ CATALOGUE OF WORKS.....117

LIST OF FIGURES

Figure 1.1 Marcel Duchamp, Nude Descending a Staircase, 1912 (Source: [Home page: http://www.betmuseum.org, http://www.beatmuseum.org/ duchamp/images/nude2.jpg, accessed: 20 August 2006])..... 5

Figure 1.2 Giacomo Balla, Girl Running on a Balcony, 1912 (Source: [Home page: http://webxhibits.org, http://webexhibits.org/colorart/futurism.html, accessed: 20 August 2006])..... 5

Figure 2.1 Left: Alexandria's pneumatic temple door opener (Source: Alexander Tzonis and Liane Lefaivre, "Dream-Work and Moving Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 17)..... 14

Right: Alexandria's automatic theater (Source: ibid. Tzonis and Lefaivre, p 17)..... 14

Figure 2.2 Sketches of Fontana, Bellicorum instrumentorum liber, 1420, (Source: [Home page: http://brunelleschi.imss.fi.it, http://brunelleschi.imss.fi.it/ genscheda.asp?appl=LIR&xsl=slideshow&lingua=ENG&chiave=1010, accessed: 25 August 2006])..... 14

Figure 2.3 Fountains from Joseph Furtembach, Architectura recreationis, 1640, (Source: ob.cit. Tzonis and Lefaivre, p 21)..... 15

Figure 2.4 Double set of rolling doors in Monticello House of Thomas Jefferson, (Source: [Home page: http://www.monticello.org, http://www.monticello.org/ house/diningroom.html, accessed: 25 August 2006] and William Zuk and Roger H. Clark, "Kinetic Geneses," Kinetic Architecture, Van Nostrand Reinhold Company, New York, 1970, p 29)..... 16

Figure 2.5 Ernsting Warehouse and Distribution Centre_ exterior view (Source: Alexander Tzonis and Liane Lefaivre, “Dream-Work and Moving Structures,” Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 33).....18

Figure 2.6 Above: Ernsting Warehouse and Distribution Centre_ sequences of unfolding_ sequential views (Source: Mirko Zardini, “Mobile Pages,” Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996, p 63).....19

Below: Ernsting Warehouse and Distribution Centre_ sequences of unfolding_ sequential sections (Source: Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 69, interpreted by the author).....19

Figure 2.7 Pfalzkeller Emergency Service Center_ exterior view (Source: ibid. Tzonis, p 40).....20

Figure 2.8 Left: Pfalzkeller Emergency Service Center_ sequences of unfolding _ sequential views (Source: ibid. Tzonis, p 41).....21

Right: Pfalzkeller Emergency Service Center_ sequences of unfolding _ sequential sections (Source: Drawn by the author).....21

Figure 2.9 Alcoy Community Hall_ exterior view (Source: ob.cit. Tzonis, p 47).22

Figure 2.10 Left: Alcoy Community Hall_ fountain_ sequences of unfolding_ sequential views (Source: ob.cit. Zardini, pp 66-67).....23

Right: Alcoy Community Hall_ fountain_ sequences of unfolding_ plan and sequential sections (Source: Alexander Tzonis, “Infrastructure and Dream-work Projects,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, pp 186-187, interpreted by the author).....23

Figure 2.11 Kuwait Pavilion _ exterior view (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p 191).....26

Figure 2.12 Left: Kuwait Pavilion _ sequences of rising_ sequential views (Source: Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 212).....27

Right: Kuwait Pavilion _ sequences of rising_ sequential sections (Source: ibid. Tzonis, p 214, interpreted by the author)…….....27

Figure 2.13 Milwaukee Art Museum_ exterior view (Source: ibid. Tzonis, p 295)…..……...28

Figure 2.14 Left: Milwaukee Art Museum_ sequences of rising_sequential views (Source: ibid. Tzonis, p 298, 299).....29

Right: Milwaukee Art Museum_ sequences of rising_sequential sections (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p 215, interpreted by the author)…….....29

Figure 2.15 Shadow Machine (Source: ob.cit. Tzonis, p 273)…….....31

Figure 2.16 Left: Shadow Machine_ sequences of revolving_ sequential views (Source: ob.cit. Tischhauser and Moos, p 200).....32

Right: Shadow Machine_ sequences of revolving_ sequential sections (Source: ibid. Tischhauser and Moos, p 201, interpreted by the author)…….....32

Figure 2.17 Left: Shadow Machine_ views of fingers and automated balls (Source: ibid. Tischhauser and Moos, pp 199-200).....33

Right: the diagram_ translation (Source: Heinrich Hertel, Structure, Form, Movement, Reinhold, New York, 1966, p 102).....33

Figure 2.18 Footbridge Puerto Mujer (Source: [Home page: www.calatrava.com, accessed: 17 September 2006]).....33

Figure 2.19 Left: Footbridge Puerto Mujer_ sequences of revolving_ aerial views (Source: [Home page: www.calatrava.com, accessed: 17 September 2006]).....34

Right: the diagram_ translation (Source: Heinrich Hertel, Structure, Form, Movement, Reinhold, New York, 1966, p 103).....34

Figure 3.1 Drawings of the Alps from John Ruskin (Source: Alexander Tzonis and Liane Lefaivre, "Movement Streamlining Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 111).....37

Figure 3.2 Drawings of the Alps from Viollet-Le-Duc (Source: ibid. Tzonis and Lefaivre, p 113).....37

Figure 3.3 Ruskin's comparison between mountain ridges and house gables (Source: ibid. Tzonis and Lefaivre, p 113).....37

Figure 3.4 Arnhem Central_ 3D view and related diagrams (Source: Ben van Berkel and Caroline Bos, Move: v.3 Effects, UN Studio and Goose Press, Amsterdam, 1999, pp 153-154).....40

Figure 3.5 IFCCA New York (1999) _ flow diagrams (Source: Ben van Berkel and Caroline Bos, UN Studio- Unfold, NAI Publishers, Rotterdam, 2002, p 30).....41

Figure 3.6 UCP Mainport (Utrecht, 1997) _ intensification of movement patterns (Source: Ben van Berkel and Caroline Bos, Move: v.1 Imagination, UN Studio and Goose Press, Amsterdam, 1999, p 74).....41

Figure 3.7 Pre-Plan Study (Nieuwegein, 1997- 1998) _ flow diagrams (Source: ibid. van Berkel and Bos, 1999, pp 121-122).....42

Figure 3.8 HOV Bridge (Utrecht, 1998- 2001) _ flow diagrams (Source: ibid. van Berkel and Bos, 1999, pp 148-149).....42

Figure 3.9 Shaping a bridge along the movements it inherits (Source: Drawn by the author).....43

Figure 3.10 Shaping a hub (train station / airport) along the movements it inherits (Source: Drawn by the author).....43

Figure 3.11 Stadelhofen Railway Station _ exterior view (Source: Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996, p 22).....45

Figure 3.12 Stadelhofen Railway Station _ plan (Source: Alexander Tzonis, "Seminal Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 49).....46

Figure 3.13 Stadelhofen Railway Station _ longitudinal section (Source: ob.cit. Sharp, p 27).....46

Figure 3.14 Stadelhofen Railway Station _ cross section (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings,Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p 50, interpreted by the author).....46

Figure 3.15 Left: Stadelhofen Railway Station_ Channel 1 _ covered promenade _ view (Source: ibid. Tischhauser and Moos, p 49).....47

Right: Stadelhofen Railway Station_Channel 1 _ covered promenade _ section drawing (Source: ibid. Tischhauser and Moos, p 49).....47

Figure 3.16 Left: Stadelhofen Railway Station_Channel 2 _ cantilevered platform roof _ sub-channel 1 _ view (Source: ibid. Tischhauser and Moos, p 50)……...48

Right: Stadelhofen Railway Station_Channel 2 _ cantilevered platform roof _ sub-channel 1 _ support (Source: Mirko Zardini, "Mobile Pages," Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996, p 82).....48

Figure 3.17 Left: Stadelhofen Railway Station_Channel 2 _ cantilevered platform roof _ sub-channel 2 _ view (Source: ob.cit. Tzonis, p 51).....48

Right: Stadelhofen Railway Station_Channel 2 _ cantilevered platform roof _ sub-channel 2 _ support (Source: ob.cit. Zardini, p 82)…….....48

Figure 3.18 Above: Stadelhofen Railway Station_Channel 3 _ underground shopping center _ view (Source: [Home page: www.http://en.structurae.de, www.http://en.structurae.de/photos/index.cfm, accessed: 03 November 2006])……..49

Below-Left: Stadelhofen Railway Station_Channel 3 _ underground shopping center _ view (Source: Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 85).....49

Below-Right: Stadelhofen Railway Station_Channel 3 _ underground shopping center _ support (Source: Mirko Zardini, "Mobile Pages," Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996, p 81).....49

Figure 3.19 The primary shapes _ Ching's illustration (Source: Francis Ching Architecture: Form, Space and Order, Van Nostrand Reinhold, New York, 1979, p 52).....51

Figure 3.20 Lyon Airport Railway Station _ exterior view (Source: An architectural documentary: Satolas – TGV un monument á la campagne by Catherine Adda).....52

Figure 3.21 Lyon Airport Railway Station_aerial view and plan (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings,Birkhäuser Verlag, Basel, Boston and Berlin, 1998, pp 61-66).....52

Figure 3.22 Above-Left: Lyon Airport Railway Station_ the concourse hall _ plan (Source: ibid. Tischhauser and Moos, p 66, interpreted by the author).....53

Above-Right & Below: Lyon Airport Railway Station_ the concourse hall _ sequential model views (Source: ob.cit. Adda)……...53

Figure 3.23 Above: Lyon Airport Railway Station_ the west vertice _ entrance _ view (Source: ibid. Adda).....54

Below-Left: Lyon Airport Railway Station_ the west vertice _ entrance _ view (Source: Alexander Tzonis, "Seminal Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 158)…….....54

Below-Right: Lyon Airport Railway Station_ the west vertice _ entrance _ detail drawing (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings,Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p 62).....54

Figure 3.24 Lyon Airport Railway Station_ gallery access to the airport _ interior view and section (Source: Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993).....21

Figure 3.25 Left: Lyon Airport Railway Station_ platform hall _ model view (Source: An architectural documentary: Satolas – TGV un monument á la campagne by Catherine Adda)….....56

Right: Lyon Airport Railway Station_ platform hall _ section (Source: ob.cit. Tischhauser and Moos, p 65)…….....56

Figure 3.26 Lyon Airport Railway Station_ triangular supports _ detail drawings and view (Source: ibid. Tischhauser and Moos, p 77).....56

Figure 3.27 Lyon Airport Railway Station_ triangular support _ view of high speed train's motion (Source: ob.cit. Adda)….....56

Figure 4.1 Configuration 1 (Source: Drawn by the author).....61

Figure 4.2 Configuration 2 (Source: Drawn by the author).....61

Figure 4.3 Alamillo Bridge (Source: Alexander Tzonis, "Seminal Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 92 and Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 147).....63

Figure 4.4 Alamillo Bridge_drawings (Source: Alexander Tzonis and Liane Lefaivre, "Movement Streamlining Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, pp 136-137).....64

Figure 4.5 La Devesa Footbridge (Source: [Home page: http://en.structurae.de, http://en.structurae.de/photos/index.cfm, accessed: 20 November 2006])……..64

Figure 4.6 Left: La Devesa Footbridge _ view from the edge (Source: [Home page: http://www.calatrava.info, http://www.calatrava.info/bridges/La_Davesa.asp, accessed: 25 November 2006]).....65

Right: La Devesa Footbridge _ drawings (Source: Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 188).....65

Figure 4.7 Trinity Footbridge (Source: [Home page: http://www.calatrava.info, http://www.calatrava.info/bridges/Trinity, accessed: 25 November 2006]).....66

Figure 4.8 Left: Trinity Footbridge _ view from one edge (Source: [Home page: http://www.calatrava.info, http://www.calatrava.info/bridges/Trinity.asp,accessed: 25 November 2006]).....67

Right: Trinity Footbridge _ drawings (Source: Dennis Sharp edits Santiago Calatrava, E and FN Spon, London, 1994, pp 88-89).....67

Figure 4.9 Left: Column capital _ Philae Temple, 4th c. BC, Egypt (Source: [Home page: http://www.bluffton.edu, http://www.bluffton.edu/~sullivanm/egypt/philae/colonnadedetdet.jpg, accessed: 30 November 2006]).....69

Middle: Column capital _ Temple of Olympian Zeus, 2nd c. AD, Greece (Source: [Home page: http://www.grisel.net, http://www.grisel.net/zeus.htm, accessed: 30 November 2006]).....69

Right: King's College Chapel, 1446-1515, England (Source: [Home page: http://www.greatbuildings.com, http://www.greatbuildings.com/buildings/Kings_College_Chapel.html, accessed: 30 November 2006]).....69

Figure 4.10 Left: Guaranty Building, 1894-1895, USA, by Louis Sullivan (Source: [Home page: http://www.bc.edu, http://www.bc.edu/bc_org/avp/cas/fnart/fa267/sullivan, accessed: 30 November 2006]).....69

Middle: Castel Beranger, 1893-1895, France, by Hector Guimard (Source: [Home page: http://perso.orange.fr, http://perso.orange.fr/artnouveau/img/artistes/guimard/, accessed: 30 November 2006]).....69

Right: Hotel Tassel, 1892-1893, France, by Victor Horta (Source: [Home page: http://www.angelo.edu, http://www.angelo.edu/faculty/rprestia/1301 /images/IN490aVHorta%20RD.jpg, accessed: 30 November 2006])....69

Figure 4.11 Milwaukee Art Museum _ "a great seagull" (Source: [Home page: http://www.calatrava.com, accessed: 30 November 2006])….....….70

Figure 4.12 Lyon Airport Railway Station _ "a bird at the point of flight" (Source: Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p 84).....….71

Figure 4.13 Planetarium of the Valencia Science Center _ "awakening eye" (Source: [Home page: http://www.calatrava.com, accessed: 30 November 2006])……..……72

Figure 4.14 BCE Place _ "forest of structural trees" (Source: Alexander Tzonis, "Seminal Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, pp 93, 94, 96)…..….73

Figure 4.15 BCE Place _ "flower" (Source: [Home page: http://www.vitruvio.ch, http://www.vitruvio.ch/arcgallery/canada/calatrava/heritagesquare, accessed: 02 December 2006])…….....73

Figure 4.16 Horatius Cocles by Hendrick Goltzius, 1558-1617 (Source: [Home page: http://www.netmuseum.org, http://www.netmuseum.org/special/ Goltzius/ 29.3.L.htm, accessed: 02 December 2006])…….....…...74

Figure 4.17 Discobolos by Mayron, 480-440 B.C. (Source: Rhys Carpenter, Greek Sculpture, A Critical Review, University of Chicago Press, Chicago, 1960, plate IX) ….....76

Figure 4.18 Doryphoros by Polykleitos, 450-420 B.C. (Source: ibid. Carpenter, plate XII) ….....78

Figure 4.19 High Rise in Malmö _ exterior view (Source: [Home page: www.designbuild-network.com, www.designbuild-network.com/projects/turning-torso, accessed: 08 December 2006])…….....80

Figure 4.20 High Rise in Malmö _ exemplary floor plans_changing angles and core-walls, and twisting steel truss (Source: [Home page: http://turningtorso.doxcentral.com, accessed: 08 December 2006])….....81

Figure 4.21 High Rise in Malmö _ exterior views and captured S-form (Source: [Home page: http://turningtorso.doxcentral.com, accessed: 08 December 2006], interpreted by the author)……..…….....81

Figure 4.22 La Rioja Bodegas Ysios Winery _ exterior view (Source: [Home page: www.calatrava.com, accessed: 10 December 2006])…….....82

Figure 4.23 La Rioja Bodegas Ysios Winery _ Southern and Northern façade (Source: [Home page: http://www.arcspace.com, http://www.arcspace.com/ architects/calatrava/wine, accessed: 10 December 2006])....83

Figure 4.24 Left: La Rioja Bodegas Ysios Winery _ interior view (Source: [Home page: www.calatrava.com, accessed: 10 December 2006])….....83

Right: La Rioja Bodegas Ysios Winery _ captured S-forms (Source: [Home page: http://www.arcspace.com, http://www.arcspace.com/ architects/calatrava/wine, accessed: 10 December 2006], interpreted by the author)…….……83

Figure 5.1 Yokohama Port Terminal _ roof plan (Source: Greg Lynn, Animate Form, Princeton Architectural Press, New York, 1999, p 122)…….....88

Figure 5.2 Yokohama Port Terminal _ aerial view looking toward the city (Source: ibid. Lynn, p 123)……...88

Figure 5.3 Yokohama Port Terminal _ the generation of tubes (Source: ibid. Lynn, p 125)……....89

Figure 5.4 House Prototype in Long Island _ mapping of the site forces in the three dimensional grid of particles (Source: Greg Lynn, Animate Form, Princeton Architectural Press, New York, 1999, pp 144-145, interpreted by the author)....90

Figure 5.5 House Prototype in Long Island _ prototype1 _ plan and perspective views (Source: ibid. Lynn, pp 150-151)……..91

Figure 5.6 House Prototype in Long Island _ prototype2 _ plan and perspective views (Source: ibid. Lynn, pp 154-157)……....91

Figure 5.7 House Prototype in Long Island _ prototype3 _ initial and intermediate conditions (Source: ibid. Lynn, pp 154-155)….....92

Figure 5.8 House Prototype in Long Island _ prototype4 _ plan and perspective views (Source: ibid. Lynn, pp 160-163)….....92

CHAPTER 1

INTRODUCTION

Santiago Calatrava has been accepted as one of the leading designers of contemporary architecture.[1] Primarily known as a Spanish architect, Calatrava is also a world wide known artist and engineer. He has received his degree in architecture from Escuela Technica Superior de Arquitectura de Valencia in 1974 and his Ph.D. degree in technical science from Eidgenöissische Technische Hochsohule (ETH), Zürich in 1981.[2] Calatrava's several public buildings and bridges, constructed mostly in Europe and United States, are the examples of his what I would call; "unique style".

This uniqueness derives from his multi-disciplinary interests in specified fields, his sophisticated architectural background, and his creative personality. Style, when conceived as something that goes beyond purposefulness and strikes with an aesthetic quality, becomes a significant feature of Calatrava's works. Including his earliest projects, every architectural work of the designer follows a particular route. This route is clearly indicated in the most inventive forms he uses, his meticulous material selection and his special treatment of the immediate landscape. The creative path he followed helped him to produce highly individualistic architectural works acclaimed internationally and turned Calatrava into a timeless signature. "Calatrava" is now a "signature" in the most explicit sense of the term based on "quality" and "reliability" and detached from all the commercial connotations of the term "trademark".

---

[1] Kenneth Frampton, "Look No Hands – Santiago Calatrava and the Well-Tempered Reconstruction," Werner Blaser edits Santiago Calatrava, Gustavo Gili , Barcelona, 1989; Anthony C. Webster, "Utility, Technology and Expression," Architectural Review, vol.191, no.1149, 1992; Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996; El Croquis, vol.11, no.5, 1992; Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996; Alexander Tzonis and Liane Lefaivre, Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995

[2] "Curriculum Vitae," Werner Blaser edits Santiago Calatrava, Gustavo Gili , Barcelona, 1989, p174

It is not new to say that Calatrava's work has been read both as a new aesthetic expression and a technological innovation.[3] The coexistence of these qualities has been emphasized in the designer's own statements. Calatrava states several times that the major source of his inspiration which brings aesthetic preferences and technological applications is "nature"; thus nature becomes a concept presented by Calatrava as the generator of his works and his original creative inspiration. There are two overriding principles Calatrava states that he has derived from nature.[4]

First overriding principle is presented by Calatrava as "the optimal use of materials".[5] The act of optimal use of materials learns from the natural objects such as trees, animal and human skeleton systems. This act is not a one to one formal application from nature to his structures but it is an ambitious research for appropriate construction methods and convenient construction materials specific for each project in its own context. Hence, the structures of Calatrava turn to be technical innovations providing simple solutions for the complex construction problems.

Second principle, on the other hand, is "the capacity of organisms to change shape, to grow, and to move".[6] This principle is suggested to be an essential source of inspiration for Calatrava through his inventive form researches. By simulation studies carried on nature, the forms capable of movement are explored to be used as inspiring structural systems. For Calatrava, not only the particular forms that natural organisms embody but also the mechanisms enabling them to move are subject matters to be investigated. Several significant architecture critics such as Alexander Tzonis, Liane Lefaivre, Anthony Tischhauser, Dennis Sharp and Mirko Zardini have been evaluated that "movement" is the principal concept that equips Calatrava's unique work.

This thesis is a critical analysis on the architectural production of Santiago Calatrava where 'movement' is chosen to be the leading concept that will

---

[3] Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996; El Croquis, vol.11, no.5, 1992

[4] Santiago Calatrava, "Foreword," Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, p1

[5] ibid. Calatrava, p 1

[6] ibid. Calatrava, p 1

contextualize this investigation. Calatrava himself underlined the term movement in his written works. Furthermore, the significance of the 'movement' concept in the architectural context of the 20th century along with the social and cultural aspects sustained from the rapid transformations in the technological ground is another leading issue for this particular choice. The concept of 'movement' has become one of the inspiring issues for the 20th century philosophers such as Gilles Deleuze, theorists such as Paul Virilio and sociologists such as Manuel Castells.[7] Depiction of 'movement' in various contemporary studies from distinct theoretical and practical fields derives from a common perception. 'Movement', with its derivative concepts such as 'dynamism', 'mobility' and 'speed', is identified as an essential factor in the formation of urban and political space together with the technological organization of this existence in the contemporary culture.

Deleuze conceives 'movement' as "present" in his book entitled *Cinema 1: the Movement-Image*.[8] He claims that "space covered is past, movement is present, the act of covering".[9] Since movement is defined as an act that exists in the present, reconstituting it is seen problematic by Deleuze. He introduces two formulas for distinct attempts to restore a movement; "real movement → concrete duration" and "immobile sections + abstract time".[10] The first formula prescribes the attempt of catching a movement by dividing time into pieces. Each instant of time is treated as a fragment that succeeds the previous to create the movement. Hence, the reconstitution realizes as depending on time instants. This attempt confronts with "duration" factor. "Each movement will have its own qualitative duration" says Deleuze.[11] Since duration indicates an interval of time rather than distinct time pieces, this *first* attempt would not be proper to reconstruct a movement. Deleuze states; "however much you divide and

---

[7] Various interpretations of movement have been explored and discussed through different studies such as, International Architecture Biennale Rotterdam: "Mobility: A Room for View"; ACLA 2006 Annual Meeting: The Human and Its Others, "Meaning in Motion" by Ilan Safit in Princeton University, March 2006; Architectural Conference: "Crossing the Boundaries XV: Time, Space and Movement" in State University of New York at Binghamton, April 2007; Slowness Studio in METU Graduate Architectural Design Program directed by Assoc. Prof. Dr. Ayşen Savaş

[8] Gilles Deleuze, "Theses on Movement: First Commentary on Bergson," Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 1

[9] ibid. Deleuze, p 1

[10] ibid. Deleuze, p 1

[11] ibid. Deleuze, p 1

subdivide time, movement will always occur in a concrete duration".[12] The second formula, on the other hand, depicts testing of sequential positions instead of time pieces. The "immobile sections" become the fragments in this case. Movement is tried to be restored by connecting sequential positions of the mobile body. This attempt is commented as leaving the movement in the back. The intervals between the positions rather than their singular identities are the matters that can embody a movement. Deleuze says that "movement will always occur in the interval" between two positions.[13] Hence, both methods; "real movement → concrete duration" and "immobile sections + abstract time" are depicted as the ways "we miss the movement".[14] Rather than these two formulas, movement is introduced as "a mobile section of duration" by Deleuze:

> Movement relates the objects between which it is established to the changing whole which it expresses, and vice versa. Through movement the whole is divided up into objects, and objects are re-united in the whole, and indeed between the two 'the whole' changes. We can consider the objects or parts of a set as *immobile sections*; but movement is established between these sections, and relates the objects or parts to the duration of a whole which changes, and thus expresses the changing of the whole in relation to the objects and is itself *a mobile section of duration*.[15]

"A qualitative change in the whole" beside "a translation of parts in space" is introduced as a derivative of movement. Changes are defined as presuppositions of the concept. Deleuze exemplifies his movement from place A to place B; "imagine I am starving at A, and at B there is something to eat. When I have reached to B and had something to eat, what has changed is not only my state, but the state of the whole which encompassed B, A, all that was between them".[16] Movement creates changes; not only on the objects it relates but also on the whole it expresses. Movement is conceptualized as a relation occurring between immobile sections and occupying duration in time. This occurrence and

---

[12] Gilles Deleuze, "Theses on Movement: First Commentary on Bergson," Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 1
[13] ibid. Deleuze, p 1
[14] ibid. Deleuze, p 11
[15] ibid. Deleuze, p 11
[16] ibid. Deleuze, p 8

occupation are the main sources of qualitative changes. Deleuze quotes Henri Bergson's analogy: [17]

$$\frac{\text{immobile sections}}{\text{movement}} = \frac{\text{movement as mobile section}}{\text{qualitative change}}$$

Immobile sections, called as objects or parts are united by movement. In this happening, they lost their contours and turn into undividable segments of a mobile section. This mobile section is again a segment. It comprises changes in the whole. This particular understanding of the concept of 'movement' derived from the Deleuzian theories, constitutes the contextual perception of the issue in this thesis.

In *Cinema 1: the Movement-Image,* Deleuze also presents antique and modern comprehensions of the 'movement' concept. In both comprehensions, he identifies the same error; that is "reconstituting movement from instants or positions" similar to first two formulas.[18] For Deleuze, in antiquity, movement is conceived as "the regulated transition from one form to another, that is, an order of *poses* or privileged instants, as in a dance".[19] The modern understanding relates movement with "any-instant-whatever" rather than "privileged instants"; Deleuze says "although movement was still recomposed, *it was no longer recomposed from formal transcendental elements (poses), but from immanent material elements (sections)*."[20] The antique comprehension is defined as "an intelligible synthesis of movement".[21] Cartoons are presented as systems which produces movement through this antique understanding. In cartoons, the sequential poses are connected to create transitions of movements, as Deleuze notes; the movement describes figures. The modern understanding, on the other hand is introduced as "a sensible analysis derived from movement."[22] The cinema, when perceived as "a mechanism for moving on images", is the system

[17] Gilles Deleuze, "Theses on Movement: First Commentary on Bergson," Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 8
[18] ibid. Deleuze, p 3
[19] ibid. Deleuze, p 4
[20] ibid. Deleuze, p 4
[21] ibid. Deleuze, p 4
[22] ibid. Deleuze, p 4

that reproduces movements as a function of “any-instant-whatever”. [23] Hence, the figures become the creators of movements.

While Deleuze is discussing the cinema from scientific and artistic viewpoints, he claims that art internalizes the antique comprehension of movement. Art is defined by Deleuze as upholding the claims of a synthesis of movement and remaining linked to the poses.[24] In this aspect, the formula of immobile sections reappears. Well-known cubist paintings from the beginning of the 20th century that furnish movement concept are the exposures of sequential immobile sections of moving images (Figures 1-1 and 1-2). The distinct poses produced through the duration of a movement are superimposed to depict the created change. Hence, visual art conceptualizes the issue as “an order of transcendental forms which are actualized in a movement”.[25]

figure 1-1 Marcel Duchamp, 1912
Nude Descending a Staircase

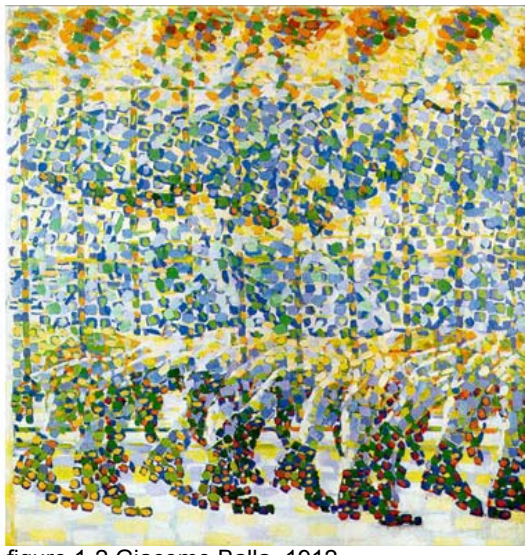


figure 1-2 Giacomo Balla, 1912
Girl Running on a Balcony

It should be noted that this claim is valid for the particular perception of movement as an action rather than an implication or experiencing way for visual art products.

---

[23] Gilles Deleuze, “Theses on Movement: First Commentary on Bergson,” Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 5
[24] ibid. Deleuze, p 6
[25] ibid. Deleuze, p 6

Needless to say, the situation is different for the works of Santiago Calatrava. Calatrava does not produce movement by ordering immobile sections with an abstract time. His products depict movement through the previously stated Deleuzian understanding which is regarded as the contextual perception. In other words, movement is comprehended as "a mobile section of duration" in Calatrava works. Not the superimpositions of sequential poses or instants but the durations creating changes are depicted by the designer. Here; the convenience of analyzing Calatrava's works in artistic terms can be discussed. Nevertheless, not only because Calatrava is an artist but also architectural products are apprehended as stable objects like art works, a related analysis can be tolerated.

Supposed stability in the architecture is stated to derive from the misinterpretation of structure "as a purely static organization" by Antoine Picon.[26] In his article entitled *Architecture, Science, Technology, and the Virtual Realm*, Picon mentions the changing understanding of structure as a dynamic character at the beginning of the 20th century. He says "structure became synonymous with the process of growth and development".[27] Calatrava's particularity in using movement as a concept of dynamic duration could be connected to his innovative use of structure. Identified as a structural expressionist, Santiago Calatrava internalizes the structure phenomenon as a dynamic potency in his architectural production.[28] His comprehension of movement as "a mobile section of duration" is embodied through his particular understanding of structure, which means growth and development in the 20th century. Alexander Tzonis states:

> In 20th century design culture, movement has, more than ever before, become a fact of life. In view of the importance of unprecedented speed and the impact of global mobility and change on our own lives, this is hardly surprising. The incorporation of movement into structures has become the preoccupation of many designers; this is probably nowhere more apparent than in the work of Santiago Calatrava.[29]

---

[26] Antoine Picon, "Architecture, Science, Technology and the Virtual Realm," Antoine Picon and Alessandra Ponte edit Architecture and the Sciences: Exchanging Metaphors, Princeton Architectural Press, Princeton, 2003, p 299

[27] ibid. Picon, p 299

[28] Calatrava is identified as a structural expessionist by Josè Luis Gonzàlez Cobelo in "Mask and Vertigo: Engineering and Alchemy in the work of Santiago Calatrava," El Croquis, vol.11, no.5, 1992, p 12

[29] Alexander Tzonis and Liane Lefaivre, "Structure, Form, Movement," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 12

"Movement" has already been investigated as a touchstone in Calatrava's architectural production by most of the mentioned critics, especially by Alexander Tzonis. Tzonis's books entitled *Santiago Calatrava: the Poetics of Movement* and *Movement, Structure and the Works of Santiago Calatrava* will be the essential sources for this study. However, differing from the already done investigations, this thesis has a significant aim. That is to conceptualize and reintroduce 'movement' as a design medium of architectural production and thinking. Calatrava's works will be analyzed in the context of 'movement' not only to reevaluate the architect's works in their aesthetic and technological aspects but to reintroduce this term as a guide for "other ways of producing architecture". Neither the conventional design media that are agreed to be used to generate architectural pieces nor the ones that are introduced as new tools during the elaboration of the profession are in the scope of this study. 'Movement' will be a method for the promotion of other ways of producing architecture.

The method for conceptualizing "movement" as a design medium is to seek the evidences of the term in the architectural history, search for possible definitions in other related fields and test these evidences within the context of architectural theory. In this study, to be able to make a critical analysis of Calatrava's works, both the mechanisms that enable the constructions to move will be explored and the elements through which the stated mobility is achieved will be researched.

It is needed to express here that when we say works of Calatrava that will exclude sketches, drawings, furniture and sculptures; only the finished structures of the designer will be analyzed. Whereas this analysis stands on Deleuze's theoretical conception of 'movement' theme, its pragmatic base is constituted through the following statements of Alexander Tzonis on the works of Calatrava:

> … [m]ovement plays a functional or symbolic role. The project's parts move or serve moving objects, or they convey the idea of movement figuratively… they do this in two principle ways: first, through parts of the structure that serve functional needs by *explicitly* moving (unfolding, rising, or revolving, or channeling) objects, people, and vehicles; and second, through parts of the structure that *implicitly* represent movement through their form.[30]

[30] Alexander Tzonis, "Schools without Walls," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, pp 17-28

Tzonis states that it is possible to analyze “movement” in the works of Calatrava in two ways; first way as he calls is “functional” that is “explicit”, and second way is “symbolic” that is “implicit”. As first, the project’s parts may move functionally by “unfolding”, “rising” or “revolving”, or the project serve moving objects again functionally by “channeling”. As second, the project may convey the idea of movement symbolically through its form.

“Functional movement” is achieved by means of two separate methods for producing mobile architecture. While the subdivision is done in an implicit manner by Tzonis, these methods will be presented with new terms in this study as ‘actual movement’ and ‘bodily movement’. “Symbolic movement”, on the other hand will be called as ‘visual movement’ throughout the thesis in order to prevent the semiological misinterpretations of the word “symbolic”. Hence, the structure in which the mechanics of ‘movement’ will be explored consists of three main divisions; ‘actual movement’, ‘bodily movement’ and ‘visual movement’.

‘Actual movement’, the first category of trilogy, is the tool for designing structures that have a mobile body or mobile parts. The term is defined in the dictionary as “the act or process of moving; especially: change of place or position or posture”.[31] Actually moving structures can transform themselves into different positions by moving entirely or partly. In Calatrava’s works, doors and roofs are the parts of the structures that can change their place or position or posture. Some mechanical systems integrated into this kind of structures are the basic sources of the movements. These mechanics will be explored both pragmatically and theoretically in this study.

As quoted before, Tzonis presents three separate tools that have been employed by Calatrava for his actually moving structures; “unfolding”, “rising”, and “revolving.”[32] These three mechanisms will constitute the particular sub-divisions of the related study. Hence, ‘actual movement’ will be explored under these three sub-headings.

---

[31] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 10 August 2006]

[32] Alexander Tzonis, “Schools without Walls,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 28

‘Bodily movement’, the second category of the trilogy, is the tool for designing structures that serve mobile objects such as automobiles, trains and human beings. This kind of structures are shaped accordingly with diverse movement types belonging to accommodated mobile bodies. Bodily moving structures are designed in such a way that their formal aspects lead their inhabitants to the directions that they wanted to go. In Calatrava’s architectural production, train stations, airports and bridges single out as far as ‘bodily movement’ is concerned. While bridges host only a limited movement from one side to another, train stations and airports are the structures where a variety of different movements occur at the same time. Flows of people, vehicles, light and even structural forces may become related design criteria for Calatrava. However, rather than the variety of mobile objects inhabited, the architectural elements that are used to attain ‘bodily movement’ in the structures are in the scope of this thesis.

“Channeling” is the term that is introduced by Tzonis to indicate ‘bodily movement’ employed in the structures, but no further categorization has been made by any critics.[33] Since the aim of this study is to reintroduce “movement” as a design tool, it is important to understand the capacity of structures to “channel” movements. Hence, two categories derived from the analysis of Calatrava’s works will be introduced under the heading of ‘bodily movement’; ‘channeling through rhythm’ and ‘channeling through shape’. These two sub-headings will be explored in the study as referring to two distinct mechanisms that enable structures move bodily.

‘Visual movement’, the last category of the trilogy, is the guide for designing structures that convey the idea of movement figuratively. “The quality (as in a painting or sculpture) of representing or suggesting motion” is the feature of these kind mobile structures.[34] Similar to constructions that employ ‘bodily movement’, the ones equipped with ‘visual movement’ do not have to possess any mobile parts. Even being totally stationary, visually moving structures appear as if they are in a state of movement. Several works of Santiago Calatrava are

---

[33] Alexander Tzonis, “Schools without Walls,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 28

[34] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 10 August 2006]

agreed to imply movement through their unusual contours. This impression is basically due to the structures' intentionally chosen form configurations. The kinds of articulations that enable a structure to move visually are under the consideration of this study.

Calatrava's structures that employ 'visual movement' can be analyzed under three sub-titles; 'structural illusion', 'representation of nature', and "figura serpentinata", a term borrowed from Tzonis. These three issues will be presented as distinct ways of attributing 'visual movement' to the structures and will be explored.

After a thorough analysis on the concept of movement that Calatrava structures embody, exploration of another movement type used in the contemporary architectural culture will constitute the last part of this study. It is the "virtual movement" which is a term borrowed from Greg Lynn.[35] Virtual movement is defined by Lynn as a way of "allowing form to occupy a multiplicity of possible positions continuously with the same form".[36] The theme is not a derivation of the analysis on Calatrava but it is a contemporary tool that is discussed to conceptualize movement in a particular architectural production.

Such a study will introduce an idea about the other possible ways of using movement issue in design culture. The particular choice of "virtual movement" as the object for this derivation is due to three reasons. The contemporariness of the issue and the distinctness of its planning and representation techniques constitute two of these reasons as pragmatic matters. The third reason, on the other hand, is more about the theoretical comprehension of "virtual movement" in the Deleuzian philosophy. Lynn's study will be explored as an embodiment of the understanding of the concept of movement that is discussed previously as the method that "misses the movement". Virtually moving projects will outline the Deleuzian formula; "immobile section + abstract time" that prescribes a particular comprehension similar to the ones in cubist paintings.

---

[35] Greg Lynn, "Animate Form," Animate Form, Princeton Architectural Press, New York, 1999, pp 9-41
[36] ibid. Lynn, p 10

The research on the virtual movement will prove Calatrava's distinctiveness about the conceptualization of movement issue in the architectural production. First, the theoretical base on which Lynn constructs his method will be explored to reevaluate the ways in which Calatrava utilizes movement in his production. Second, the particular perception Lynn's structures create will be discussed to reconsider the implications of movement Calatrava's mobile structures generate. The discussions that will be done about the architectural thinking and practice of Lynn in the theoretical context of Deleuzian methodology will reveal that Calatrava is unique in his utilization of the concept of movement as a design medium and his actually, bodily and visually moving structures are remarkable demonstrations of this uniqueness.

CHAPTER 2

ACTUAL MOVEMENT

> movement / *noun*: ***1 a (1): the act or process of moving; especially: change of place or position or posture**** (2): a particular instance or manner of moving b: ACTION, ACTIVITY -- usually used in plural
> 2 a: TENDENCY, TREND <detected a movement toward fairer pricing> b: a series of organized activities working toward an objective; also: an organized effort to promote or attain an end
> 3: the moving parts of a mechanism that transmit a definite motion
> 4 a: MOTION 7 b: the rhythmic character or quality of a musical composition c: a distinct structural unit or division having its own key, rhythmic structure, and themes and forming part of an extended musical composition d: particular rhythmic flow of language: CADENCE
> 5: the quality (as in a painting or sculpture) of representing or suggesting motion[37]

Alexander Tzonis predicates the usage of actual movement in architecture to the Hellenistic times.[38] The "mobile artifacts" of Alexandria, such as a temple door that opens and closes owing to a pneumatic apparatus and a mechanical theatre with moving doors and moving puppet-actors, are assumed as the first instances of actually movable architecture (Figure 2-1). Tzonis discusses Vitruvius' treatise *De Architectura* as a work that identifies "designing of machines endowed with kinesis (movement)" as an area which makes up the knowledge and activities of an architect. *The Mirabilia,* a collection of some tales dating from the 10th century to the end of the 14th, describes buildings endowed with movement such as castles twirling in the wind or great halls rotating entirely.[39]

For the 15th century, on the other hand, "fantastic sounding automata and mobile structures" of Giovanni Fontana are exemplified by Tzonis as products

---

[37] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 10 August 2006]
* Emphasis by the author.
[38] Alexander Tzonis and Liane Lefaivre, "Structure, Form, Movement," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 16
[39] ibid. Tzonis and Lefaivre, pp 16-18

which are difficult to be judged being either architectural or simply fantastical. Fontana is known as a Renaissance engineer who had a sketchbook entitled *Bellicorum instrumentorum liber (Book of War Instruments)* dated 1420. The book demonstrates Fontana's interest in military systems and his competence in hydraulics and precision mechanics. He applied these skills to build toys and produce special contraptions.[40] Some sketches from the book are illustrated below (Figure 2-2).

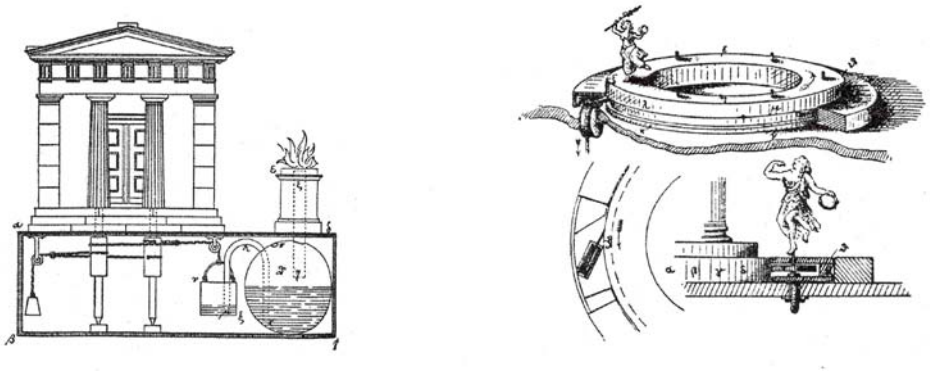


Figure 2-1 left: Alexandria's pneumatic temple door opener
right: Alexandria's automatic theater

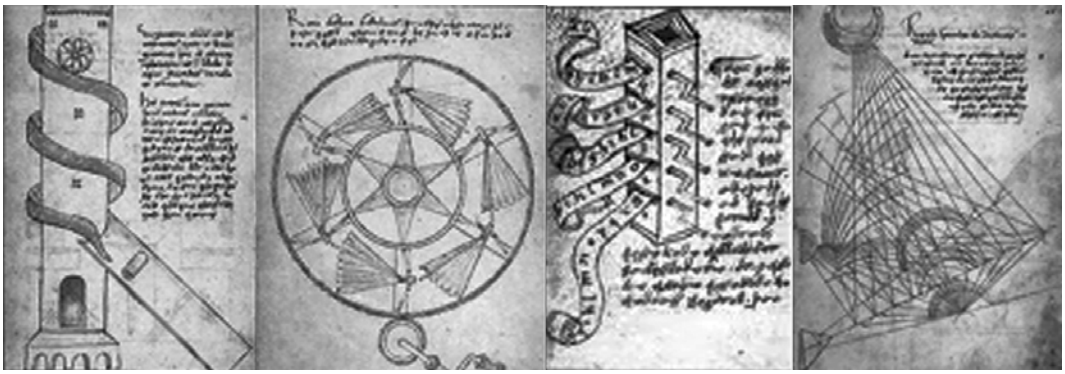


Figure 2-2 sketches of Fontana, Bellicorum instrumentorum liber, 1420

Dating from the 16th century, actual movement becomes a key issue for planning garden and urban settings. Studies on water movement, discussed as

[40] See for further information [Home page: http://brunelleschi.imss.fi.it, http://brunelleschi.imss.fi.it/museum/isim.asp?c=300236, accessed: 20 November 2006]

the main concern of the time by Tzonis, initiates usages of mobiles such as "artificial water sources: streams, cataracts, spouts, jets" (Figure 2-3). [41]

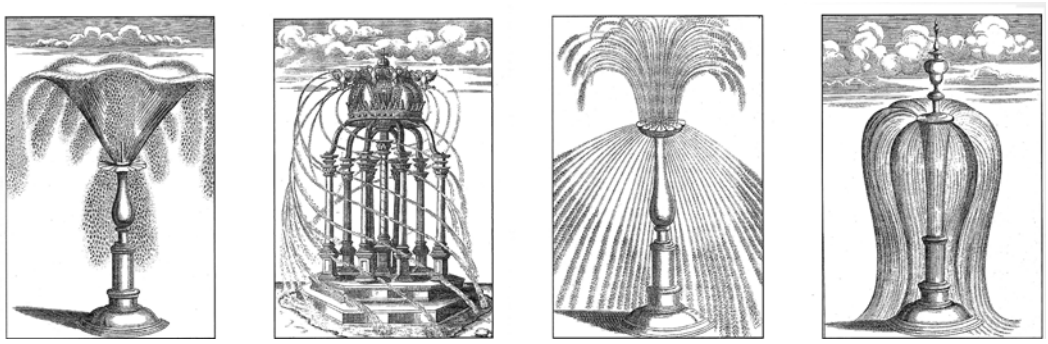


Figure 2-3 fountains from Joseph Furtembach, Architectura recreationis, 1640

In his book entitled *Kinetic Architecture,* William Zuk depicts The Palace of Versailles in France as a later example from the 17th century with its interesting dining room.[42] Zuk describes the room as having a portion that could be lowered to another level where servants set the banquet table. The floor was raised to the dining room level again for the serving.[43] Although the method for changing the floor level is not mentioned by Zuk, the aim for constructing a device to minimize the disturbance caused by the servants is illustrated as an architectural research for a movable space.

Crystal Palace, on the other hand, is a special instance from 19th century. Due to its total dismantling and re-erection on a different site, the palace is defined as a totally movable structure by Zuk.[44] Firstly established in London for the Great Exhibition in 1851, the palace was carried to Sydenham Hill in South London in 1854 since the exhibition was over. This carrying was made possible due to the particular structural configuration of the palace. The prefabricated iron components which were bolted together were the main devices that made the structure move.

---

[41] Alexander Tzonis and Liane Lefaivre, "Dream-Work and Moving Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, pp 18-19

[42] William Zuk and Roger H. Clark, "Kinetic Geneses," Kinetic Architecture, Van Nostrand Reinhold Company, New York, 1970, p 30

[43] ibid. Zuk and Clark, p 30

[44] ibid. Zuk and Clark, p 30

Windmills and beacons could also be counted as movable architectural instances that have been constructed since early years. Nevertheless, the actual movement generated in architectural production has been observed as a special feature applied mostly for door and roof structures through the history.

Zuk claims that movable openings have been produced since the invention of the wheel.[45] “Movable stones, logs, or skins covering cave or hut openings were the first items used architecturally with some trace of adaptation or mobility” says Zuk and asserts the introduction of metals, pivots and hinges as a beginning for better and easier production of movable doors.[46]

Figure 2-4 double set of rolling doors in Monticello House of Thomas Jefferson

The drawbridges introduced in middle ages for defense purposes, could be counted as other early examples. More recent and remarkable examples are designed by Thomas Jefferson for his own house in Monticello, Virginia. One of them is a service door placed in the dining room. The door has the capability of turning due to its pivoting system. When it turns, shelves attached to the back side become accessible for the diners. The system enables servants to move dishes in and out of the room more easily and with fewer distributions. The other instance is a double set of pocket doors separating tea room from dining room. These doors are placed on a roller system which is claimed by Zuk to be found in 1953 when the room floor was uncovered.[47] The roller system enables a

[45] William Zuk and Roger H. Clark, “Kinetic Geneses,” Kinetic Architecture, Van Nostrand Reinhold Company, New York, 1970, p 30
[46] ibid. Zuk and Clark, p 30
[47] ibid. Zuk and Clark, p 28

simultaneous opening for all the leaves of the doors when any one is opened. Figure 2-4 illustrates the simple device invented by Jefferson. The constructions of both systems are dated as 1772 in the official website of Monticello House.[48]

For the movable roof structures, on the other hand, Zuk presents the case of Roman Colosseum.[49] A retractable canvas roof covering the structure is claimed to be produced in 70 A.C. for keeping out the heat. The roof is stated to be raised and lowered by a specially trained team of Roman sailors known for their skill with rigging ships.[50] The poles placed around the edge of the Colosseum are asserted to support the huge movable roof.[51]

Actually moving structures of Santiago Calatrava, which are mostly mobile door and roof systems, are the contemporary examples of a such production. Tzonis considers Calatrava as one of the few architects that "incorporate movement into their structures in a literal way since the 17th century".[52]

The quotation below, from Mirko Zardini's article titled *Mobile Pages* is a comment on Calatrava's structures that can actually move:

> The building is no longer a fixed element, but one that assumes different configurations, changing over time with respect to the various needs and uses of its spaces. It is enough for Calatrava to play with standard elements such as doors and windows to change the appearance or shape of the entire building.[53]

This change in the appearance or shape of the building is the result of actual movement which will be discussed in this chapter. Calatrava is discussed as using three distinct ways to bring actual mobility in his structures, these are "unfolding", "rising" and "revolving", which are terms borrowed from Tzonis.[54]

---

[48] See [Home page: http://www.monticello.org, accessed: 20 November 2006]
[49] William Zuk and Roger H. Clark, "Kinetic Geneses," Kinetic Architecture, Van Nostrand Reinhold Company, New York, 1970, p 29
[50] See [Home page: http://www.eyeconart.net, http://www.eyeconart.net/history/ancient/Colosseum.htm, accessed: 25 November 2006]
[51] ob.cit. Zuk and Roger, p 29
[52] Alexander Tzonis and Liane Lefaivre, "Dream-Work and Moving Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 19
[53] Mirko Zardini, "Mobile Pages," Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996, p 59
[54] Alexander Tzonis, "Schools without Walls," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, pp 17-28

2.1. UNFOLDING

> unfold / *transitive verb*: 1 a: to open the folds of: spread or straighten out: EXPAND <unfolded the map> b: to remove (as a package) from the folds: UNWRAP
> 2: to open to the view: REVEAL; especially: to make clear by gradual disclosure and often by recital
> / *intransitive verb:* 1 a: to open from a folded state: open out: EXPAND b: BLOSSOM
> 2: DEVELOP, EVOLVE <as the story unfolds>
> 3: to open out gradually to the view or understanding: become known <a panorama unfolds before their eyes>[55]

Calatrava has designed works that have unfolding parts. The moving parts of all these structures are surfaces consisting of "repeated long and slender elements, or slats".[56] These slats are connected to each other by means of pivotal joints. Other than these joints represented as 'points of unfolding' in the following sketches, two more significant points are observed in the basic structures of Calatrava's unfolding works; 'free point' and 'fixed point'. The mechanism of movement will be analyzed in the guidance of these structural points.

Ernsting Warehouse and Distribution Centre

(Coesfeld, Germany, 1983-1985):

Figure 2-5 Ernsting Warehouse and Distribution Centre_ exterior view

[55] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 20 November 2006]

[56] Anthony Tischhauser, "Aspects of Movement in the Work of Santiago Calatrava," Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996, p 16

The plan and the structural system of Ernsting Warehouse and Distribution Center were designed by Gerzi, a specialized construction firm. As being an orthogonal prism, the structure has 102.3 meters length, 68.6 meters width and 15 meters height (Figure 2-5).[57] Calatrava in collaboration with other two architects, Bruno Reichlin and Fabio Reinhart, designed the facades of the centre. As covered with a corrugated aluminum cladding, the skin of the structure has convex and concave sequences like a folding surface. The task of Calatrava to dress a pre-designed structure also comprises the design of three large service entrances. The entrances have the capability of folding to give access. [58]

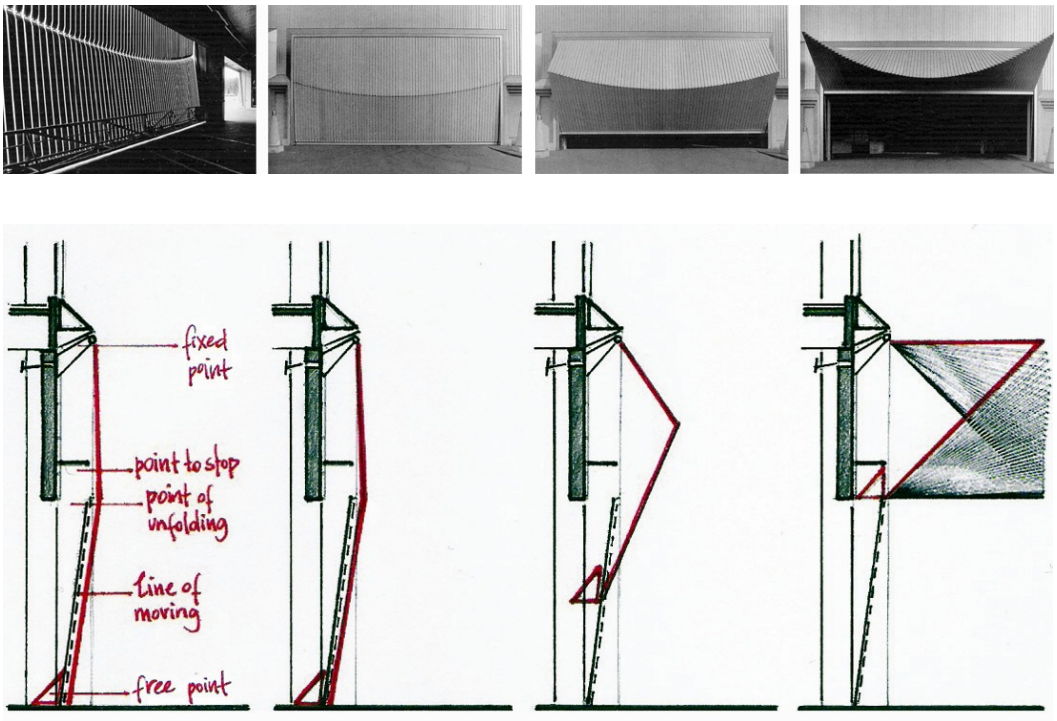


Figure 2-6 Ernsting Warehouse and Distribution Centre_ sequences of unfolding
above: sequential views
below: sequential sections

Three garage doors of Ernsting Warehouse and Distribution Centre open by means of folding. The doors are continuous planes composed of varying profiles. U profiles are used to form the upper parts while the lower parts are made of

[57] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0000440, accessed: 21 November 2006]
[58] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, pp 66-68

aluminum T profiles. Upper ends of each U profile are fixed to the door structure to create ‘fixed points’. The other ends of them are connected with their pairs in the lower part by means of pivotal joints to create ‘points of unfolding’. The lower ends of T profiles, on the other hand, create ‘free points’ although they are tied to each other with a horizontal truss element. Doors fold with the movement of this truss element. While the truss arises along its rail, the profiles protrude forward as folding themselves to unfold the interior. The action of folding continues till the truss completes its way. The doors become horizontal canopies at this last phase. The uniform change in the lengths of upper and lower profiles is an essential design principle that makes this process possible. The ‘points of unfolding’ are placed lower at the sides and higher towards the center. This articulation provides a functional solution while implying movement with its deliberate form. Such intentions in the form researches will be explained in the further chapter.

Pfalzkeller Emergency Services Center (St. Gallen, Switzerland, 1988-1998):

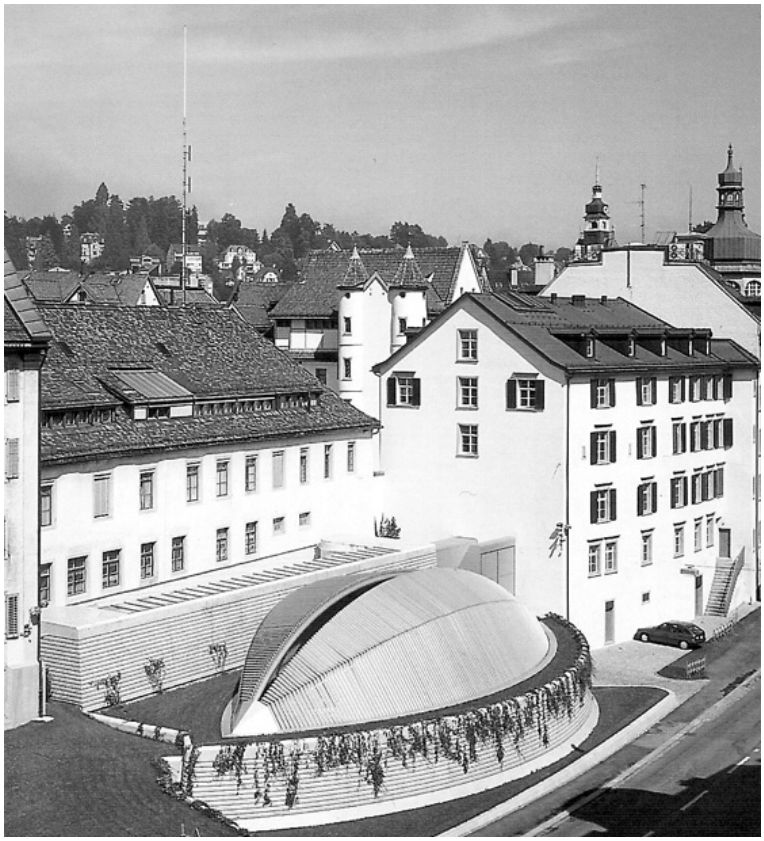


Figure 2-7 Pfalzkeller Emergency Service Center_ exterior view

Pfalzkeller Emergency Services Center is a twenty-four-hour facility from which the canton's traffic system is coordinated. The center is placed underground to respect the historical characteristics of its physical context which is a UNESCO-designated World Heritage site. Longing 43 meters with a height of 7.6 meters, the structure widens 15.3 meters at its largest section (Figure 2-7).[59] The center is covered with an elliptical roof made out of glass elements supporting themselves along the curved ridge of the structure. An unfolding wrap constructed on the glass roof is the apparatus used to control daylight and temperature. [60]

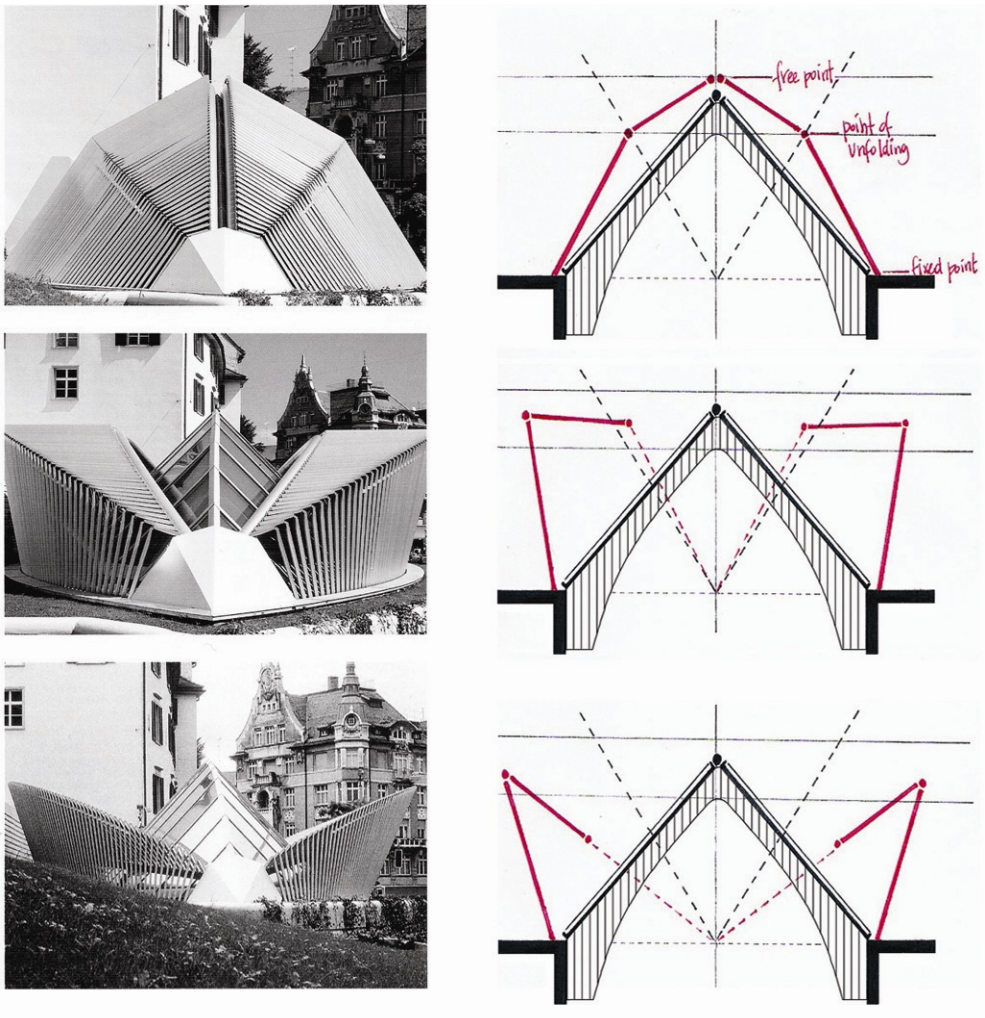


Figure 2-8 Pfalzkeller Emergency Service Center_ sequences of unfolding
left: sequential views
right: sequential sections

[59] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0004099_261006, accessed: 28 November 2006]
[60] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 164

The wrap is configured similarly with the garage doors of Ernsting Warehouse. However, this system differs in several ways. Firstly, the act of unfolding is mechanical in this case. The slats of the wrap are unfolded by a mechanical hoist which is designed particularly for the center. Secondly, the ‘fixed points’ and ‘free points’ change their places alternatively. The slats are fixed from their lower sides to the ground and freed from the structure at the upper side where they are connected to arched tubes. Moreover, a symmetrical configuration is used here to unwrap the inside. Two opposing structures fold themselves and apart from each other to unfold the interior. Unfolding the wrap is needed to illuminate inside.

Alcoy Community Hall (Alcoy, Spain, 1992-1995):

Figure 2-9 Alcoy Community Hall_ exterior view

Remodeling of a central square; Plaza de España including the construction of a community hall with a capacity of six hundred people is the scope of the project. Alcoy Community Hall is designed as an underground space. It has a trapezoidal shape that longs 90 meters. Its width ranges between 7 and 16 meters with a constant height of 9 meters. Supported by means of a concrete arch system, the

roof of the hall is in fact a part of a central square; Plaza de España. Both sides of the plaza host entrances for the hall. The Western entrance, other than its function of access, becomes a part of paving of the plaza when it is closed. The Eastern entrance, on the other hand, is marked by a fountain in a circular pool which can be closed by means of folding to form a secure surface for pedestrians.[61]

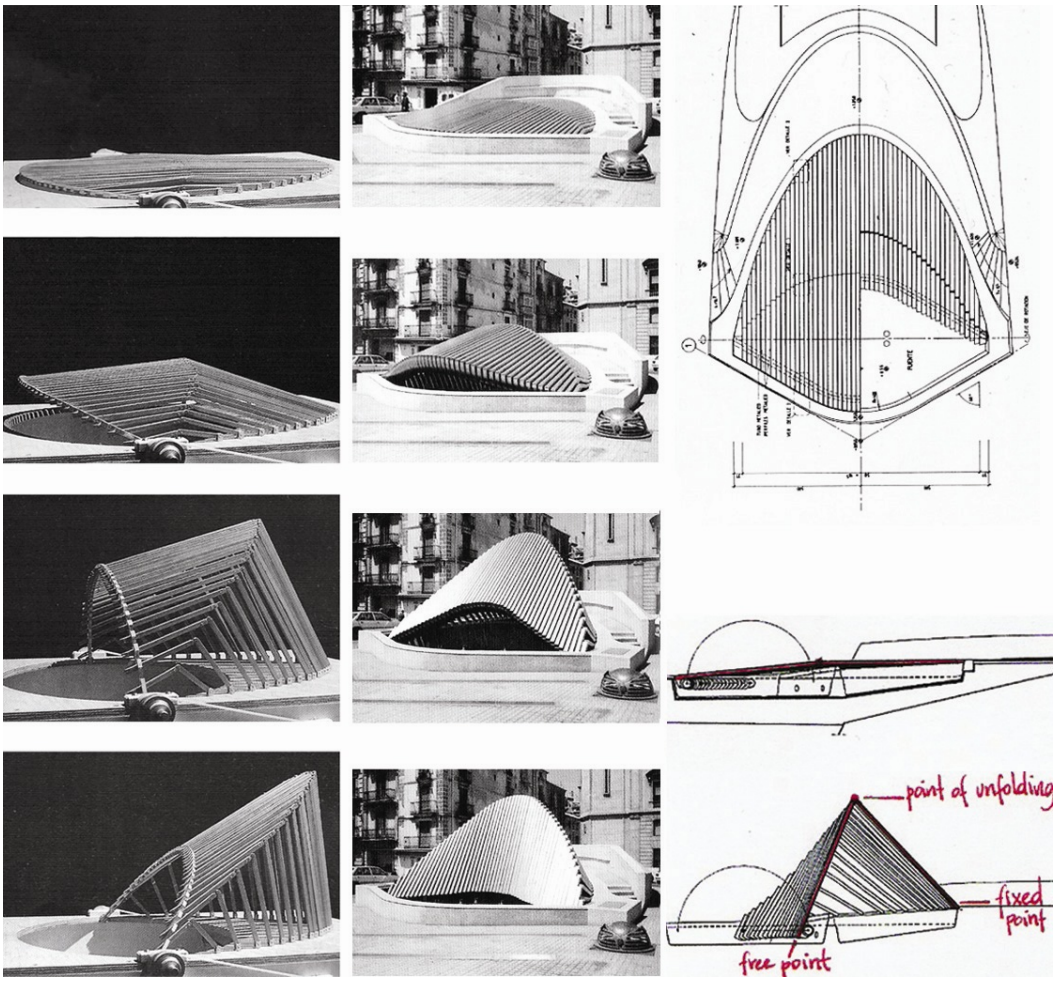


Figure 2-10 Alcoy Community Hall – fountain _ sequences of unfolding
left: sequential views
right: plan and sequential sections

The unfolding envelope that covers the fountain also has the same basic structural configuration with the unfolding doors and roof. The slats placed side by side have 'fixed points' on the ground, 'points of unfolding' at their junction

[61] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 240

peaks and ‘free points’ at their other ends where they are connected to a mobile beam. The beam is an arched tube that sweeps a circular path through its imaginary orbit. This circular move enables the slats protrude towards the air and fold the structure. The arched beam completes its journey as creating remarkable changes in the environment. Pavement leaves its place to a fountain while sunlight shining on the ground becomes reflected on the water. Just one system is used to reveal the fountain. The envelope folds itself to unfold the wrapped hidden inside.

In all the cases studied, folding action occurs to unfold the hidden. Hence, there is a mutual existence of folding and unfolding in the structures of Calatrava. Some parts of the structure fold themselves to unfold other parts. This dialectical existence is possible since folding and unfolding are not opposing issues. Gilles Deleuze states in his book entitled *the Fold: Leibniz and the Baroque* that “unfolding is not the contrary of folding, but follows the fold up to the following fold”.[62] To unfold is defined as “to increase, to grow” whereas to fold is defined as “to diminish, to reduce” by Deleuze.[63]

It is possible to see conditions of folding and unfolding as a mutual binary that occur simultaneously. A part folds; diminishes and reduces its size and therefore the inner part unfolds; increases its size and grows. This increase continues till the following fold is developed. Therefore, unfolding happens after one fold up to another. The wrap of the Pfalzkeller Emergency Center diminishes and folds itself as its glass roof grows and unfolds as another fold.

Although they transform due to simultaneous movements, unfolding structures are discussed as continuous systems by Greg Lynn in his article entitled *Architectural Curvilinearity: the Folded, the Pliant and the Supple:*

> If there is a single effect produced in architecture by folding, it will be the ability to integrate unrelated elements within a new continuous mixture. [64]

---

[62] Gilles Deleuze, The Fold: Leibniz and the Baroque, translated by Tom Conley, University of Minnesota Press, Minneapolis, 1993, p 6
[63] ibid. Deleuze, pp 8-9
[64] Greg Lynn, “Architectural Curvilinearity: the Folded, the Pliant and the Supple,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, p 8

Lynn states that folding employs “a supple layering” to obtain this continuous mixture. He develops this idea by defining folding in geology. In geology, the stratum is accepted as a compressed integrity of continuous layers. These layers are composed of sedimented mineral elements or deposits that slowly bent and compacted.[65]

Similarly, the unfolding structures of Calatrava can be read as strata, similarly. They are composed of different layers placed on each other. For instance, the fountain of Alcoy Community Hall has three layers; the outer envelope, the basin of the circular pool and the entrance of the hall.

These distinct layers, each carrying its own identity, are related to each other through unfolding. By making each layer perceivable due to constant movements, a continuous mixture is obtained. Movement, materialized as unfolding, is introduced as a tool to bring distinct architectural layers together. Deleuze suggests that unfolding not only connects these layers but also adds to their identities:

> It is an envelope of inherence or of unilateral “inhesion”: inclusion or inherence is *the final cause of the fold*, such that we move indiscernibly from the latter to the former. Between the two, a gap is opened which makes the envelope the reason for the fold: what is folded is the included, the inherent. It can be stated that what is folded is only virtual and currently exists only in an envelope, in something that envelopes it.[66]

2.2. RISING

> rise / *intransitive verb*: 1 a: to assume an upright position especially from lying, kneeling, or sitting
> 2 a: to return from death
> 3: to respond warmly: APPLAUD
> 4: to appear above the horizon <the sun rises at six>
> 5 a: to move upward: ASCEND b: to increase in height, size, volume, or pitch
> 6: to extend above other objects
> 8 a: to take place: HAPPEN b: to come into being: ORIGINATE
> 9: to follow as a consequence: RESULT [67]

---

[65] Greg Lynn, “Architectural Curvilinearity: the Folded, the Pliant and the Supple,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, p 9

[66] Gilles Deleuze, The Fold: Leibniz and the Baroque, translated by Tom Conley, University of Minnesota Press, Minneapolis, 1993, p 22

[67] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 05 September 2006]

Unlike ‘unfolding’, ‘rising’ has not been an issue that is studied to be conceptualized by critics. No architectural practice has redefined ‘rising’ as a design strategy, either. Nevertheless, the term carries powerful intellectual connotations. Rising of a structure could be introduced as an architectural response to the particular changes in physical and pre-physical conditions. By employing the concept as a mental issue in architectural production, a new perceptive can develop. High-rise buildings competing with each other on the horizon are the icons of powers they stand for. Other than being an iconic value, ‘rising’ could be used as an actual action in architectural production. Structures could rise or have rising parts to adapt themselves for different physical conditions or to respond pre-physical changes.

Santiago Calatrava’s following structures explore rising as an actual movement. Particular mechanics of the action can be analyzed with the guidance of two structural points; these are “point of unfolding” and “free point”.

Kuwait Pavilion (Seville, Spain, 1991-1992):

Figure 2-11 Kuwait Pavilion _ exterior view

Kuwait Pavilion was designed for the 1992 World's Fair in Seville. The structure is composed of an enclosed exhibition space and a raised piazza covered with a movable roof. The 525 square meter piazza is supported by arched trusses that spring at 2.4 meter intervals at the underground exhibition space. The piazza has a curvilinear surface which is emphasized with terraces of steps descending in the same curvilinearity along each side of the structure. At the top, the steps are parted by concrete supports which carry the ribs of the pavilion's main feature – the movable roof. [68]

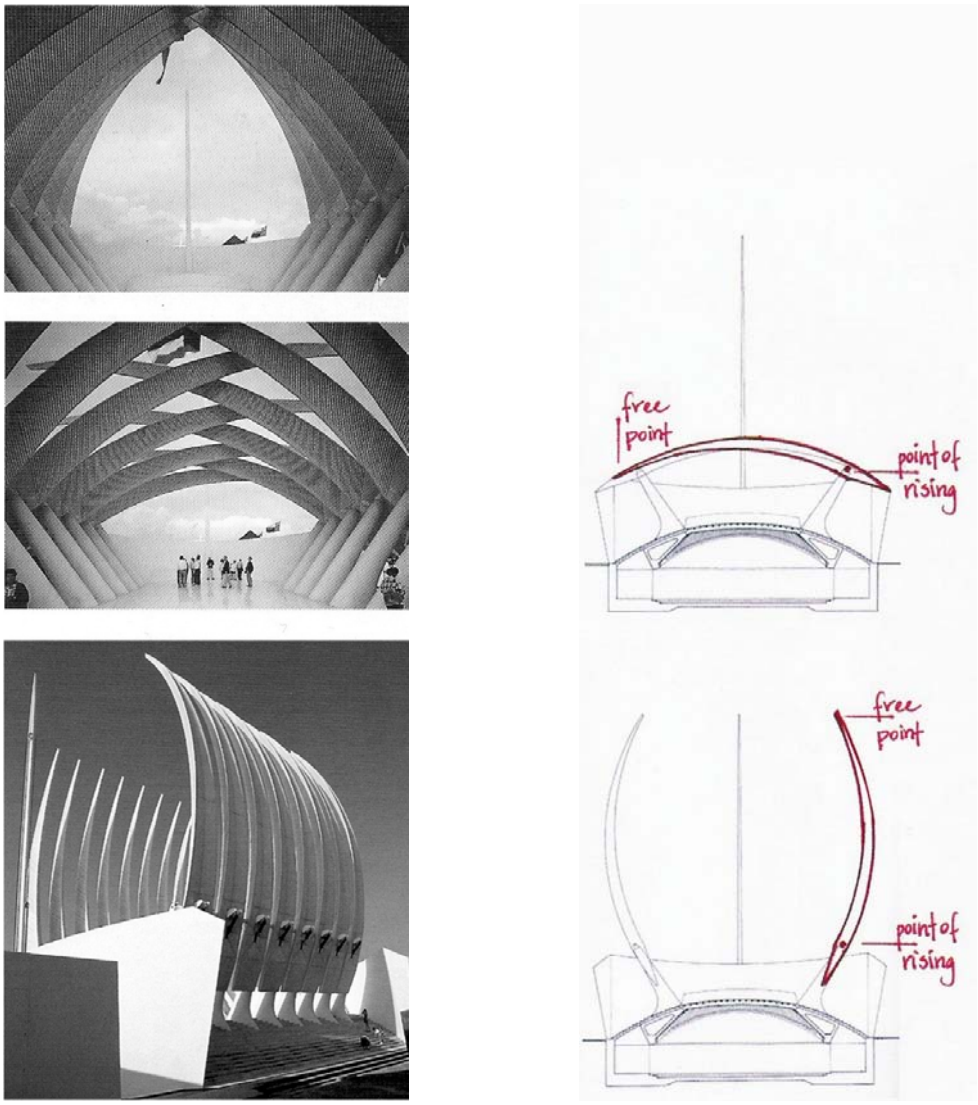


Figure 2-12 Kuwait Pavilion _ sequences of rising
left: sequential views
right: sequential sections

[68] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 210

Seventeen ribs, eight at one side and nine at the other, are the main elements of the movable roof. These ribs are supported on reinforced concrete pillars from their 'points of rising'. When the ribs are closed, they interlace with each other to form a cover but when they rise, the 'free points' go up to sky and the plaza becomes uncovered. Transformation created by rising is a way to reconsider the borders.

Milwaukee Art Museum (Milwaukee, Wisconsin, 1994-2000):

Figure 2-13 Milwaukee Art Museum_ exterior view

To design an overall scheme with a stronger public image for the existing site composed of Eero Saarinen's Metropolitan Milwaukee War Memorial and David Kahler's exhibition space was the scope of the project dating 1994. By letting the existing structure remain intact as a separate unity, a new building near the lake is constructed. This new structure includes an atrium, 1500 square meters of gallery space for temporary exhibitions, an education center with a 300 seat lecture hall, a gift shop, and a restaurant. A footbridge, designed by Calatrava

again, remarks the entrance with its inclined pylon. Another pylon inclined with the same angle supports the conical roof covering the entrance hall. Composed of mobile ribs, the roof is the most striking feature of the project.[69]

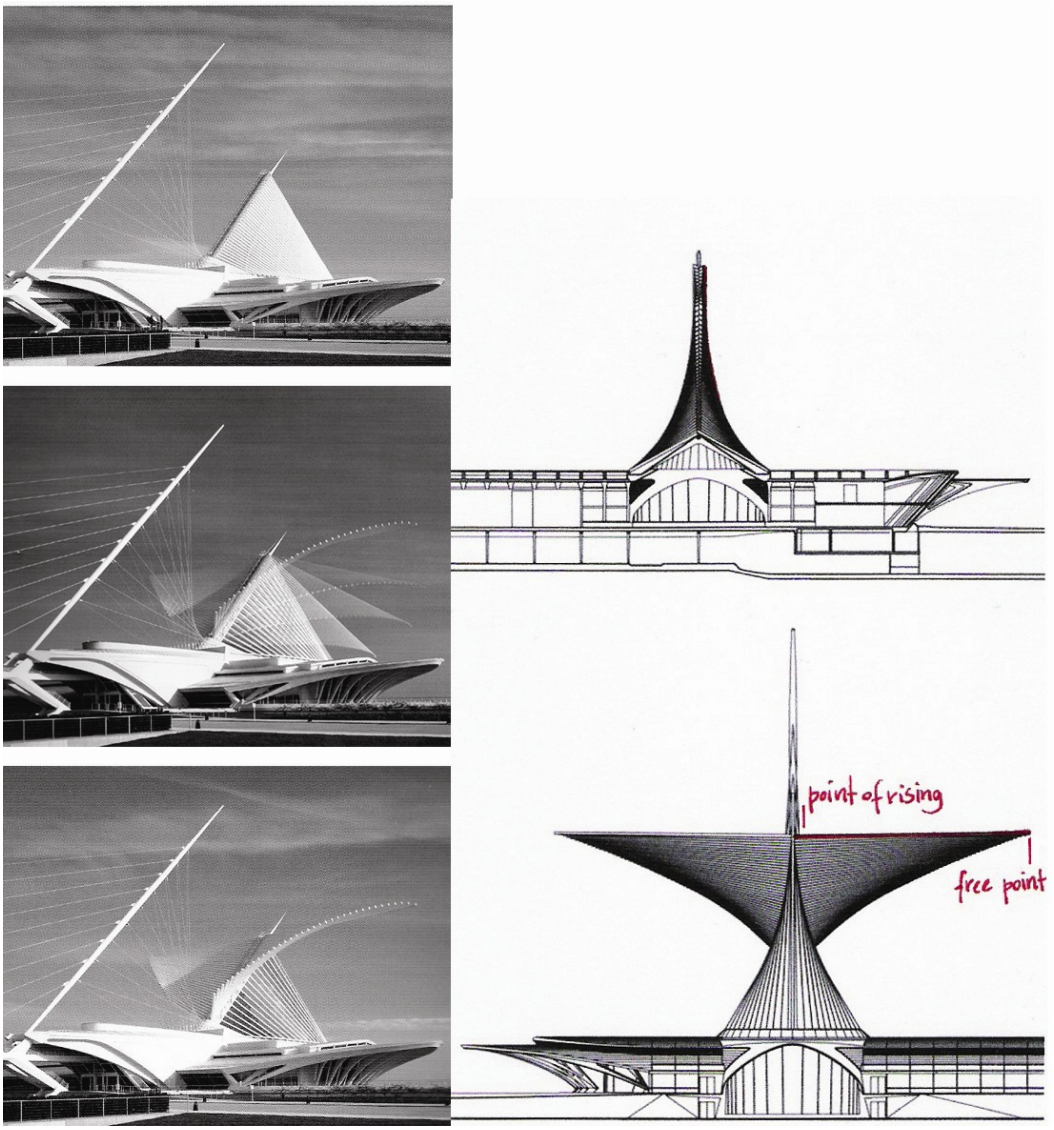


Figure 2-14 Milwaukee Art Museum_ sequences of rising
left: sequential views
right: sequential sections

The conical roof of the museum is composed of two wing elements. Each wing contains thirty-six ribs whose length ranges between 32 and 8 meters. Ribs' 'points of rising' are connected to the central inclined pylon. In their closed

[69] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 290

position, the wings become surfaces that cover the conical structure. In their open position, the glazed facades of structure become uncovered. In this condition, the longest rib remains parallel to the ground plane and the 'free points' form two symmetrical curves. These elegant curves are the features that turn the mobile structure to a "great seagull" taking off towards the lake.[70] Transformation is both functional and symbolic.

2.3. REVOLVING

> revolve / *transitive verb*: 1: to turn over at length in the mind: PONDER <revolve a scheme>
> 2 a *obsolete*: to cause to go round in an orbit b: ROTATE
> / *intransitive verb:* 1: RECUR
> 2 a: to move in a curved path round a center or axis b: to turn or roll round on an axis
> 3: to have or come to a specified focus: CENTER -- usually used with around <the dispute revolved around wages>[71]

"Revolving" will be introduced as the last method of producing actually moving structures. Calatrava designed a few projects that move by means of revolving. These projects vary due to revolving movement they perform.

Heinrich Hertel defines two revolving actions in his book entitled *Structure - Form - Movement*. For the first, "the particle in rotation retains its orientation relative to the center of the circle by turning at the same time around its own center so that the same interior side of the particle is always seen from the center of the circle" (Figure 2-19).[72] On the other hand, the second action is "the rotation of a body around a center without at the same time turning itself" (Figure 2-17). [73] Hertel calls the first action "rotation", and the second action "translational rotation". Rotation is exemplified with the movement of a wheel, where all particles rotate around a center with the same angular velocity. Translational rotation, on the other hand, is demonstrated with the movement of the foot in pedaling a bicycle, where the sole of the foot rotates around a center but always remains horizontal.[74]

---

[70] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 290
[71] Merriam-Webster Online D., [Home page: http://www.m-w.com, accessed: 15 September 2006]
[72] Heinrich Hertel, Structure, Form, Movement, Reinhold, New York, 1966, p 101
[73] ibid. Hertel, p 102
[74] ibid. Hertel, p 102

Among many projects, two specific mobile structures of Calatrava that utilize revolving will be studied. The first one employs translational rotation whereas the second one employs rotation. The diagrams illustrated with the images will be guides to understand the mechanisms of movements.

Shadow Machine (New York, USA and Venice, Italy as Icaros, 1992-1993):

Figure 2-15 Shadow Machine

Shadow Machine is a moving sculpture designed by Calatrava for his 1992 solo exhibition mounted by the Museum of Modern Art in New York. The machine is composed of twelve slender "fingers" and a base. Each finger has 8 meters length and weighs 600 kilograms. The base, on the other hand, is 30 tons and carries protruding fixed supports on which the fingers rest. The moving sculpture creates shadows owing to revolving movements of the fingers.[75]

[75] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 272

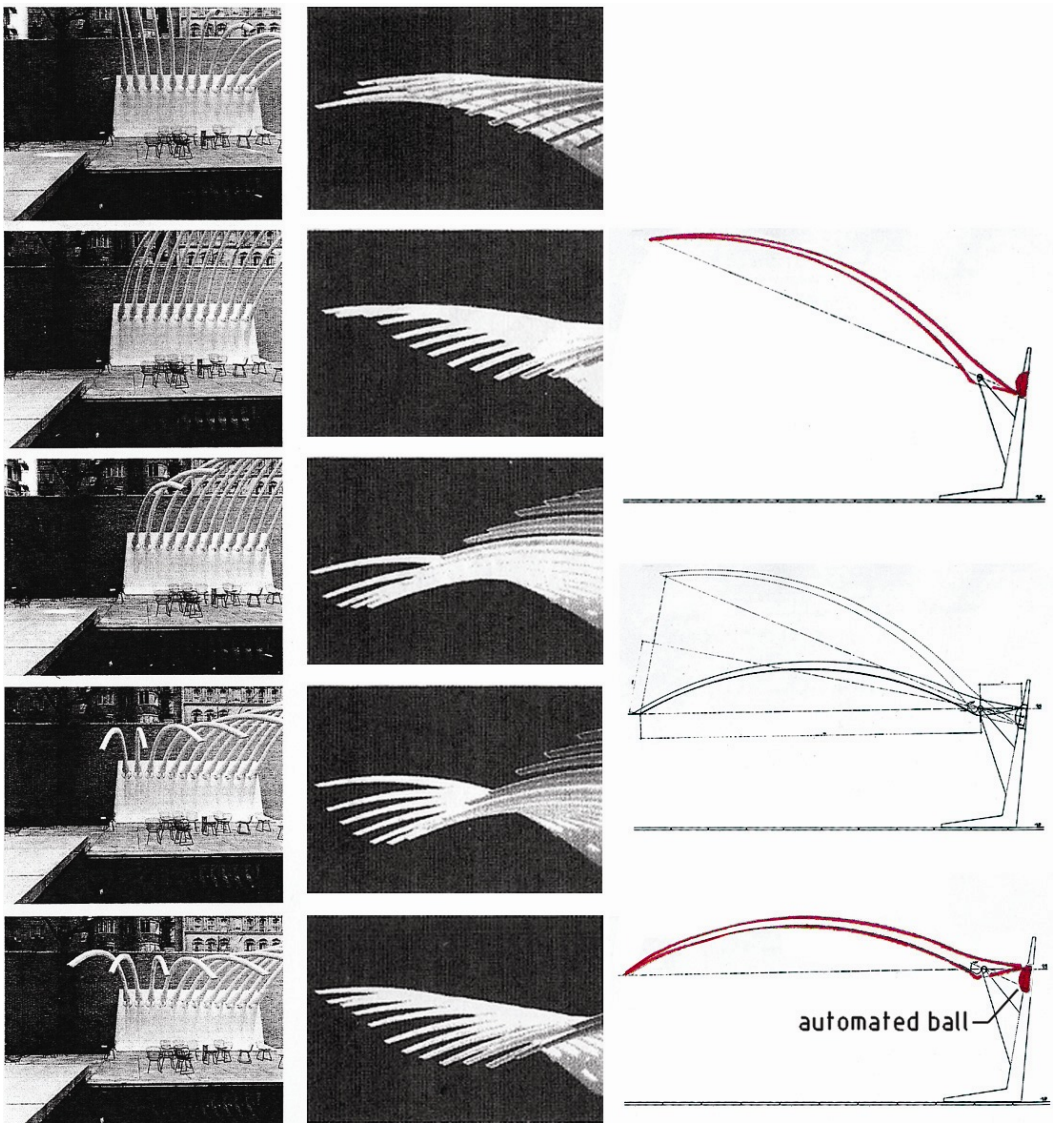


Figure 2-16 Shadow Machine_ sequences of revolving
left: sequential views
right: sequential sections

An intelligent mechanical system is the source for the movements. Each of revolving fingers is connected to an automated ball placed on the supporting wall. These balls are powered by mounted drive sockets on the support rear panel. When the balls turn, the fingers transmit the full circular motions to the tips. This movement is a translation whose mechanics is figured with the below diagram (Figure 2-17). For Shadow Machine, the radius of the circle generated by the fingers as sweeping in the air is the radius; R whereas the center of the automated ball is the center of circle; M. Since the action is a translation, the fingers protect their particular directions during the movement. However, both the heights and the positions of their tips change continuously. The translations

in the fingers are not simultaneous. The action on the each ball has a different start point since each finger is placed at a different point on the circumference of the ball (Figure 2-17). The overall configuration, on the other hand, creates a regular pattern.

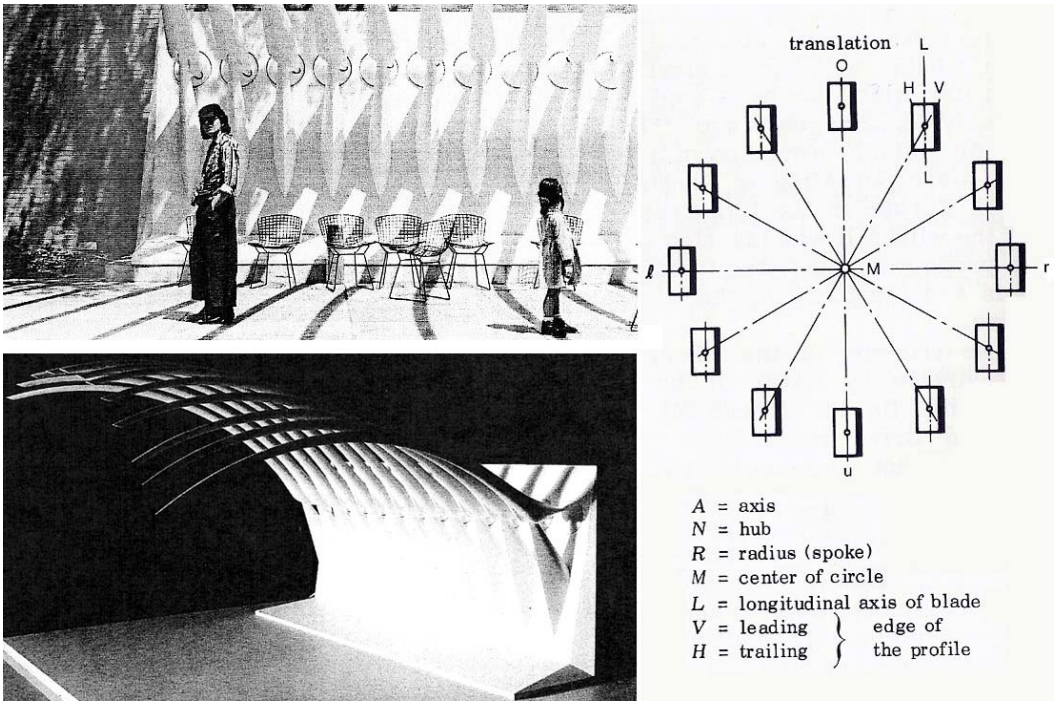


Figure 2-17 left: Shadow Machine _ views of fingers and automated balls
right: the diagram _ translation

Footbridge Puerto Mujer (Buenos Aires, Argentina, 1998-2001):

Figure 2-18 Footbridge Puerto Mujer

Footbridge Puerto Mujer is planned to be designed for marking the renewal of its surrounding area; the old harbor of Buenos Aires. The structure is composed of a single inclined pylon and a revolving deck. The concrete pylon has 39 meters height and the deck has 102 meters length, the bridge is 160 meters at total. The deck is suspended by cables and set between fixed bridges placed at each coast. [76] There is one great pillar formed under the pylon besides three smaller ones. Two of these smaller pillars are placed at the ends of fixed bridges, while the other one is situated in the water at the same line with the great pillar. This pillar in the water is the host for the rotating deck.

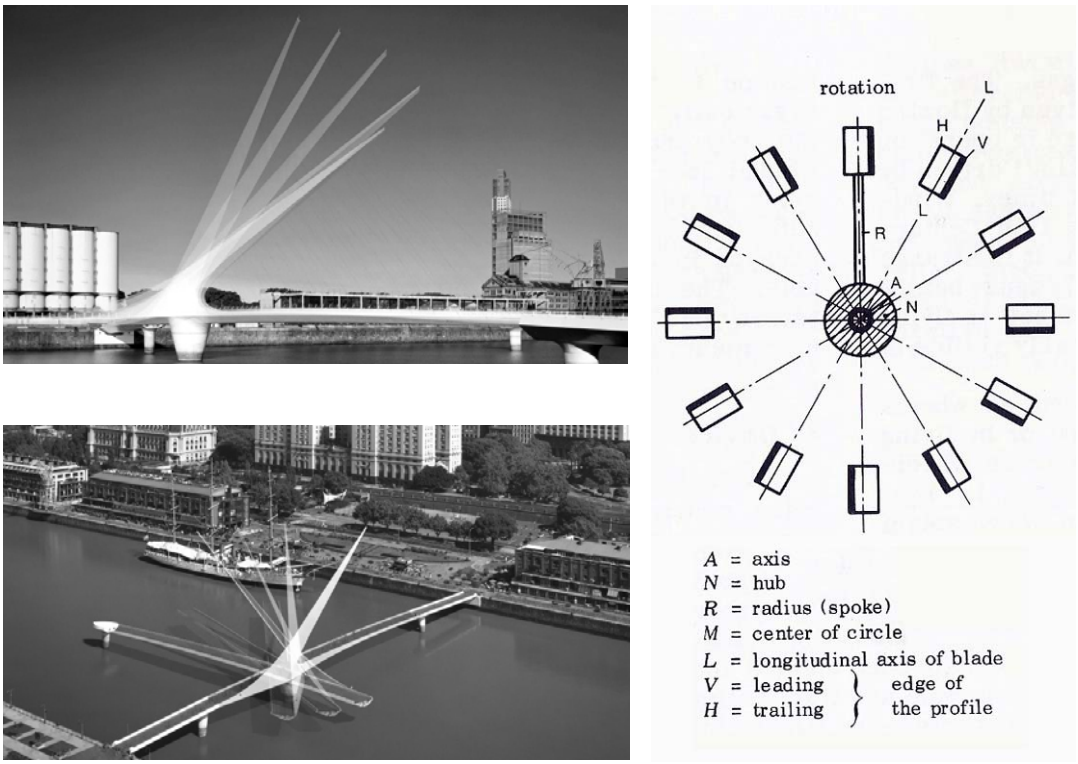


Figure 2-19 Footbridge Puerto Mujer_ sequences of revolving
left: aerial views
right: the diagram_ rotation

The first way of revolving, namely rotating, is the tool that is employed for the movement of Footbridge Puerto Mujer. Bridge's deck rotates 90 degrees on the great pillar. While one end of the deck becomes free, the other end changes its host from one small pillar to another. The diagram of rotation illustrated above

[76] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 328

displays the mechanism of the movement. If the structure is labeled accordingly, the deck is the radius; R, the great pillar is the center; M, and the whole bridge is the longitudinal axis of blade; L. The bridge revolves in order to allow free passages of water traffic. Transformation is needed for answering environmental changes.

CHAPTER 3

BODILY MOVEMENT

> movement / *noun*: 1 a (1): the act or process of moving; especially: change of place or position or posture ***(2): a particular instance or manner of moving**** b: ACTION, ACTIVITY -- usually used in plural
> 2 a: TENDENCY, TREND <detected a movement toward fairer pricing> b: a series of organized activities working toward an objective; also: an organized effort to promote or attain an end
> 3: the moving parts of a mechanism that transmit a definite motion
> 4 a: MOTION 7 b: the rhythmic character or quality of a musical composition c: a distinct structural unit or division having its own key, rhythmic structure, and themes and forming part of an extended musical composition d: particular rhythmic flow of language: CADENCE
> 5 the quality (as in a painting or sculpture) of representing or suggesting motion.[77]

Bodily movement is the tool for designing structures "that serve mobile objects" such as automobiles, trains and human beings.[78] Movement becomes a device to generate structures as systems that channel particular instances of moving. Alexander Tzonis presents Horace Benedict de Saussure's study on the morphology of mountains dating 18th century as the first experiment to define movement as a generative tool.[79] Saussure's researches on the configurations of Alps resulted in the conclusion that the mountains are shaped "through the action of glaciers, torrents, or other kinds of movement".[80] John Ruskin's writings on the same subject entitled On the Sculpture of Mountains and Resulting Form are also indicated by Tzonis as studies that identify mountains as forms produced by actions, power and motion.[81]

---

[77] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 5 October 2006]
* Emphasis by the author.
[78] Alexander Tzonis, "Schools without Walls," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 28
[79] Alexander Tzonis and Liane Lefaivre, "Movement Streamlining Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 108
[80] ibid. Tzonis and Lefaivre, p 108
[81] ibid. Tzonis and Lefaivre, p 110

Figure 3-1 shows Ruskin's drawings illustrating his studies on the morphogenetic process that shapes the structure of Alps.

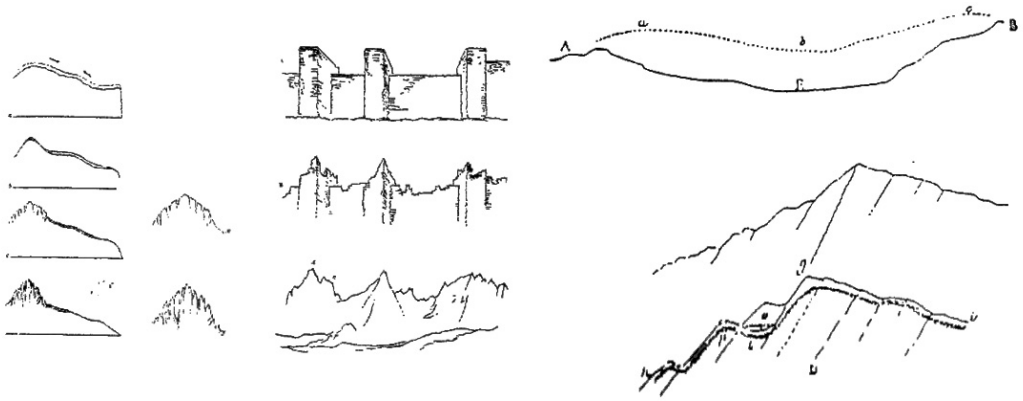


Figure 3-1 drawings of the Alps from John Ruskin

In the 19th century, Eugene Viollet-Le-Duc studied the same subject. He explained the current form of mountains as works of movement similar to Ruskin.[82] Viollet-Le-Duc's book entitled Massif of the Mont-Blanc is presented by Tzonis as a major work that covers series of diagrams showing the formal transformations of mountains (Figure 3-2).

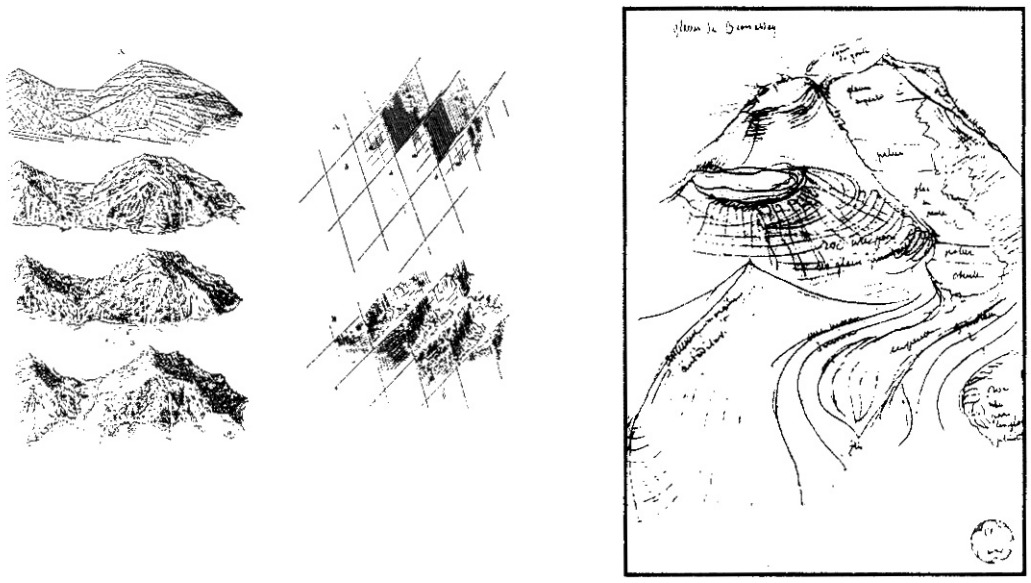


Figure 3-2 drawings of the Alps from Viollet-Le-Duc

[82] Alexander Tzonis and Liane Lefaivre, "Movement Streamlining Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 112

Studies of Saussure, Ruskin and Viollet-Le-Duc on the morphology of mountains prove that a particular movement may become an essential tool for shaping a mass. In this respect, the study of Ruskin on “the shape of the roof of a building” is introduced as the only convincing application to architecture.[83] Tzonis depicts Ruskin’s study as presenting “the climate of a region, the movement of water and snow” as the determining factors of a roof shape “as an analogy of the movement of glaciers shaping the Alps”.[84] Figure 3-3 illustrates the related drawings. Ruskin’s attempt to form the structure according to flows it holds can be derived from the drawings. Hence, besides masses, movement becomes a tool for shaping structures also.

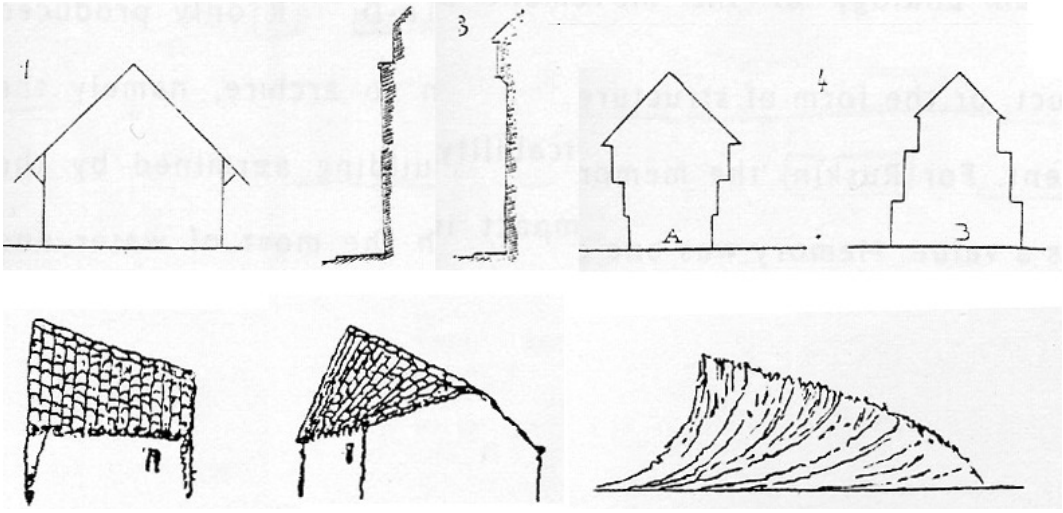


Figure 3-3 Ruskin’s comparison between mountain ridges and house gables.

Mountains are formed with the movements of water and wind mainly and they serve to their generators. The mass becomes the earth for the paths of water and paths of wind. Similarly, the roof is developed into a surface for the same paths. The difference in between is the producer. For the case of mountains, the producer is the generators, water and wind, since they open their ways on the mass themselves. For the case of roof, on the other hand, the producer is the architect who chooses movement as the appropriate tool for shaping the structure. The situation is identified as “a paradigm about form, structure, and

[83] Alexander Tzonis and Liane Lefaivre, “Non Finito,” Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 116
[84] ibid. Tzonis and Lefaivre, p 110

movement, rather than an isolated story about the shaping of a single object" by Tzonis.[85] Although shaping a roof is a very basic example, the case exposes the particular architectural attitude. The structures which serve to distinct movements may be designed by the architect as the bodily moving channels. The outline of the structure together with its inner articulation is designed with the data obtained from the accommodated flows. The directions of the fluxes, the types of mobiles creating these flows, their speed and density are just some of the data that constitute the design criteria. The bodily moving structure obeys such rules of the movements it inherits so serve to its generators.

In the 20th century, UN Studio, an international architectural office situated in Amsterdam, reintroduced bodily movement as the tool for "Deep Planning". Deep Planning is defined as "the integrated, time- and user-based approach to urbanism and infrastructure" by Ben van Berkel and Caroline Bos, two co-founders and directors of UN Studio.[86] The designers note that the strategy is developed in a series of projects starting from their well known Erasmus Bridge (1990-1996) in Rotterdam and continuing with several others including studies of the future of Manhattanization on New York's West Side for the IFCCA, and the relation between urban identity and demographics in Arnhem.[87] The series include projects for urban redevelopment studies and station structures. Common feature in the projects is the architectural research for a "global network" which connects several distinct flows that belong to distinct mobiles. This search turns the concept of movement to a cornerstone for the design strategy:

> Movement studies are a cornerstone of Deep Planning: analysis of the types of movement on a particular location includes the directions of the various trajectories, their prominence in relation to the forms of transportation available, their duration, their links to various programs and their inter-connections. The reason why so much effort is invested in mapping information about the actual and projected flow of movement, is that this information, together with time, defines use; and use is the most vital ingredient determining the future of a location. Since no program is thinkable without people, no value can exist without users.[88]

---

[85] Alexander Tzonis and Liane Lefaivre, "Movement Streamlining Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 114
[86] Ben van Berkel and Caroline Bos, UN Studio- Unfold, NAI Publishers, Rotterdam, 2002, p 38
[87] ibid. Berkel and Bos, p 38
[88] ibid. Berkel and Bos, pp 38-39

The flows of users are not seen just as physical movements by UN Studio. They are defined as “the sequences of exchange and interaction in the economic, political and symbolic structures of society”.[89] The changes lived in such mental bodies are also taken as the essential design tools. Their effects on the flows emerge the concept of time as another key issue for Deep Planning strategy. Several distinct flow types changing with time turn the structures into living organisms. The structures become channels for overlapping and conflicting living forces. They are seen as “performance envelopes” that operate through “mobile forces”.[90] Mobile forces are identified by Berkel and Bos as both physical and mental forces, never distinct or static but always in motion.[91] The physical reflections of these forces are the basic generative guides for the design processes. These reflections are provided with the aid of parameter-based techniques. “Mapping of political, managerial, planning, community and private relations, using scenarios, diagrams, parameters, formulas and themes” are some of the methods of UN Studio that they use to embody distinct movements accommodated in the structures. Following figure depicts some movement diagrams created by the office for the Arnhem Central Project (1996-2000).

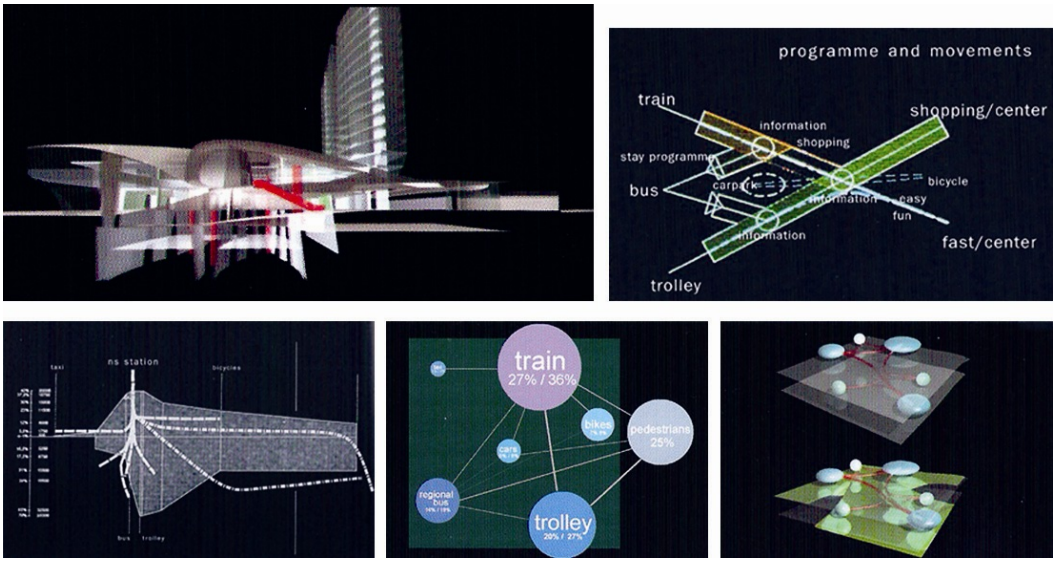


Figure 3-4 up & left: Arnhem Central _ 3D view
up & right: Arnhem Central _ program and movement diagram
down: Arnhem Central _ transportation diagrams

[89] Ben van Berkel and Caroline Bos, UN Studio- Unfold, NAI Publishers, Rotterdam, 2002, p 38
[90] Ben van Berkel and Caroline Bos, “Deep Plan,” Move: v.1 Imagination, UN Studio and Goose Press, Amsterdam,1999, p 31
[91] Ben van Berkel and Caroline Bos, “Personal Dictionary,” Move: v.3 Effects, UN Studio and Goose Press, Amsterdam,1999, p 249

“Arnhem Central fuses pedestrian movements, transport systems, light, construction and various programs into one continuous, utilitarian landscape.”[92] The program includes spaces for transfer hall, underground car park, tunnel, shops and offices. 55,000 travelers, 1,000 cars and 5,000 bicycles move through the center on every week day. Sİx different transport systems converge on the station area.[93] “The transfer zone Arnhem focuses on the finding of overlapping areas of shared parameters and common values. Movement studies are the cornerstone of the proposal” say Berkel and Bos in their book entitled UN Studio – Unfold.[94] Several movement diagrams presented in the book depict the fact. Arnhem Central is designed with the aid of flow studies done on the various motions inherited in the structure. The followings are the similar movement studies of the office for some other projects:

Figure 3-5 IFCCA New York (1999) _ flow diagrams

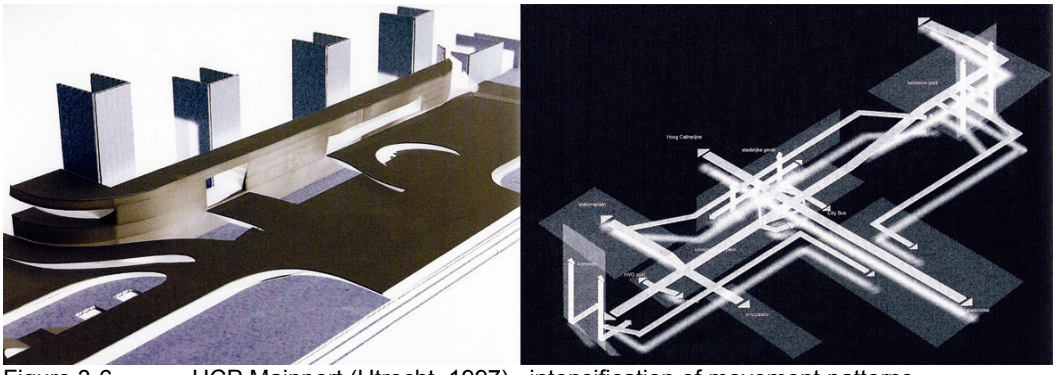


Figure 3-6 UCP Mainport (Utrecht, 1997)_ intensification of movement patterns

[92] Ben van Berkel and Caroline Bos, Move: v.3 Effects, UN Studio and Goose Press, Amsterdam,1999, p 142
[93] Ben van Berkel and Caroline Bos, UN Studio- Unfold, NAI Publishers, Rotterdam, 2002, p 37
[94] ibid. Berkel and Bos, p 37

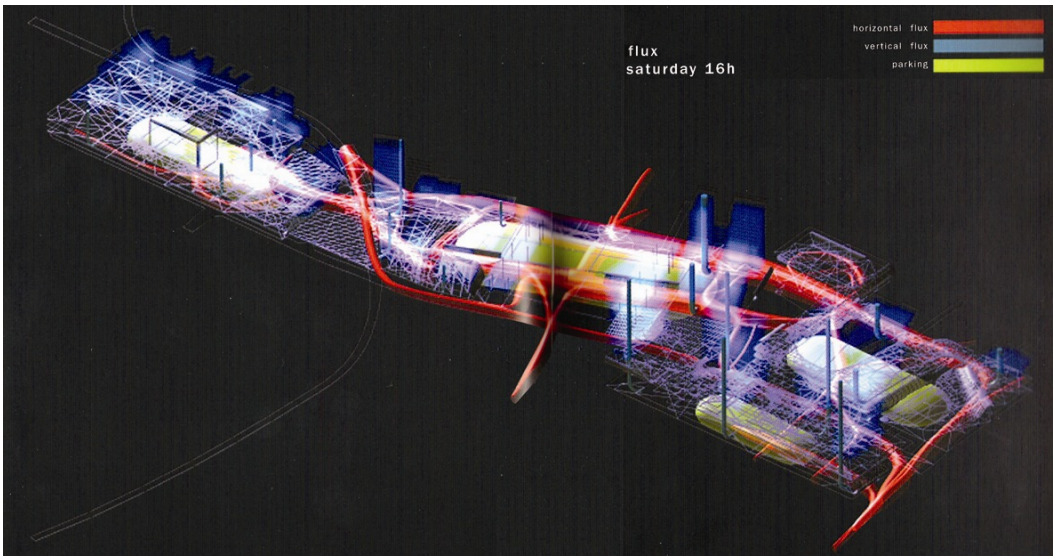


Figure 3-7 Pre-Plan Study (Nieuwegein, 1997- 1998) _ flow diagrams

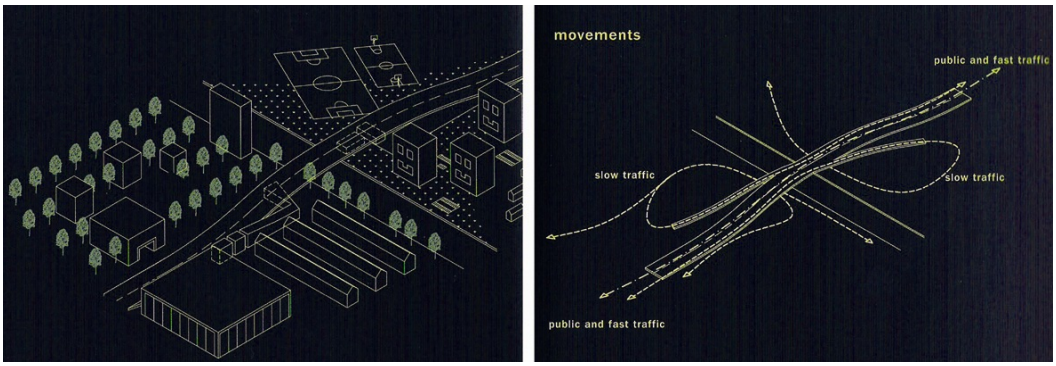


Figure 3-8 HOV Bridge (Utrecht, 1998- 2001) _ flow diagrams

Diagramming is used as a method of embodying mobile forces by UN Studio to practice Deep Planning strategy. It is an interface between the mental body of inherited flows and their physical reflections. Many other methods could be used to provide the related data and form similar interfaces. But rather than such methods, this thesis researches the processes that transform the interfaces into real articulations. The architectural progressions that produce bodily moving spaces with the obtained movement data are the main concern issues. Santiago Calatrava's projects will be explored from this viewpoint.

Similarly, in Calatrava's architectural production, train stations, airports and bridges are the structures that maintain bodily movement. For bridges, channeling diverse movements is an inherent structural characteristic. A flux

from one side to another is the main reason for them to exist. Flows, accommodated by a bridge are the main tools that shape its body. A horizontal plate serves as the connection between the sides as holding fluxes. There is no need to another element for the required function. A bridge is basically a somehow carried deck along which the bodies flow (Figure 3-9). Train stations and airports, on the other hand are the structures that embody several simultaneous movements of distinct mobiles. They may be called as hubs that receive various flows to be circulated for particular directions. This variation in the directions of inherited flows makes the hubs complex structures. The need to create them as good servicing circulatory systems becomes apparent. For this type of an articulation, a significant issue is to obey the rules of the fastest body which is the train in a train station and the airplane for an airport. A train station is a system that connects the passengers to the trains and therefore should follow the ways of train flows. Similarly, an airport connects the travelers with the planes and it is designed accordingly with the routes of plane movements. After the motion lines of the fastest, come other flows which are realized between the fastest and the passengers. Hubs are configured as multiple corridors that link the passengers to their destinations; trains, airplanes or the outlets (Figure 3-10).

Figure 3-9 shaping a bridge along the movements it inherits

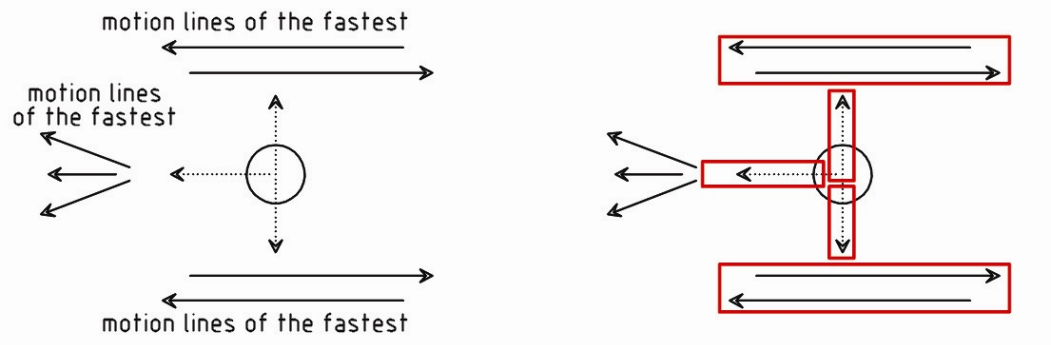


Figure 3-10 shaping a hub (train station / airport) along the movements it inherits

As sheltering several actual motions, such structures introduce various design approaches. Calatrava equips his hubs with bodily movement. His train stations and airports are formed according to the flows they inherit. To achieve this, he uses two main approaches: “channeling through rhythm” and “channeling through shape”.

3.1. CHANNELING THROUGH RHYTHM

> rhythm / *noun*: 1 a: an ordered recurrent alternation of strong and weak elements in the flow of sound and silence in speech b: a particular example or form of rhythm
> 2 a: the aspect of music comprising all the elements (as accent, meter, and tempo) that relate to forward movement b: a characteristic rhythmic pattern <rumba rhythm> c: the group of instruments in a band supplying the rhythm
> 3 a: movement, fluctuation, or variation marked by the regular recurrence or natural flow of related elements b: the repetition in a literary work of phrase, incident, character type, or symbol
> 4: the effect created by the elements in a play, movie, or novel that relate to the temporal development of the action [95]

In his book entitled The Language of Architecture, Sven Hesselgren defines rhythm as “the periodic repetition of similar but non-identical movements”.[96] Hesselgren’s other definitions, given from the view point of perception psychology, illustrate the contextual connection between rhythm and movement.

As rhythm extends in time, motion becomes an essential part of its experience… rhythm can be said to be connected to a transformation to conception of motion… it is also to a great extent perception of motion. [97]

These definitions demonstrate a bidirectional relation between rhythm and movement. First, movement is introduced as an essential part of experiencing rhythm. When rhythm occurs as periodic repetitions of similar elements actualizing within similar time intervals, movement through these repeated elements becomes a way of distinguishing their rhythm. Second, rhythm is presented as a perception of movement. Hesselgren expresses the essence of rhythm “as something flowing by means of continuous repeated oscillations

---

[95] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 15 October 2006]
[96] Sven Hesselgren, The Language of Architecture, Studentlitteratur, Lund, 1969, p 158
[97] ibid. Hesselgren, p 159

between two extremes".[98] If rhythm is a flow that can be perceived by movement, the spaces configured with rhythmical articulations become channels for these flows. As moving along these channels, the inhabitant perceives the rhythm and directs him/herself accordingly through the conduit. Moreover, distinct rhythmical articulations define distinct architectural spaces. The places differentiate owning to particular configurations of repetitions they inherit. Hence, to follow his/her way in the right channel becomes an easy task for an occupant. The use of rhythm as a design tool to equip bodily movement is exemplified with Stadelhofen Railway Station project of Santiago Calatrava.

Stadelhofen Railway Station (Zurich, Switzerland, 1983- 1990):

Figure 3-11 Stadelhofen Railway Station _ exterior view

The project, held with Arnold Amsler and Werner Rueger, comprises the expansion and redefinition of an existing railway station placed between Stadelhofen Square and Hohe Promenade Hill. The structure has 270 meters length that follows the curve of the tracks placed under the hill. Station embodies distinct movements of vehicles and people. To cope with these movements, the structure is parted into separate channels each of which is differentiated by a particular rhythmic configuration. This partition is applied in the vertical configuration hence perceived through the cross section. The plan and the longitudinal section remain identical throughout the full length except the interruptions of four bridges connecting square with the hill through the station

[98] Sven Hesselgren, The Language of Architecture, Studentlitteratur, Lund, 1969, p 162

(Figures 3-12 and 3-13). Three main channels sheltering distinct flows are identified on the cross section (Figure 3-14).

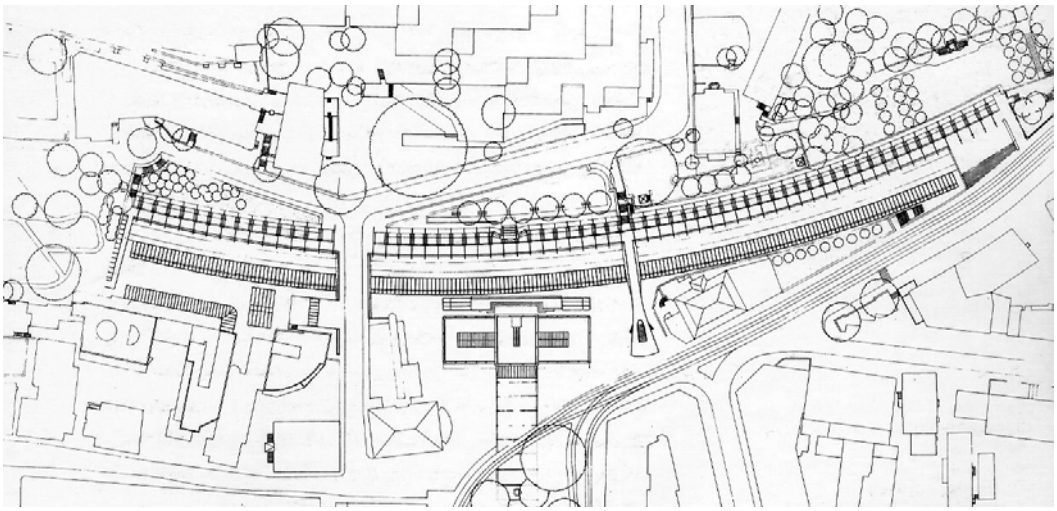


Figure 3-12 Stadelhofen Railway Station _ plan

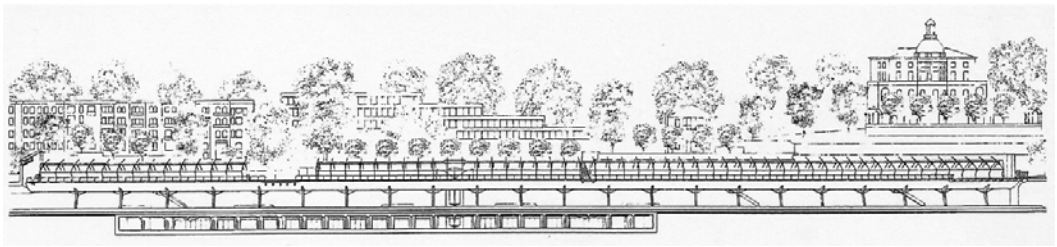


Figure 3-13 Stadelhofen Railway Station _ longitudinal section

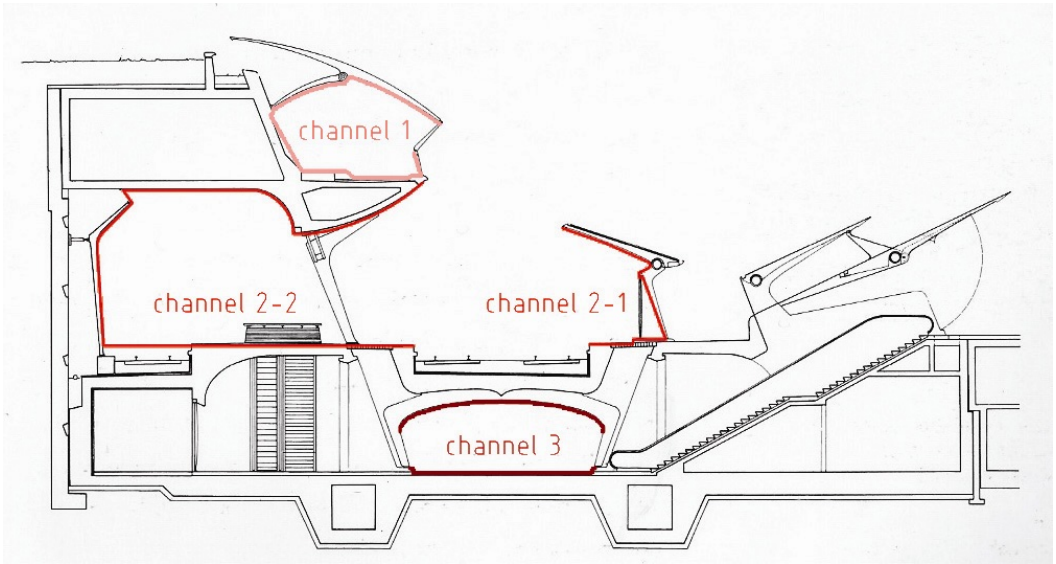


Figure 3-14 Stadelhofen Railway Station _ cross section

The first channel is “the covered promenade overlooking the tracks” that comprises “a series of 5-meter-long steel pergolas sweeping back from the promenade’s edge towards the hill at 4-meter intervals”.[99] This covered promenade is placed at the top level on the hill. It channels the flow of people coming to the station from the hill side, flow of pedestrians approaching the structure from the square through the bridges and flow of “less-harried families and couples who leisurely strolls up and down the hill along the promenade”.[100] The directional continuation of the channel is obtained by the repetition of structural elements including steel structures forming the pergola, balustrades running through the cantilevered edge and the identical modules of concrete composing the retaining wall (Figure 3-15).

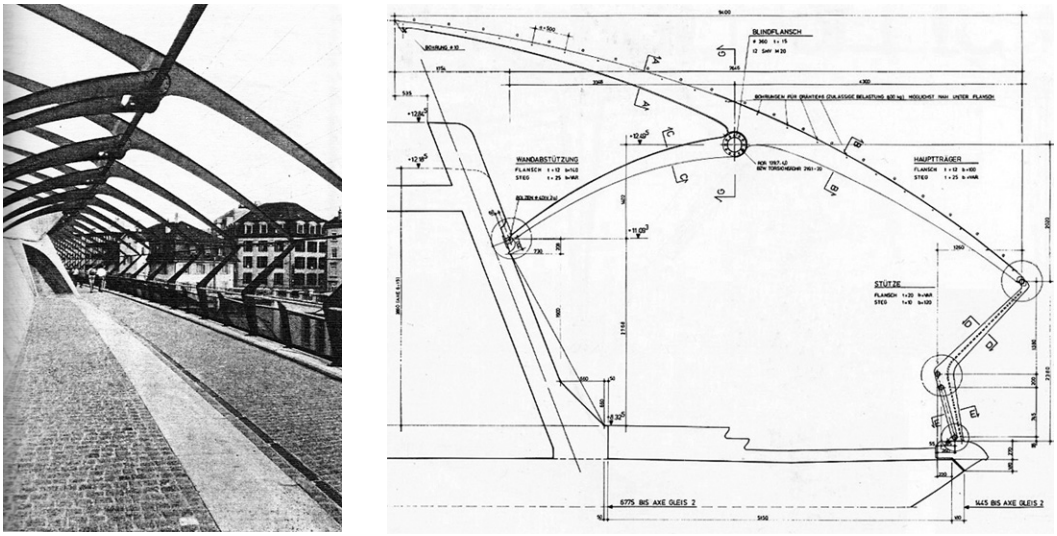


Figure 3-15 left: channel 1 _ covered promenade _ view
right: channel 1 _ covered promenade _ section drawing

The second channel is “the cantilevered platform roof” which is formed by “repeated tripartite Y-shaped columns that support either glass or concrete canopies”.[101] This channel is at the ground level. “The fast regular flow of trains along the tracks, the hasty pedestrian flow entering and leaving the vehicles along the platforms, ascending and descending through the shopping center” are

[99] Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996, p 23
[100] Alexander Tzonis, “Seminal Projects,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 48
[101] Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993

the motions hosted by the cantilevered platform roof.[102] To direct people properly, this channel is subdivided into two. The first sub-channel is configured by tripartite Y-shaped columns that support a glass canopy. Motions of people entering and leaving the trains are sheltered by this structure (Figure 3-16). The second sub-channel, on the other hand, is covered with a concrete canopy carried by similar Y-shaped columns. Stairs, escalators and elevators are placed under this concrete canopy. Hence, this sub-channel shelter people ascending and descending through levels other than the ones entering and leaving the trains (Figure 3-17).

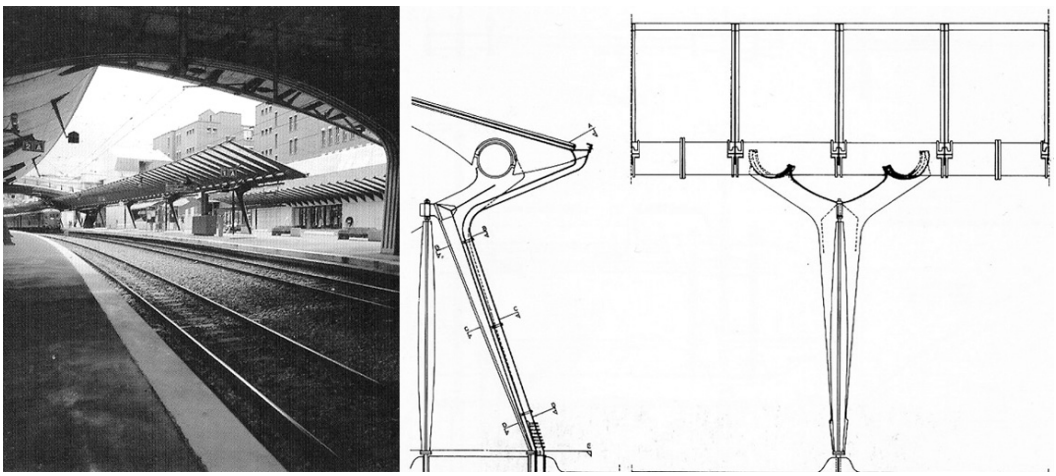


Figure 3-16 left: channel 2 _ cantilevered platform roof _ sub-channel 1 _ view
right: channel 2 _ cantilevered platform roof _ sub-channel 1 _ support

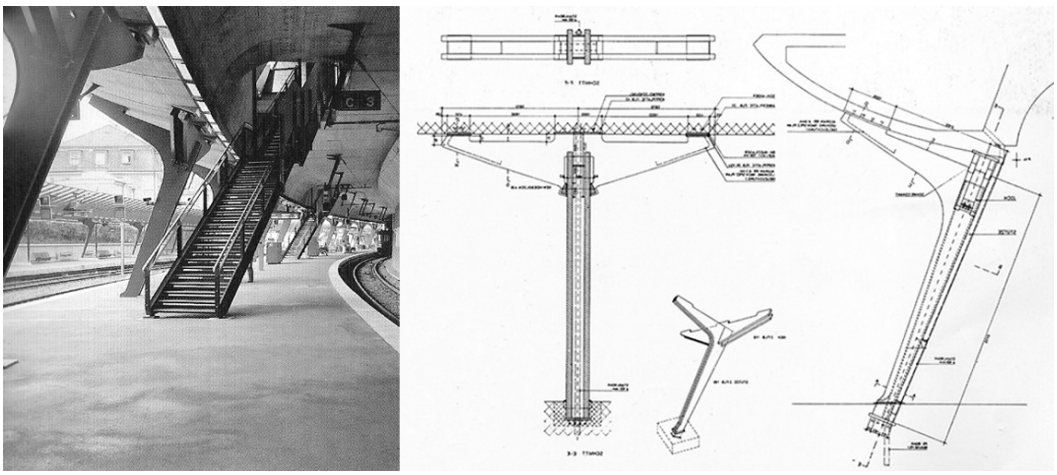
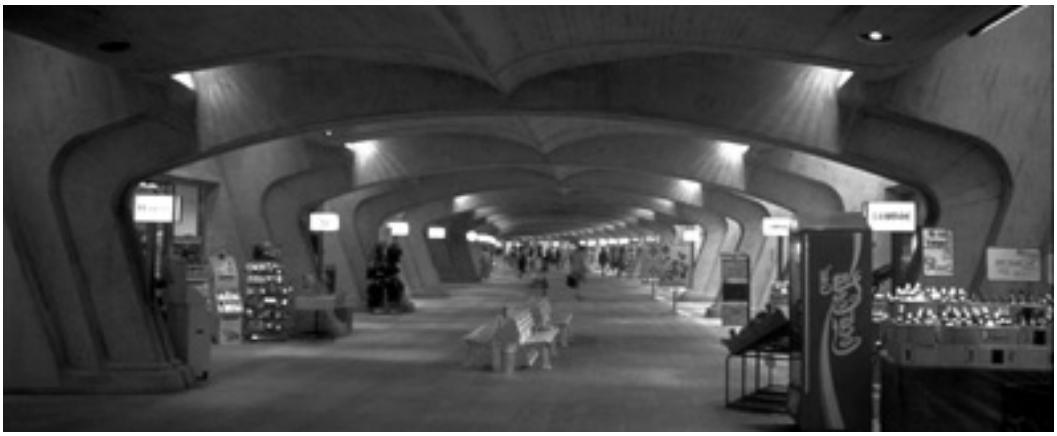
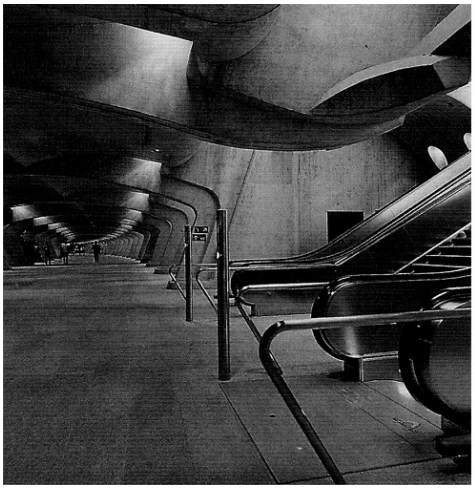


Figure 3-17 left: channel 2 _ cantilevered platform roof _ sub-channel 2 _ view
right: channel 2 _ cantilevered platform roof _ sub-channel 2 _ support

[102] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 74

The last channel is “the underground shopping center” that “exploits the sculptural quality of concrete and resembles a large ribcage.”[103] The commercial channel is at the bottom level, underneath the second one and the train track. It shelters “the flow of pedestrians mingling or walking through the shopping center”.[104] One continuous, undulating concrete surface covers the subterranean shopping center and therefore supports the track bed and platforms. Identical concrete arches carrying this undulating cover are repeated through the channel but omitted at each point of entrance. Hence, the commercial basement directs the people to their destinations by giving clues through the architectural configuration (Figure 3-18).





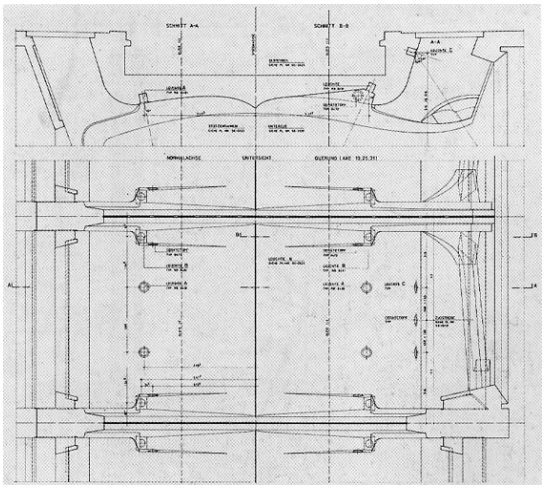


Figure 3-18 above & below-left: channel 3 _ underground shopping center _ view
below-right: channel 3 _ underground shopping center _ support

[103] Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993
[104] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 74

Stadelhofen Railway Station accommodates multiple conduits for distinct movements. Three main channels are used to shelter flows of trains and people. These channels guide mobiles to their destinations through their particular routes. Rhythm is the basic design tool for this guidance. Sven Hesselgren presents rhythm as "the perception of a series of stimuli in such a way that a series of group is perceived. Consecutive groups are mostly similar in pattern and are experienced as repetitions."[105] As characterizing different channels by continuous repetition of specific structural elements, rhythmic organization becomes one of the methods for employing bodily movement.

Stadelhofen Railway Station is compartmentalized into conduits accommodating distinct flows. Not only are the movements along the channels but also the transitions between these conduits properly configured. The success in this configuration is hidden in Calatrava's intelligent cross section design. Three separate channels are tied together in the cross section as both participating differentiating motions and also connecting them in a well woven architectural system. Calatrava refers his design scheme for the station as "design by section" (Figure 3-14).[106]

3.2. CHANNELING THROUGH SHAPE

> shape / *noun*: 1 a: the visible makeup characteristic of a particular item or kind of item b (1): spatial form or contour <the clouds kept changing shape> (2): a standard or universally recognized spatial form <a stain in the shape of a perfect circle>
> 2: the appearance of the body as distinguished from that of the face: FIGURE
> 3 a: PHANTOM, APPARITION <eerie shapes floating in the mist>
> b: assumed appearance
> 4: form of embodiment <our plans are taking shape>
> 5: a mode of existence or form of being having identifying features
> 6: the condition in which someone or something exists at a particular time <the car was in fine shape>[107]

Francis D.K. Ching discusses three items to be concerned with their shapes in architecture. These are "planes (floors, walls, and ceiling) that enclose space",

---

[105] Sven Hesselgren, The Language of Architecture, Studentlitteratur, Lund, 1969, p 158
[106] Alexander Tzonis, "Seminal Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 48
[107] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 20 October 2006]

"openings (windows and doors) within a spatial enclosure" and "the silhouettes of building forms".[108] Deliberately chosen shapes of these architectural elements could become formal configurations that channel movements. Particular characteristics of primary shapes can be used as design tools to control accommodated mobiles. Rather than the circle with its "centralized, introverted figure that is normally stable and self-centering in its environment" and the square which represents "the pure and the rational with a static and neutral figure having no preferred direction", the triangle comes out as the primary shape embodying movement due to its directional quality (Figure 3-19).[109]

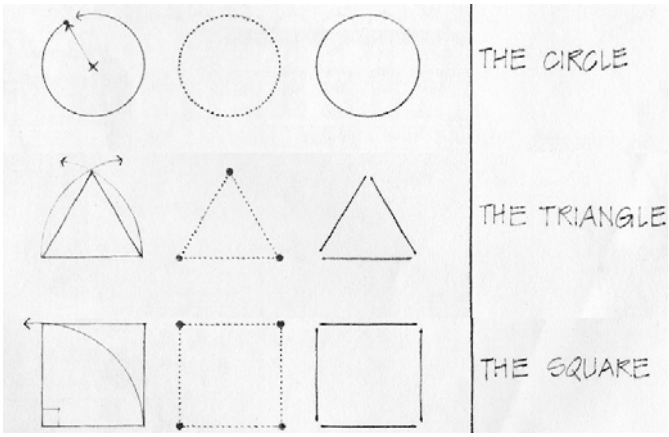


Figure 3-19 the primary shapes _ Ching's illustration

Calatrava uses particular formal characteristics of triangle in his project Lyon Airport Railway Station to embody movements of trains and people.

Lyon Airport Railway Station (Satolas, Lyon, France, 1989- 1994):

A main station building comprising a concourse hall, train platforms and a passageway connecting the station to the adjacent airport is the scheme of the project. "To provide a smooth passenger flow while creating an exciting and symbolic gateway to the region" was the main aim.[110] The structure has 450 meters total length with 100 meters wide, 39 meters high concourse hall.[111] Two

---

[108] Francis Ching, Architecture: Form, Space and Order, Van Nostrand Reinhold, New York, 1979, p 52

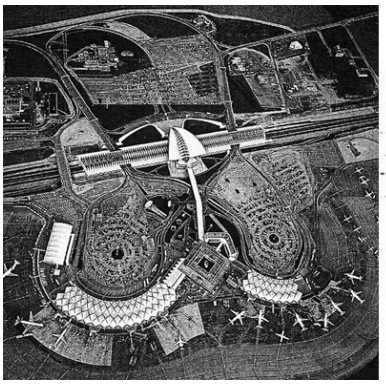
[109] ibid. Ching, pp 55-57

[110] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 174

[111] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0004099_261006, accessed: 15 October 2006]

major parts are identified in the structure; the central concourse hall and two train platform halls spreading on Northern and Southern sides (Figure 3- 21).

Figure 3- 20 Lyon Airport Railway Station _ exterior view



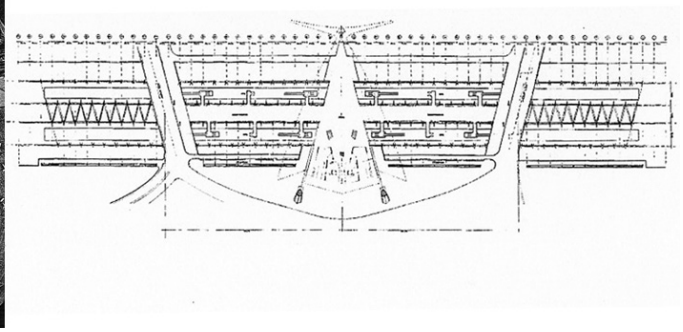
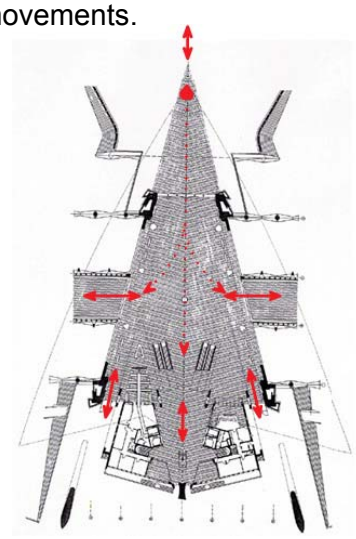
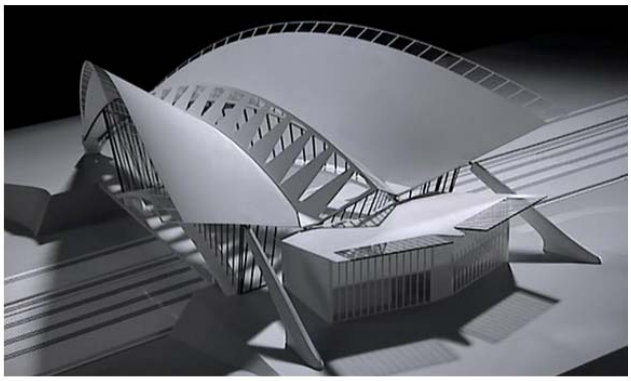


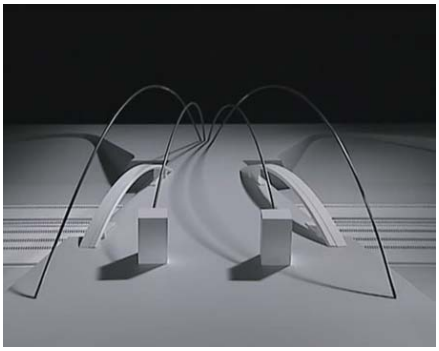
Figure 3- 21 left: Lyon Airport Railway Station _ arial view
right: Lyon Airport Railway Station _ plan

The concourse hall has a triangular plan. Its West vertice acts as the entrance while its other vertices constitute the East side that serves as the interface between the station and the airport (Figure 3-22). The West vertice is signified with a single, V-shaped, concrete pylon supporting four steel arches that comprise the main body of the structure. With its huge, sculpted body, the pylon embodies a departure point, which is the beginning of a travel in the same direction with the inclined form (Figure 3-23). Hence, the West vertice turns to a start point for flows. People arriving by busses and taxis whose terminals are located at this West side are welcomed and directed to the inside by the vertice. The triangular form of the concourse hall guides the flows towards its East side,

where a service core and a raised 180 meters long covered steel gallery are located. The service core is a massive structure housing four levels for staff accommodation, rail services including ticket sales, shops, offices, a bar, a restaurant and a temporary exhibition space. The covered steel gallery is the utensil for the passengers to access the airport (Figure 3-24). Two equal sides of the triangle, on the other hand, the Northern and the Southern surfaces are used as the gateways for the train platforms. Consequently, the concourse hall is designed as an isosceles triangular channel that directs the flow of people either to the service core and the airport on the East periphery or to the platforms for trains spreading on the Northern and the Southern sides. The triangular configuration embodied by the plan and the roof system is the basic design tool for this directional arrangement. The movements take start from a point and flow towards the target at the across side while the other two equal sides serve as secondary targets for other flows. The equality of the Northern and the Southern sides is due to their identical functions as gateways for the same kind of movements.







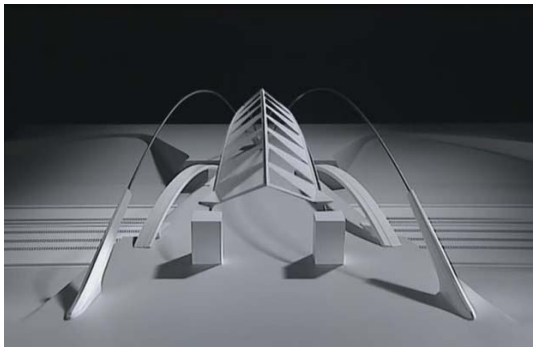
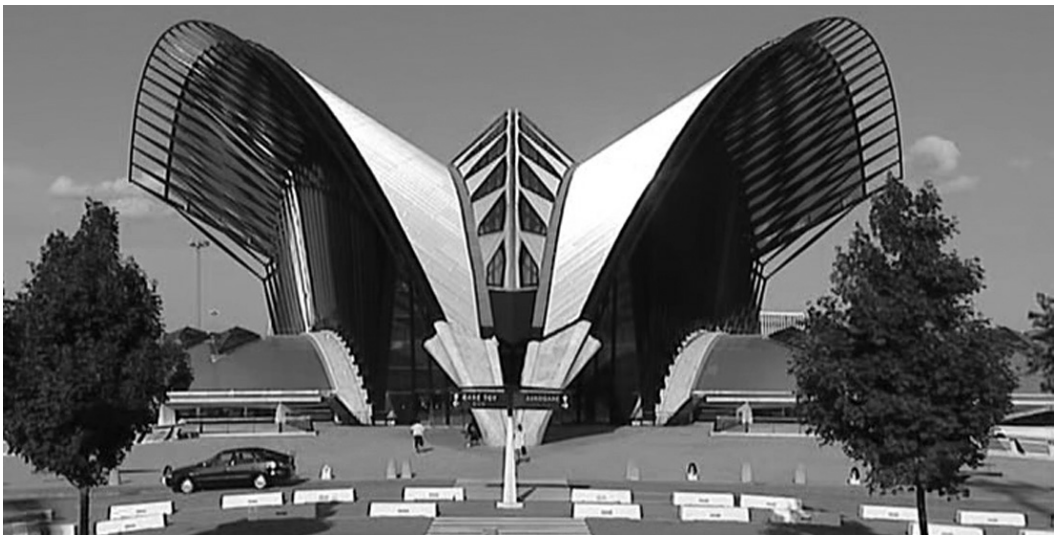
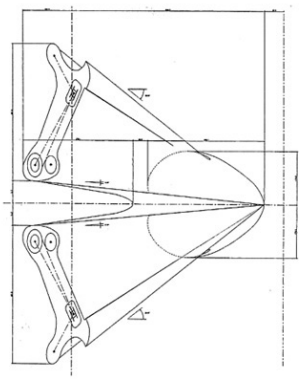


Figure 3-22 above-left: the concourse hall _ plan
above-right & below: the concourse hall _ sequential model views





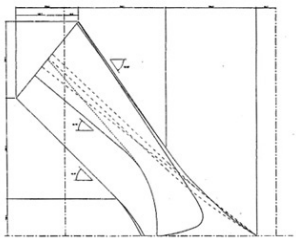
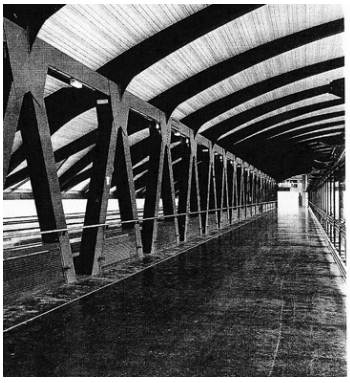


Figure 3-23 above & below-left: the west vertice _ entrance _ view
below-right: the west vertice _ entrance _ detail drawings



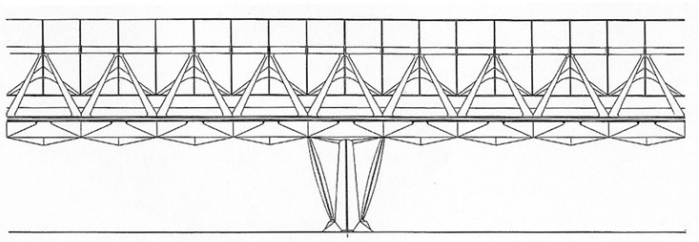


Figure 3-24 left: gallery access to the airport _ interior view
right: gallery access to the airport _ section

The platform halls spreading from the central concourse cover 6 tracks for trains and 2 platforms for passengers. 2 tracks at the middle serve for non-stop high speed trains. To protect the station from sharp waves of trains passing through with 300km/h, this middle part is covered with a concrete caisson. Top of this caisson structure functions for two aims. First, it supports the arches of outer shallow vaults and second, it serves as the surface that links concourse to the platforms via stairs, escalators and lifts (Figure 3-25). This top slab is composed of lateral triangular elements, which turn to be vertical supports for the walls of the halls (Figure 3-26). The outer walls are formed with continuous series of these triangular elements. They are used as empty frameworks at both sides while becoming modulated and filled for the inner walls covering caisson structure. The shape triangle is deliberately chosen for the structure. Calatrava expresses in his speech for the film entitled Satolas – TGV un monument á la campagne:

> Which element really has motion in Satolas Station? The TGV; the train. The fact that a train is passing with 300 km/h can only be shown by extremely static structures. That is why the V-shape is repeated. [112]

"The triangle signifies stability. When resting on one of its sides, the triangle is an extremely stable figure."[113] Hence it is the ideal shape to frame a motion to make it observable. Figure 3-27 illustrates one of the triangular elements on the outer walls of platform halls as a border that frames the movement of a passing train. Triangle resting on one of its sides as implying pure stability becomes the channel to observe a flow owing to inherent contrasting effects in the situation. Nevertheless, the perception of triangle as a stable figure is not a condition contradicting with its suggested directional quality. As mentioned throughout this thesis, movement could also be depicted by a motionless body. Therefore, an intentionally designed form could direct flows although it is as stable as to frame motions.

For Lyon Railway Station, triangle is used both as "the plane that enclose the space" and "the silhouette of the building form" to channel flow of people for their

---

[112] Santiago Calatrava's speech in architectural documentary: Satolas – TGV un monument á la campagne by Catherine Adda.
[113] Francis Ching, Architecture: Form, Space and Order, Van Nostrand Reinhold, New York, 1979, p 56

destinations. Furthermore, the shape becomes the frames of “openings within the spatial enclosure” to illustrate the motion of high speed trains. The structure turns to be a formal research to embody distinct movements. The overall profile of the station and the particular arrangements of its structural elements are the evidences that verifies the fact that shape can be used as a design tool to employ bodily movement for architectural products.

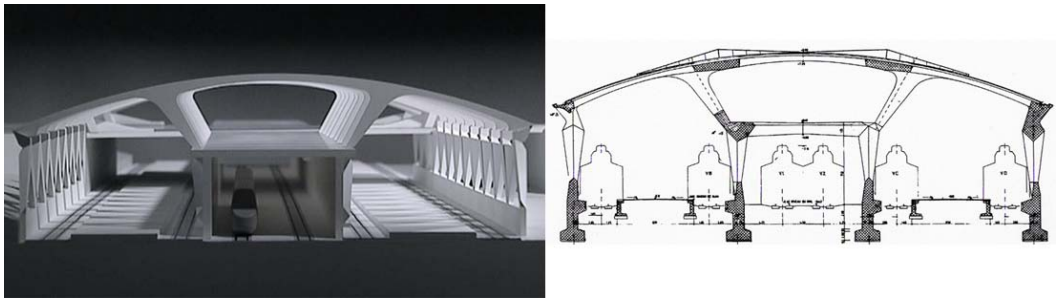


Figure 3-25 left: platform hall _ model view
right: platform hall _ section

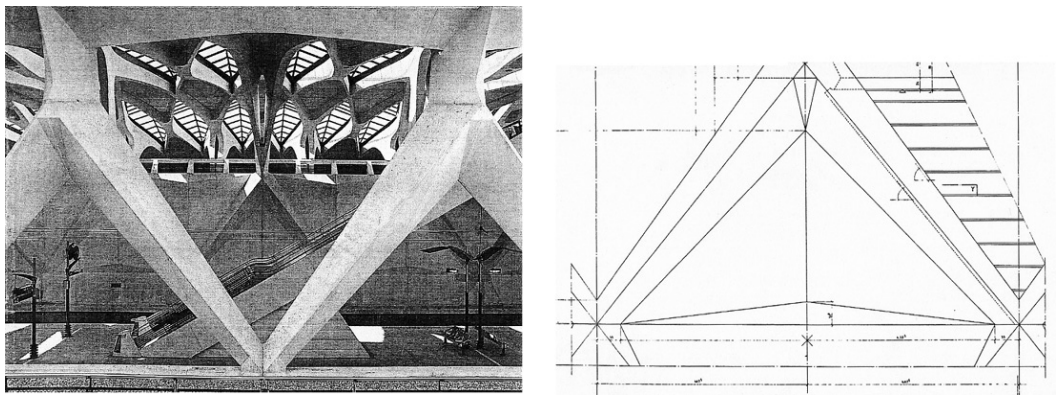


Figure 3-26 left: triangular supports _ view
right: triangular supports _ detail drawings

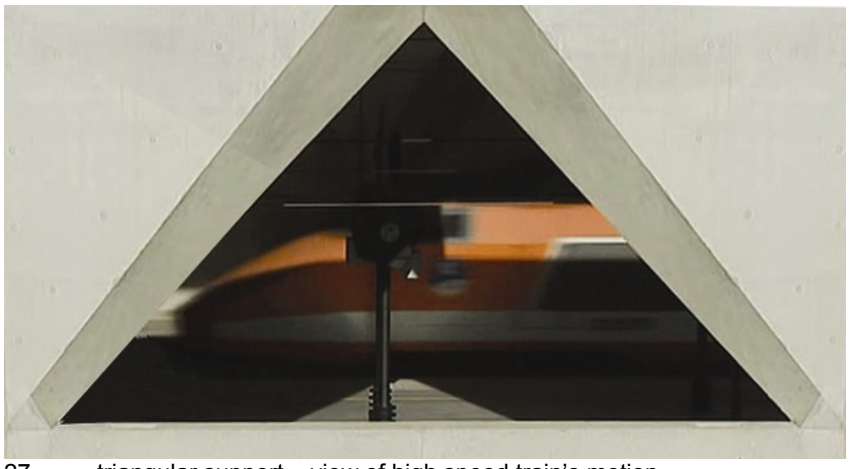


Figure 3-27 triangular support _ view of high speed train’s motion

CHAPTER 4

VISUAL MOVEMENT

> movement / *noun*: 1 a (1): the act or process of moving; especially: change of place or position or posture (2): a particular instance or manner of moving b: ACTION, ACTIVITY -- usually used in plural
> 2 a: TENDENCY, TREND <detected a movement toward fairer pricing> b: a series of organized activities working toward an objective; also: an organized effort to promote or attain an end
> 3: the moving parts of a mechanism that transmit a definite motion
> 4 a: MOTION 7 b: the rhythmic character or quality of a musical composition c: a distinct structural unit or division having its own key, rhythmic structure, and themes and forming part of an extended musical composition d: particular rhythmic flow of language: CADENCE
> ***5 the quality (as in a painting or sculpture) of representing or suggesting motion.**** [114]

Visual movement is the tool for designing structures that "convey the idea of movement figuratively".[115] Intentionally articulated forms cause the observer to perceive suggested motions. Although they are fully stationary; employing no movable parts, these structures seem as if they are moving.

The suggestion of movement in a visually moving structure differs from the one employed by a bodily moving structure. To represent motions figuratively is different than embodying them. Structures that are formed to give the impression of motion seem as employing different movements such as falling, turning or flying. Therefore, a visually moving structure is perceived as moving even if it is fully stationary. On the other hand, bodily moving structures could be observed as stable forms although they are interrelated with distinct motions that are channeled by them. Forms create movements in visually moving structures while

---

[114] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 25 October 2006]
* Emphasis by the author.
[115] Alexander Tzonis, "Schools without Walls," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 17

movements are the creator of forms in bodily moving ones. Hence, visually moving structures define “acting through being” while bodily moving ones define “being through acting” to borrow Rudolf Arnheim’s descriptions.[116] Arnheim made these descriptions to identify the perceptions of movements received from a painting/ statue and a dance/ play in his book entitled Art and Visual Perception: a Psychology of the Creative Eye. Since an architectural work that implies movement resembles a painting or a statue representing motion as “acting through being”, it would be proper to direct the research towards the subject of “the perception of movement in pictorial art”.[117]

Jale Erzen discusses the perception of movement in pictorial art as follows in her master thesis entitled Pictorial Movement:

> When a picture is not actually experienced (when it is, as it were, simply sitting as a material thing), movement is present within it only virtually. Only when it is perceived or experienced does movement in a painting become actual. Hence, movement is not in the painting as it is in the material things that we ordinarily speak of as moving, such as a moving car, or animal, etc., in which movement exists independently of its being perceived or experienced.
> Let us say that movement is not in the painting ‘materially’… we can say that the kind of movement we are concerned with, is not at all in a picture in a merely material way (not even virtually – for we are not concerned with the possibility that the picture might topple over, or be picked up and moved.) Our concern is with the movement in the painting as experienced, and that movement may be present either in an actual or virtual manner.[118]

The movement, an architectural work suggests visually, does not contain any “material reference”. It unfolds when the structure is experienced as a pictorial installation. Deliberately chosen forms or their intentional articulations imply movement to the observer. The perceived motion is dependent to the structure, it could be observed if only the overall configuration is experienced.

---

[116] Rudolf Arnheim, Art and Visual Perception: A Psychology of the Creative Eye, University of California Press, Berkeley, 1974, p 309

[117] The term is defined by Prof. Dr. Jale Nejdet Erzen as a title in her master thesis entitled Pictorial Movement : Its Aesthetics and Mechanics submitted to Art Center College of Design, Los Angeles, California,1973

[118] Jale Nejdet Erzen, Pictorial Movement: It’s Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, pp 29-30

Erzen makes a classification of ways in which the movement enters into the aesthetic experience. This classification contains both “noetic” and “noematic” factors.[119] Since the perceived movement in an architectural work is present as an element of the work; the object, noematic factors are suggested to be effective for the representation of motion in structures. Class A named by Erzen as “through suggestion of specific types of movements, or of one specific type of movement, within the totality of the picture” among the other four noematic classes is the one that is concerned with the ways of producing visually moving structures.[120] In the class A, two different types are discussed. Type 1; “actual (immediate)” movement comprises pictorial structures that evoke sensations of specific types of movement which are felt directly upon perception.[121] Type 2; “anticipatory” movement embraces particular structures of pictorial and symbolic forces that suggest movements which are projected to the future.[122] This is also valid for the architectural works that convey the idea of movement figuratively. The perceived movement in them is not an immediate action but it is an anticipated one. Hence, the anticipatory ways through which the specific types of motions are suggested are valid for architectural production of visual movement.

Erzen introduces two different ways of form articulation which suggest movements that are anticipated and projected into future. These are “imbalances in the pictorial structure (that will result in a future movement)” and “associations that create anticipation of future happenings”.[123] Both ways are also valid for architectural articulations. “Structural illusion” observed in some works of Santiago Calatrava represents movements occurred by the optical imbalances created in the structures. “Representation of nature” and “figura serpentinata” concepts, which are perceived on other visually moving structures of Calatrava, on the other hand, use particular associations with some mobiles to give the motion effect. These three concepts are discussed as the ways of employing visually movement in the architectural production.

---

[119] “Noetic” is defined as “factors through which we experience (but which themselves do not enter into the object of an experience)” while “noematic” is defined as “factors or properties of the ‘object’, or of what is experienced” by Erzen, Pictorial Movement: It’s Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 38

[120] Jale Nejdet Erzen, Pictorial Movement: It’s Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 38

[121] ibid. Erzen, p 38

[122] ibid. Erzen, p 43

[123] ibid. Erzen, p 43

4.1. STRUCTURAL ILLUSION

> illusion / *noun*: 1 a obsolete: the action of deceiving b (1): the state or fact of being intellectually deceived or misled: MISAPPREHENSION (2): an instance of such deception
> 2 a (1): a misleading image presented to the vision (2): something that deceives or misleads intellectually b (1): perception of something objectively existing in such a way as to cause misinterpretation of its actual nature (2): HALLUCINATION (3): a pattern capable of reversible perspective [124]

"In structures where the physical laws perceived optically are not balanced, we anticipate a happening as a result of this" says Erzen to explain the "anticipation of a specific movement due to the structure of the pictorial and symbolic forces in the spatial field and the elements." [125]

Some Calatrava structures, due to their optically unbalanced forms, suggest motions. Either the whole configuration or just a small part of it makes the observer feel the potential movement. The structure seems to be falling, or turning, or even collapsing, although it stands still with an inner structural equilibrium. Hence, there occurs an illusionary effect originated from intentionally configured structural systems. Josè Luis Gonzàlez Cobelo defines such works of Calatrava, which represent the elaborated dramatizations of balance, with the word "clinamen"; a heading by Kenneth Frampton for one of his studies about Calatrava's works.[126] The term expresses "the possibility of creation like a poetic mutation, like an inflection or deviation from the apparent course of a process to produce a sudden aperture to other unforeseen effects and possibilities" as described by Cobelo.[127] Calatrava works that imply visual movements through structural illusions represent such deviations employed deliberately to generate

---

[124] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 25 October 2006]

[125] Jale Nejdet Erzen, Pictorial Movement: It's Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 43

[126] "Clinamen" is the name Lucretius gave to the spontaneous microscopic swerving of atoms from a vertical path as they fall. According to Lucretius, there would be no contact between atoms without the clinamen, and so, "No collision would take place and no impact of atom upon atom would be created. Thus nature would never have created anything."
"Clinamen" has been taken up in discussions of determinism as a possible explanation for an incompatibilist free will. Source: [Home page: http://en.wikipedia.org, http://en.wikipedia.org/wiki/Clinamen, accessed: 25 October 2006]
The term has also been taken up by Harold Bloom to describe the inclinations of writers to "swerve" from the influence of their predecessors.

[127] Josè Luis Gonzàlez Cobelo, "Mask and Vertigo: Engineering and Alchemy in the work of Santiago Calatrava," El Croquis, vol.11, no.5, 1992, p 11

motional effects. These deviations are observed as to be applied directly on the structural elements. Two structural configuration themes introduced by Tzonis as elaborated motifs of Calatrava exemplify such structural deviations. Both cases signify physical studies to balance “a leaning, apparently falling column”.[128] In the first case; the column is saved from its fate “by folding the member in the opposite direction to counterbalance the act of falling, resulting in a palindromic figure” (Figure 4-1).[129] In the second case, on the other hand, the same member is balanced “by adding to the column some auxiliary element that either supports or suspends it” (Figure 4-2).[130] Although these deviations applied to leaning columns balance the structural element to stand stable, the overall configurations still seem as unbalanced to suggest future movements. Columns are still predicted to fall and collapse with the illusion of movement.

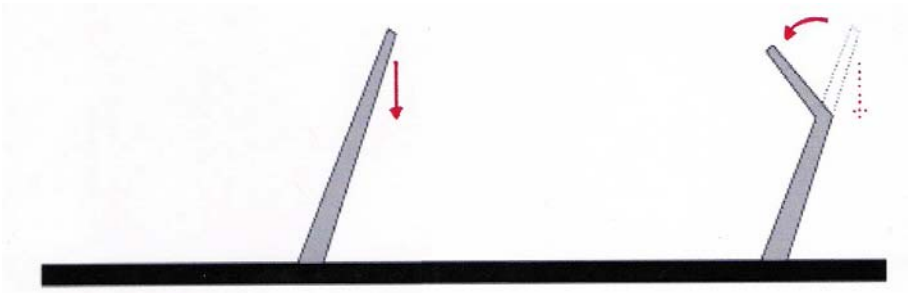


Figure 4-1 configuration 1

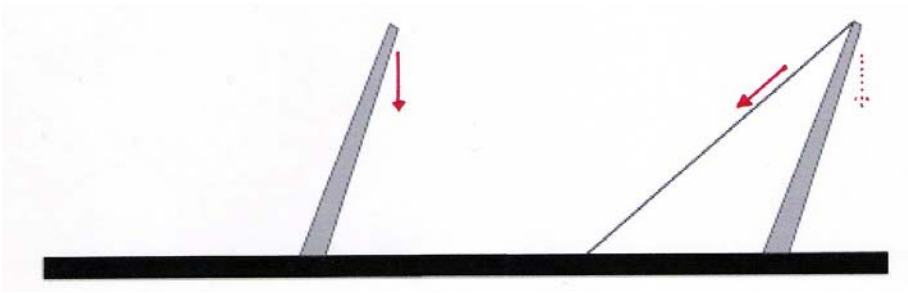


Figure 4-2 configuration 2

A sophisticated engineering study, besides an elaborate aesthetical enterprise, is accepted as the originator of these kind structures. As an engineer, Calatrava

[128] Alexander Tzonis, “Seminal Projects,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 32
[129] Jale Nejdet Erzen, Pictorial Movement: It’s Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 38
[130] ibid. Erzen, p 38

is discussed to deal with mechanics in a particular manner. The force, which is accepted as a key concept by Galileo and Newton in their scientific studies on mechanics, is defined as a "crystallized movement" by Calatrava:

> In understanding mechanical analysis, we see that the forces are made up of two components: mass and the acceleration of mass. A force is the result of the product of a mass and its acceleration is part of a kinematic world; "kinematic" implies a variable for movement, and in fact acceleration takes place in space and time. So within a force, time is also variable, since forces present mass at a universal constant. Time thus appears to be the result of acceleration. Forces are not so permanent. I could almost say that forces are like crystallized movement. Forces are events that will happen if allotted time. They do not happen because -like ice- they are crystallized. But when released, they will produce movement through space.[131]

Calatrava's particularized understanding of mechanics comprehends forces as sources for future movements. Although forces acting in the structures counterbalance each other at a still situation, they are in fact used as inherent generators of motions in the optical sense by Calatrava. The capacity of anticipated movements is externalized through "creative statements about structural forces"; as defined by Matilda McQuaid.[132]

Outstanding bridges of Calatrava are such intelligently configured structures. Principles of engineering mechanics are discussed to be used as springboards for the particular formal expressions of these bridges by Anthony C. Webster in his article entitled Utility, Technology and Expression.[133] As being one of the hardest problems in the field of engineering, bridge design is a significant process for Calatrava to create illusionary effects that suggest movements. Webster presents some Calatrava bridges as structures that "appear unstable at first glance, as if some sleight of hand is needed to prevent their collapse".[134]

---

[131] Santiago Calatrava, "Inner-city Regeneration: Works and Projects," RSA Journal, August/September, 1994, as quoted by Anthony Tischhauser "Aspects of Movement in the Work of Santiago Calatrava," Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996, p 15

[132] Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993, p 11

[133] Anthony C. Webster, "Utility, Technology and Expression," Architectural Review, vol.191, no.1149, 1992, p 69

[134] ibid. Webster, p 70

Alamillo Bridge (Seville, Spain, 1987- 1992):

Alamillo Bridge was designed for 1992 World's Fair in Seville. Not only to improve the connections between Seville and its neighboring towns but also to design a landmark for the new development in the region constitutes the target of the project. The bridge crosses over River Guadalquivir as carrying two motorways and a footway among them.

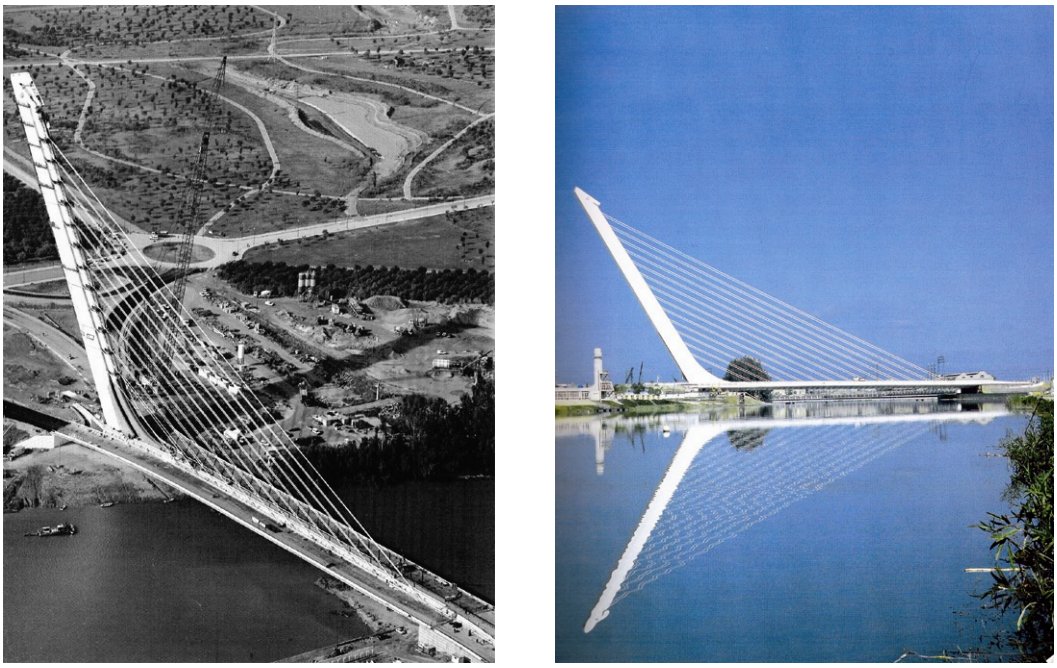


Figure 4-3 Alamillo Bridge

Alamillo Bridge spans 200 meters with its 250 meters long reinforced concrete deck, 142 meters high reinforced concrete pylon and 13 pairs of steel cables.[135] The single pylon placed at one tip of the deck is inclined with an angle of 58°. This inclination results in two conditions.

First, the structure is balanced. The weight of the deck transmitted to the pylon by means of steel cables is counterbalanced by the weight of the pylon that pulls it downward. By leaning the pylon, Calatrava eliminates traditional back stays used in symmetrical bridges. The equilibrium that would be provided between tension cables and back stays by means of an upright pylon is achieved here between tension cables and the own weight of the pylon by inclining it.

[135] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0000002_241106, accessed: 28 October 2006]

Figure 4-4 Alamillo Bridge _ drawings

As second, the structure seems unbalanced. The single pylon appears as if collapsing to the side it is inclined. As being the first member of the structure that attracts notice with its huge dimensions, the pylon gives the idea of an anticipated movement. Its silhouette represents a falling action suspended in time. Moreover, the mirroring image of the structure on the river strengthens the idea of collapse.

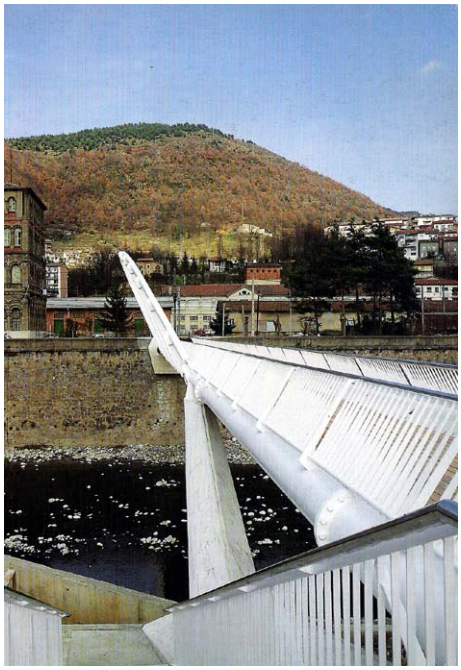
La Devesa Footbridge (Ripoll, Spain, 1989- 1991):

La Devesa Footbridge connects the area of La Devesa to the railway station of the town. The bridge crosses Ter River and also accommodates 5 meters grade change. The structure spans 44 meters with its 65 meters long timber-surfaced deck and 6.5 meters high steel arch.[136] The deck is cantilevered from the steel

[136] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0000320, accessed: 30 October 2006]

arch. The dead and live loads on the walkway are transmitted to the arch system by means of steel tension arms. However, since there causes an asymmetrical arrangement due to placement of steel arch at one side of the deck, the weight is not centered beneath the arch system. To counterbalance this condition and prevent the probable buckling, the steel arch is tilted.

Figure 4-5 La Devesa Footbridge



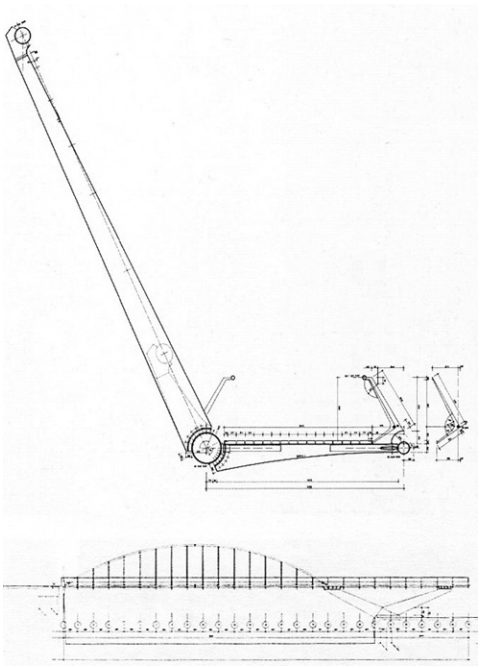


Figure 4-6 left: La Devesa Footbridge _ view from the edge
right: La Devesa Footbridge _ drawings

The deviation of the architectural component from its upright position is caused by structural reasons again. Similarly, the result is the same; a structural illusion that sources an anticipated movement. The arch seems as falling. Its duty of balancing the structure turns into an optical effect of imbalance representing a suspended motion.

Trinity Footbridge (Salford, England, 1993-1995):

Trinity Footbridge connects the cities of Salford and Manchester as the first foot crossing. Pedestrians that access the bridge from one point on Manchester side are directed to either a new car park or an extensive redevelopment area on Salford side. The structure spans 54 meters with its 78.5 meters long steel deck and 41 meters high steel pylon.[137]

The deck is suspended from the steel pylon by means of stainless steel tension stay cables. Three sets of cables mark the three distinct tips of the bridge. Calatrava chooses to use an inclined pylon again to balance the structure rather than using an upright element. This inclination is stabled by the intentional arrangements of tension cables.

Figure 4-7 Trinity Footbridge

The single steel pylon is designed as a highly visible element. Hence, its perception as a falling part is very strong. Its form becoming thicker at the middle part and again slimming towards its peak point also strengthens this perception.

[137] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0000443, accessed: 05 November 2006]

The idea of a future movement to be realized in a few second, which is the collapsing of the huge pylon, is presented through a sophisticated study on structure and an elegant conception of aesthetics.

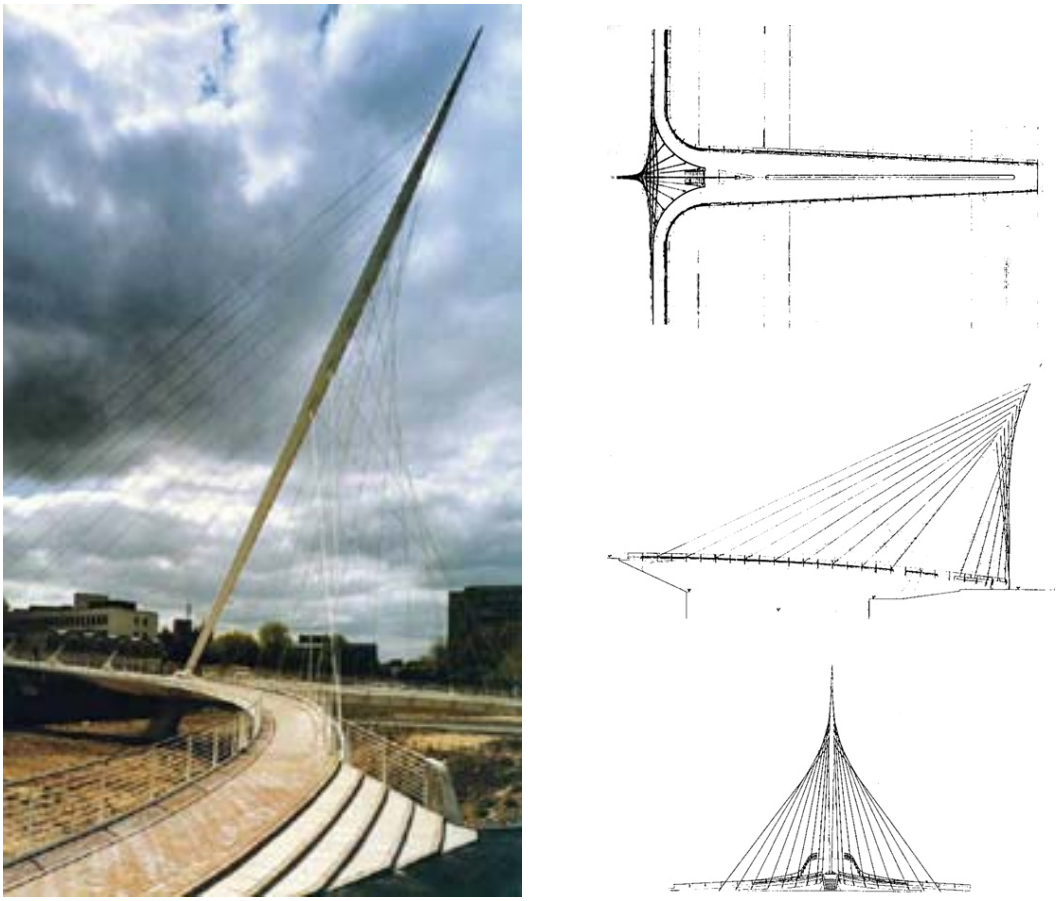


Figure 4-8 left: Trinity Footbridge _ view from one edge
right: Trinity Footbridge _ drawings

4.2. REPRESENTATION OF NATURE

nature / *noun*: 1 a: the inherent character or basic constitution of a person or thing : ESSENCE b: DISPOSITION, TEMPERAMENT
2: a creative and controlling force in the universe
3: a kind or class usually distinguished by fundamental or essential characteristics <acts of a ceremonial nature>
4: the physical constitution or drives of an organism
5: the external world in its entirety
6 a: humankind's original or natural condition b: a simplified mode of life resembling this condition
7: natural scenery [138]

[138] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 08 November 2006]

Nature is introduced as an "association that creates anticipation of future happenings" in this study.[139] Movement is in the essence of nature. Both the inherent capabilities of mobile natural creatures, such as the flying of a bird, and the concealed movements of so-called immobile ones, such as the growing of a plant, are the evidences that prove the fact that nature moves temperamentally. "In the world of natural forms, movement, whether slow or fast, is the rule. It is a world of unstable equilibriums, always changeable, in which the bodies or the plants assume ever-changing shape" says Mirko Zardini in his article titled Mobile Pages. [140]

Nature, as an association anticipating movement, has always been a reference for architectural thinking and production. Alexander Tzonis presents "palm-leaf or scallops of the Philae capitals of Egypt, the acanthus on the Corinthian capitals of Greek and Roman antiquity; the foliated or flowing arches, tracery, vaulted roofs of Gothic construction, the imitations of botanical forms by Baroque architects and the vegetal originals of more recent architects such as Louis Sullivan or Hector Guimard" as historical verifications of "the simulacra of the slow movement of growing plants or trees attached to the structural members of buildings".[141] Some of the natural references in these examples may be discussed as just ornamental intentions. Nevertheless, the idea of dynamism adopted by the architectural thinking producing these works could be comprehended from some deliberate choices. In all examples, the columns are the structural elements that are associated with natural forms and the plants are chosen as the organic bodies to be referenced (Figures 4-9 and 4-10). A regular endeavor to represent the column as a dynamic figure rather than a stable structural element can be discussed as the reason of this consistency. The plant forms, especially foliated ones that seem growing, are used for crowning the capitals. Hence, the columns appear as if organic bodies that grow longer and so move towards up continuously. This intention unfolds the fact that the

---

[139] Jale Nejdet Erzen, Pictorial Movement: It's Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 43

[140] Mirko Zardini, "Mobile Pages," Mirko Zardini edits Santiago Calatrava: Secret Sketchbook, The Monacelli Press, New York, 1996, p 59

[141] Alexander Tzonis and Liane Lefaivre, "Structures, Icons of Movement," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 92

representations of nature in discussed works should be defined as “simulations” rather than “simulacra”.[142]

Figure 4-9 left: column capital _ Philae Temple,4th c. BC,Egypt
middle: column capital _ Temple of Olympian Zeus, 2nd c. AD, Greece
right: King’s College Chapel, 1446-1515, England

Figure 4-10 left: Guaranty Building, 1894-1895, USA, by Louis Sullivan
middle: Castel Beranger, 1893-1895, France, by Hector Guimard
right: Hotel Tassel, 1892-1893, France, by Victor Horta

[142] “Simulacrum” is discussed as maintaining the ‘image’ but not the ‘essence’ as being an aesthetic existence rather than a moral one by Emre Seles in his master thesis entitled Representation(s) of Topkapı Palace. Seles quotes Deleuze: “The copy is an image endowed with resemblance; the simulacrum is an image without resemblance.” “Simulation”, on the other hand, is defined by Seles as a cover of the reality by quoting Baudrillard: “Simulation is no longer territory, a referential being, or a substance. It is the generation by models of a real without origin or reality: a hyperreal.”_ See part *2.2.Simulations and Simulacra*, Emre Seles, Representation(s) of Topkapı Palace, unpublished master thesis, Department of Interior Architecture and Environmental Design, Bilkent University, Ankara, 2004

Calatrava is also a designer who represents nature with its essence. He uses the organic bodies that possess the ability of movement inherently as sources for creating visually moving structures. Rather than imitating the natural forms just as aesthetical existences, Calatrava re-present their essence. By studying the organic structures of mobile natural beings, Calatrava obtains clues about the ways of constructing his movement-implying forms. Hence, "each contact with the earth or nature becomes also a new acquisition for culture, modifying or changing it" as Erzen says in her article entitled Nature, Its Aesthetic Knowledge and Art. [143]

The following works exemplify Calatrava's method of using natural references to produce visually moving structures. All projects illustrate natural associations that create anticipation of future happenings. Milwaukee Art Museum, studied previously as an actually moving structure, is one of these projects.

Milwaukee Art Museum (Wisconsin, USA, 1994-2000):

Figure 4-11 Milwaukee Art Museum _ "a great seagull"

Milwaukee Art Museum seems like "a great seagull" taking off towards the lake.[144] The symmetrical louvers covering conical structure signify wings of a bird. The pylon at the middle symbolizes the spine of the seagull's skeleton. The

[143] Jale Erzen, "Nature, Its Aesthetic and Knowledge and Art," Güven Arif Sargın edits Nature as Space (re)Understanding Nature and Natural Environments, METU Faculty of Architecture Press, Ankara, 2000, p 86

[144] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 290

overall inclination, on the other hand, anticipates the action of flying that will take start in a few seconds. Although the actual movement equipped by the louvers has a strengthening effect, the stationary condition of the structure, both with closed and opened louvers, is enough to imply the idea of movement. A bird flies with its wings; Milwaukee Art Museum appears as flying with its wing like louvers.

Lyon Airport Railway Station (Satolas, Lyon, France, 1989- 1994):

Figure 4-12 Lyon Airport Railway Station _ “a bird at the point of flight”

Lyon Airport Railway Station was studied as one of Calatrava structures that equip bodily movement in the previous chapter. Nevertheless, the structure is also a product of visual movement studies. The huge main body resembles a great “bird at the point of flight”.[145] With its open wings prepared for a take off and central spine carrying all body, the station turns to be a bird; a natural organism that can move. This resemblance is sourced from the simulation of a natural body. The station anticipates a further flying besides the actual ones realized by the planes taking off from the nearby airport.

Planetarium of the Valencia Science Center (Valencia, Spain, 1991):

The planetarium is designed as a part of the City of Arts and Sciences complex. The structure is composed of an inner spherical planetarium and a concrete shell housing it. The transparent shell covers an area of 100 meters length and 55.5 meters width.[146] The surrounding reflection pool mirrors the whole structure. Hence, the concrete shell turns to be an eyelid while the planetarium becomes a

[145] See [Home page: www.calatrava.com, accessed: 15 October 2006]
[146] See [Home page: http://en.structurae.de, http://en.structurae.de/structures/data/index.cfm?ID=s0002425, accessed: 15 November 2006]

pupil. The foreseen attitude is the movement of eyelids that will cover or uncover the eye. The structure fulfills the action. The enormous movable door in front of the planetarium opens and closes mechanically. Project represents an organic body; an "awakening eye" with its particular formal and structural characteristics.[147] Moreover, the unique movement of the organic body is simulated. Nature becomes the source to articulate a structure as an implication of movement.

Figure 4-13 Planetarium of the Valencia Science Center _ "awakening eye"

BCE Place (Toronto, Canada, 1987-1992):

BCE Place is basically a roof structure that covers a passage and a public square. By standing as an arcade, the structure protects the public space left in between commercial blocks of Toronto. The project shelters 130 meters long, 14 meters wide area with a roof 27 meters above.[148] Tree like steel columns carrying vaulting steel structures are the main elements. They support the outer glazed roof. The passage ending with the square is covered by pointed vaults carried by rhythmically placed inclined columns. These columns are branched into two and then into four along their lengths. Hence, each column supports four steel arches forming three vaults. For the square, on the other hand, nine intersecting barrel vaults are designed, again to be carried by steel columns.

[147] Alexander Tzonis, "Infrastructure and Dream-work Projects," Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 168

[148] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 142

Tree form is current for the columns at the square, too. The branching starts from their pedestals. This intentional configuration of vertical supports that makes them resemble to trunks and the articulation of vaults made of several tiny ribs similar to branches turns BCE Place to a “forest of structural trees”.[149] The feeling of an uninterrupted growth for these structural trees that extend to very high limits is the main reason to anticipate a movement. The columns seem like growing longer and the ribs of vaults seem as if becoming denser. The visual movement that is created by simulating a forest constitution is supported by an actual motion. The fountain designed by Calatrava for the center of the public square is composed of steel tubes that open like a “flower”.[150]

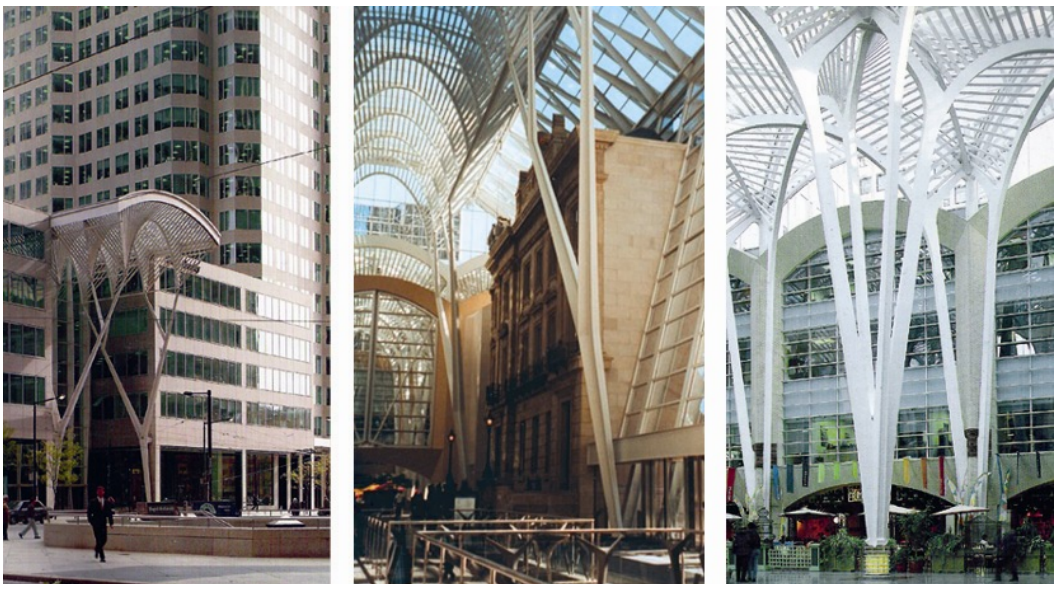


Figure 4-14 BCE Place _ “forest of structural trees”

Figure 4-15 BCE Place _ “flower”

[149] Alexander Tzonis, “Structure, Icons of Movement,” Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999, p 82
[150] ibid. Tzonis, p 82

4.3. FIGURA SERPENTINATA

serpentine / *adjective*: 1: of or resembling a serpent (as in form or movement) [serpent / *noun*: 1 a archaic: a noxious creature that creeps, hisses, or stings b: SNAKE]
2: subtly wily or tempting
3 a: winding or turning one way and another <a serpentine road> b: having a compound curve whose central curve is convex. [151]

Figure 4-16 Horatius Cocles, from the series The Roman Heroes, 1586
Engraved by Hendrick Goltzius (Dutch, 1558–1617)
Engraving; first state of two; 14 1/2 x 9 3/8 in. (36.7 x 23.6 cm)
Rijksmuseum, Rijksprentenkabinet, Amsterdam

Figura serpentinata is defined as "the name for a wound painted or plastic implemented figure that is named as particularly spiral motives in the ornamental art" in Wikipedia Encyclopedia.[152] Giovanni Paolo Lomazzo, a painter, an art historian and an art theoretician from 16th century, is presented as the reporter of the concept as the characteristic formula of the Mannerism through his book entitled Trattato dell' arte della pittura.[153]

---

[151] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 15 November 2006]
[152] See [Home page: http://de.wikipedia.org, http://de.wikipedia.org/wiki/Figura_Serpentinata, accessed: 15 November 2006]
[153] "Mannerism is the term applied to an artistic style (usually painting), which emerged after the Sack of Rome (1527) and in concept and time immediately followed the High Renaissance. Mannerism is actually a fusion of various highly individual styles that poses as an alternative to the neoclassical punctiliousness achieved in the Roman art and architecture of the High Renaissance."

Alexander Tzonis, as quoting from Lomazzo, introduced the term figura serpentinata as an artistic idea that is applied to the human body in order to empower it with movement.[154] The main idea behind the concept was the S-form. The curvilinear alignment of the human posture rather than a straight alignment was explored as the way of implying movement. The balance of the posture was tried to be caught through a stance of motion. The limbs were detached from the main body and used as parts of a system that constructs the S-form. This articulation created a living balance which suggests movement. Horatius Cocles, from the series The Roman Heroes, engraved by Hendrick Goltzius (Dutch, 1558–1617) in 1586 is depicted as a mannerist work that embodies the concept of figura serpentinata (Figure 4-16). The S-form drawn through the limbs of the figure is apparent to imply the hero's movement.

Similar to figura serpentinata, the shape of "the flame of fire" is introduced as a form that anticipates motion owning to its S-form. In Art and Visual Perception, Rudolf Arnheim quotes Lomazzo:

> For the greatest grace and life that a picture can have is that it express motion, which the painters call the spirit of a picture. Now there is no form so fit to express this motion as that of the flame of fire, which according to Aristotle and the other philosophers is an element most active of all others because the form of the flame is most apt for motion.[155]

Aristotle's further notes on the flame of fire where he resembles the shape to the letter S is cited by Tzonis.[156] The S-form such praised as the form of movement by the theoreticians is also the main articulation method for some "living" Greek sculptures. Discobolos of Myron (Greek, 480-440 B.C.) is one of the examples (Figure 4-17). Gisela M. A. Richter depicts the master piece with the words of Lucian: "…the quoit-thrower who stoops in the attitude of one who is making his cast, turning round toward the hand that holds the quoit, and bending the other

---

Source: [Home page: http://de.wikipedia.org, http://en.wikipedia.org/wiki/Mannerism, accessed: 15 November 2006]

[154] Alexander Tzonis and Liane Lefaivre, "Potential Movement, Possible Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 143

[155] Rudolf Arnheim, Art and Visual Perception: A Psychology of the Creative Eye, University of California Press, Berkeley, 1974, p 342

[156] Alexander Tzonis and Liane Lefaivre, "Potential Movement, Possible Structures," Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 143

knee gently beneath him, like one who will rise erect as he hurls the quoit" in the book entitled The Sculpture and Sculptors of the Greeks.[157] The twisted body is seen as the representation of a "violent action" that is not restless but harmonious. The movement effect that is not an actual but a suggested one is also pointed by Rhys Carpenter. He illustrates the work as an implication of the inception of a movement rather than a direct depiction. Nonetheless, the sculpture is discussed as "a text on which to base a homily on the representation of motion in art" by Carpenter.[158]

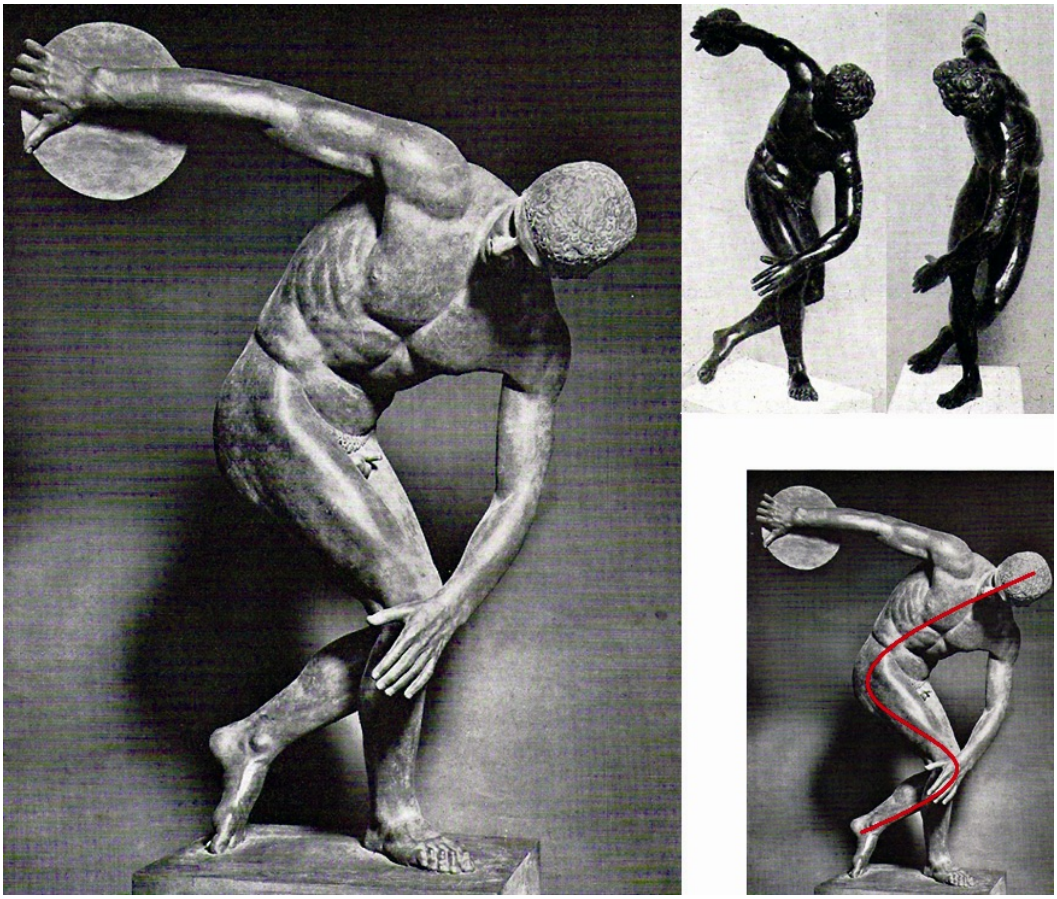


Figure 4-17 Discobolos,
Sculpted by Myron (Greek, 480–440 B.C.)
left: reconstruction
right: above: bronze statuette
below: captured S-form

[157] Gisela M. A. Richter, The Sculpture and Sculptors of the Greeks, Yale University Press, New Haven, 1950, p 161
[158] Rhys Carpenter, Greek Sculpture, A Critical Review, University of Chicago Press, Chicago, 1960, p 83

The S-form captured in the sculpture is illustrated. Overall configuration of the leaning head, the inclining upper body and the bending knee depicts the serpentine figure. Although Myron is criticized as carving a flatten image for a living athlete, Carpenter disagrees with this idea for the fact that the sculpture concentrated on a visual comprehension within its limited angle of effective visibility.[159] If the observer focuses on the overall form rather than concentrating on the emotional depiction or the muscular articulation, the implied movement will be apparent. A motion that will happen soon is depicted by the accurate positions of the limbs through an S-form.

Doryphoros of Polykleitos (Greek, 450-420 B.C.) is another Greek sculpture that embodies visual movement. When compared with Myron's Discobolos, Doryphoros is found to be "more natural" and "more accurate in the reproduction of muscular behavior".[160] This claim is supported by a further opinion of Carpenter which defines Doryphoros of Polykleitos as the perfection of the "living balance" formula (Figure 4-18).[161] The sculpture depicts a body in walking position. The left leg with a bending knee and a raised heel demonstrates the following step. Two sides of the posture are separated from each other; the left side illustrates mobility while the right side depicts steadiness. Stepping left leg with a bending left arm is counterbalanced with a stationary right leg and a freely hanging right arm. Carpenter describes:

> By this symmetrical asymmetry a visible differentiation between tension and relaxation, between muscular contraction and expansion, is introduced into each bodily feature in contrast with its opposite counterpart; and a gently swaying curve expressive of the erect body's living balance replaces the straightly vertical axis of the un-living archaic stance.[162]

A gently swaying curve is discussed as the expression of the living balance for Doryphoros. That is the S-form created by the articulation of the limbs. A natural standing which is in fact a part of the walking action is represented through this articulation. The statue seems as if taking steps. The asymmetry between the sides is balanced by using figura serpentinata concept. A curvilinear whole is

---

[159] Rhys Carpenter, Greek Sculpture, A Critical Review, University of Chicago Press, Chicago, 1960, p 84
[160] ibid Carpenter, p 106
[161] ibid.Carpenter, p 106
[162] ibid.Carpenter, p 105

achieved through the limbs and Doryphoros gains “a harmony of line, a poise and relaxation in the attitude never before attained in the history of Greek sculpture.”[163] This particular attitude of Polykleitos is identified by Tzonis as follows:

> The structure of the human body is as resting on one leg, pushed a little to the rear, with the one leg bent at the knee and applying less pressure. The chest, while tilted backwards, was slightly bent also, and the head leaned to the side in the opposite direction to the chest. This “counter posing” of the members of the body was seen as a way of expressing graceful movement, a quality Polykleitos’ sculptures were praised for.[164]

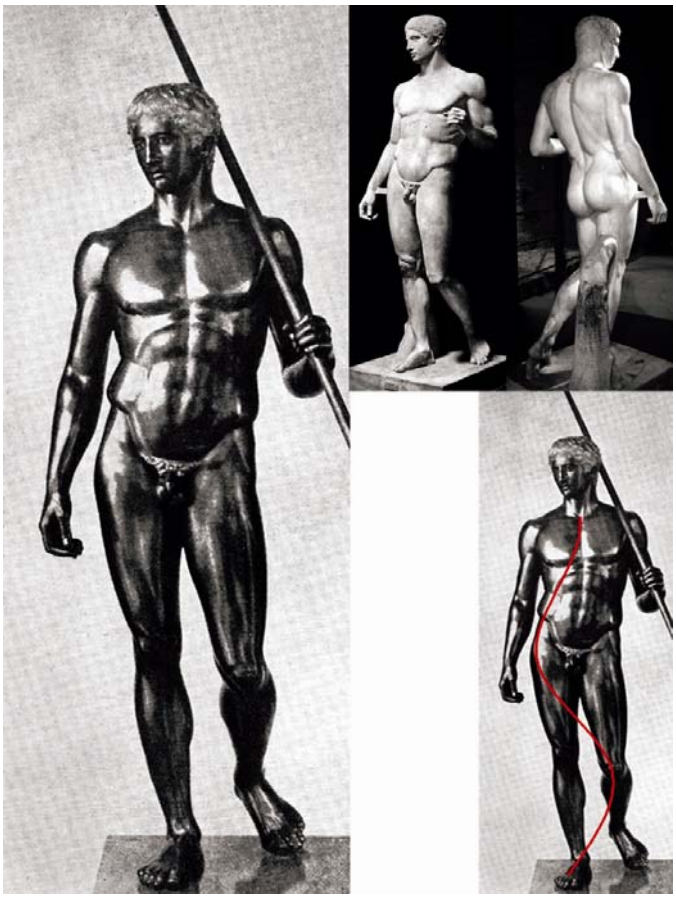


Figure 4-18 Doryphoros,
Sculpted by Polykleitos (Greek, 450–420 B.C.)
left: reconstruction
right: above: marble reconstructions
below: captured S-form

[163] Gisela M. A. Richter, The Sculpture and Sculptors of the Greeks, Yale University Press, New Haven, 1950, p 190
[164] Alexander Tzonis and Liane Lefaivre, “Pregnant Movement,” Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995, p 140

"Counter posing" as being synonymous with "contrapposto" is defined as "the position of a human figure in painting or sculpture in which the hips and legs are turned in a different direction from that of the shoulders and head; the twisting of a figure on its own vertical axis" in Artlex Art Dictionary.[165] Hence, twisting of Doryphoros on its vertical axis is the main idea creating the gently swaying curve; the S-form and so the expression of movement.

As examples depict, the concept of figura serpentinata is common for all these movement implying forms. The S-form as the basic configuration is valid for the flame of fire, Myron's Discobolos and the counter posing idea. Hence figura serpentinata is introduced as the other "association that creates anticipation of future happenings" in this study.[166] Calatrava's structures that are designed to depict S-forms are analyzed in this part. These structures demonstrate the usage of figura serpentinata concept in the architectural production as a tool of suggesting visual movement.

High Rise in Malmö (Malmö, Sweden, 1999-2005):

High Rise in Malmö is designed to be "a landmark visible from a distance that gives a stronger identity to the area" as an important part of Malmö Western Harbour redevelopment project.[167] The structure was also intended to satisfy the requirements for the area's dense habitation.

Calatrava designed the landmark as a 190 meters tower that twists 90º around its core from top to bottom. 9 cubes each containing 5 floors are tied with different angles to the core. This differentiation articulated in a sequential manner forms the turning body. The tying core inherits the elevators and stairs through which the cubes communicate.

The tower houses offices, conference rooms and apartments. First two cubes service as office floors that have their separate lifts, heating and cooling systems. Top two floors, on the other hand, are separated for conference rooms.

---

[165] See [Home page: http://www.artlex.com, accessed: 20 November 2006]

[166] Jale Nejdet Erzen, Pictorial Movement: It's Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973, p 43

[167] Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004, p 332

The apartments are placed on the floors in-between. 147 residences that range in size are serviced by high speed lifts. The difference in the space size of the apartments is sourced from the changes of the core-wall sizes.

The core is a concrete structure that is designed like a pipe with an inner diameter of 10.6 meters. The thickness of the walls forming the structure changes gradually. Core-walls are 2.5 meters thick at the bottom floor and approximately 0.4 meters thick at the top.[168] This structural configuration results in a 60 m^2 change between the bottom and the top floors. Other than the huge concrete core that carries the structure, an outer steel truss is employed as the stiffening element. Steel spine columns placed at the corner of each floor and horizontal and diagonal steel members form the framework. The truss is active for horizontal forces mainly, especially the wind forces that are very effective in the region. The “exoskeleton” also twists with the tower.[169]

Figure 4-19 High Rise in Malmö _ exterior view

[168] See [Home page: www.designbuild-network.com, www.designbuild-network.com/projects/turning-torso, accessed: 08 December 2006]
[169] See [Home page: www.designbuild-network.com, www.designbuild-network.com/projects/turning-torso, accessed: 08 December 2006]

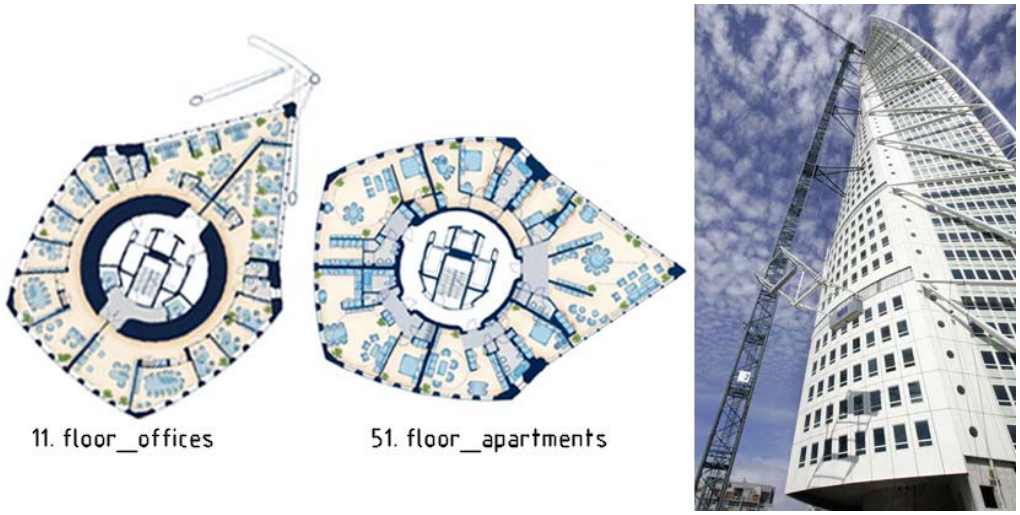


Figure 4-20 left: High Rise in Malmö _ exemplary floor plans changing angles and core-walls
right: High Rise in Malmö _ twisting steel truss

The cubes of High Rise in Malmö turn around the central core with the outer steel truss. Sequential ordering of the floors that completes a 90º rotation from bottom to top makes the observer to perceive an S-form. The figura serpentinata governs the overall configuration. Calatrava did not choose to place all the floors on top of each other with same orientation but preferred to rotate them to create a spiral whole. By doing so, he implied movement. The structure seems turning. The effect is endless. The cubes appear as if adding to their number by twisting constantly towards to sky. That is the reason for the structure to be named as “Turning Torso” in several publications.

Figure 4-21 left & middle: High Rise in Malmö _ exterior views
right: High Rise in Malmö _ captured S-form

Turning Torso anticipates movement due to figura serpentinata concept ruling both its structural configuration and aesthetical articulation.

La Rioja Bodegas Ysios Winery (La Guardia, Spain, 1998-2000):

La Rioja Bodegas Ysios Winery complex is a low-industry facility that houses the basic operations of wine production. Wine for the Bodegas & Bebidas Group is made, stored and sold in the complex. The building also stands as an iconic structure for the trademark.

The 8000 m^2 plan is outlined as a simple rectangle to accommodate the linear program for the wine making process. The gates on the eastern and western facades strengthen this idea of linearity. Another gate is located at the center of southern façade to welcome the visitors coming for watching the process and tasting wine.

Figure 4-22 La Rioja Bodegas Ysios Winery _ exterior view

Two concrete load bearing walls carrying the roof construction form the structure. 196 meters long walls trace a sinusoidal shape in both plan and elevation. 26 meters wide place between these walls is the main space for the required functions. The southern façade of the structure is clad with horizontally placed wooden slats whereas the northern façade is dressed with precast concrete panels. Other two façades are clad with aluminum plates similar to roof. The roof composed of wooden beams sits on the sinusoidal cornices of the lateral walls. These wooden beams are dressed with aluminum at the exterior.

Figure 4-23 left: La Rioja Bodegas Ysios Winery _ Southern façade
right: La Rioja Bodegas Ysios Winery _ Northern façade

Figure 4-24 left: La Rioja Bodegas Ysios Winery _ interior view
right: La Rioja Bodegas Ysios Winery _ captured S-forms

La Rioja Bodegas Ysios Winery is a snake crawling on the rough ground at the deserted region. The aluminum roof cladding is its imposing skin that shines under the sun while moving. It does not only crawling but also waving. These waves are mirrored on the reflecting pool. Wooden slats covering the body are placed horizontally to depict the idea of longitudinal movement. The structure moves along the east-west axis by winding. Shining aluminum, reflecting water and horizontal wooden planks prove this. Intentionally chosen materials strengthen the idea of motion.

The winery as a serpent moves on the earth. The visual movement it anticipates is reinforced by the deserted landscape. Surrounded by the vineyards, the site is very acceptable to nestle a snake. “Building is conceived as an element that is integrated into the powerful, surrounding landscape while being somewhat autonomous at the same time” says the explanatory text on the official web site

of Calatrava.[170] The autonomous character of the winery is directly related with the effect of movement. A visually moving structure that seems winding like a serpent is naturally perceived as an independent body among the motionless landscape.

[170] See [Home page: www.calatrava.com, accessed: 10 December 2006]

CHAPTER 5

VIRTUAL MOVEMENT

> movement / *noun*: 1 a (1): the act or process of moving; especially: change of place or position or posture (2): a particular instance or manner of moving b: ACTION, ACTIVITY -- usually used in plural
> 2 a: TENDENCY, TREND <detected a movement toward fairer pricing> b: a series of organized activities working toward an objective; also: an organized effort to promote or attain an end
> ***3: the moving parts of a mechanism that transmit a definite motion****
> 4 a: MOTION 7 b: the rhythmic character or quality of a musical composition c: a distinct structural unit or division having its own key, rhythmic structure, and themes and forming part of an extended musical composition d: particular rhythmic flow of language: CADENCE
> 5 the quality (as in a painting or sculpture) of representing or suggesting motion [171]

"Virtual movement" is a concept introduced by Greg Lynn; a contemporary American architect, philosopher, and science-fiction writer. Although there is no clear sample of the concept in Santiago Calatrava's architectural production, virtual movement has been considered as an essential tool to reinterpret Calatrava's work. The prevalence of the theme in the contemporary design culture and the theoretical framework that conceptualize the term influences this reconsideration.

In his book entitled Animate Form, Greg Lynn defines the concept of virtual movement by discussing emerging sub-issues and depicting his own projects. Movement in Lynn's projects has to be sought not in the structure but in the larger context that surrounds it. A "topology" substituting various inner forces to create movements is this larger context. The created movements form the

---

[171] Merriam-Webster Online Dictionary, [Home page: http://www.m-w.com, accessed: 10 December 2006]
* Emphasis by the author.

structures “to occupy a multiplicity of possible positions continuously with the same form”.[172] Lynn illustrates the form of a hull to exemplify:

> The particular form of a hull stores multiple vectors of motion and flow from the space in which it was designed. A sailboat hull, for example, is designed to perform under multiple points of sail. For sailing downwind, the hull is designed as a planing surface. For sailing into the wind, the hull is designed to heal, presenting a greater surface area to the water. A boat hull does not change its shape when it changes its direction, obviously, but variable points of sail are incorporated into its surface. In this way, topology allows for not just the incorporation of a single moment but rather a multiplicity of vectors, and therefore, a multiplicity of times, in a single continuous surface.[173]

The topology in which the hull exists is defined as the creator of its form. Lynn says “the virtual force of the environment in which it is designed contributes to its shape”.[174] The movements occurring in the “outer context” shape the structure by equipping it with an “adaptable form”. The motion is the reason for the existence. The particular comprehension of the design environment “as an environment of force and motion rather than as a neutral vacuum” is a crucial issue in the conceptualization of virtual movement.[175] Such an environment is defined as “an active abstract space” by Lynn. The so-called conventional design space for architecture is depicted as “a passive environment of static coordinates” whereas the topology for virtual movement is required to be “an active space of interactions”.[176] The basic difference between two environments is the existence of movement. The active abstract space consists of forces. These forces are originated from some particular contents. A tree may be the source for a gathering vortex force or an existing driveway may create a linear directional one. Hence, the contents in the environment are not treated as static points in the map but discussed as origins of distinct forces. The virtual movements sourced from these forces are used as the real creators of forms. As Lynn says “the context for design becomes an active abstract space that directs form within a current of forces that can be stored as information in the shape of

---

[172] Greg Lynn, “Animate Form,” Animate Form, Princeton Architectural Press, New York, 1999,p 10
[173] ibid. Lynn, p 10
[174] ibid. Lynn, p 10
[175] ibid. Lynn, p 11
[176] ibid. Lynn, p 11

the form".[177] All these discussions illustrate the presence of force and movement at the initial moment of virtually moving structures' formal production.

For such a distinct production process, which requires a design space that is active due to forces and movements it inherits, the representation and planning techniques are also particular. Computers with special soft-ware are used "as tools for design rather than as devices for rendering, visualization and imaging".[178] The electronic topologies constructed by the computers are used as active design spaces. The forces sourcing from environmental substances are embodied virtually with the aid of special computer programs and the project is formed among this virtual space. The projects of Lynn that are analyzed at further pages will depict the formulation phases done through computers. The leading design role of computers in the production of virtually moving structures can also be related with the changing comprehension of "space" idea in the contemporary social organization. The transformation of "space" notion from real to virtual is pointed by Paul Virilio:

> There is no *plenum*; space is not filled with matter. Instead, an unbounded expanse appears in the false perspective of the machines' luminous emissions. From here on, constructed space occurs within an electronic topology…[179]

This "electronic topology" provided by computers is an essential tool for both the production and the representation of virtual movements. Lynn's projects; Yokohama Port Terminal and House Prototype in Long Island demonstrate how these constructed electronic topologies turn to active design spaces.

Yokohama Port Terminal (Yokohama, Japan, 1994):

The project is prepared for the competition held in 1994. Lynn depicts the terminal as "a location of complex movement and interchange between passengers and citizens, between land and sea, between city and garden,

---

[177] Greg Lynn, "Animate Form," Animate Form, Princeton Architectural Press, New York, 1999,p 11
[178] ibid Lynn, p 10
[178] ibid. Lynn, p 11
[179] Paul Virilio, "Overexposed city," Neil Leach edits Rethinking Architecture: A Reader in Cultural Theory, Routledge, London and New York, 1997

between vehicles and cargo".[180] This "dynamic exchanges", as he calls, are used as opportunities to celebrate movement.[181]

The project comprises three main elements. These are the terminal tube, the citizens' tube and the garden. Each element is designed as made of distinct materials due to their particular functions. All of them extend the full length of the site as they complement each other. These complements, which create intersections and passages between the tubes, are projected through forces of environmental substances generated in computers.

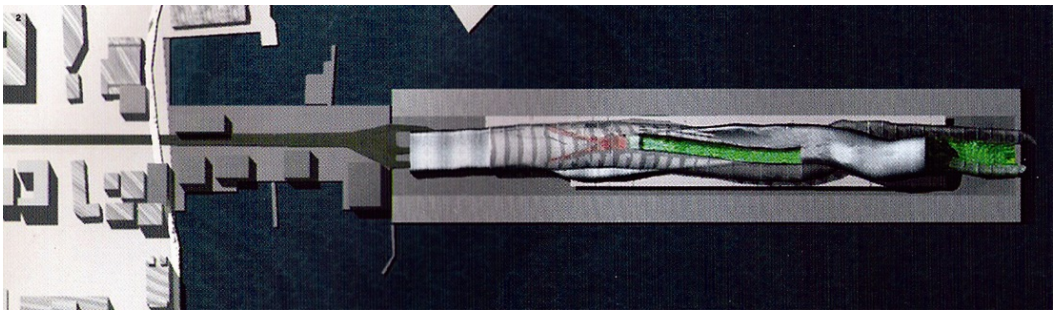


figure 5-1 Yokohama Port Terminal _ roof plan

figure 5-2 Yokohama Port Terminal _ aerial view looking toward the city

[180] Greg Lynn, "Animate Form," Animate Form, Princeton Architectural Press, New York, 1999, p 121
[181] ibid. Lynn, p 121

The tubes are formed according to docking patterns of the ships using the terminal. The figure 5-3 illustrates this formation. The red points in the figure depict the places where ships approach to the port. The white line is the terminal tube that is shaped as a "spline" drawn through specific red points to service the ships. The blue line, on the other hand, is the citizens' tube which is the mirrored image of the white line. Since their programs are commented as opposing, the tracks of tubes are designed as reversing. The terminal tube "interpolates continuously as a curve between the specific docking points of all of the boats using the terminal" as the white line.[182] Hence, this tube relates passengers with the boats. The citizen's tube, on the other hand, is for "public programs" such as parking, cafeteria, shops, visitor lobbies and conference facilities.[183] Being depicted as the blue line in the figure, the citizen's tube intersects with the terminal tube at some points to relate passengers with social activities. Including the places of these intersections, all elements of the project are formed according to ship movements generated virtually. The particular way of design is explained by Lynn; "Emphasis on smooth and continuous movement organizes the project programmatically, contextually and spatially".[184]

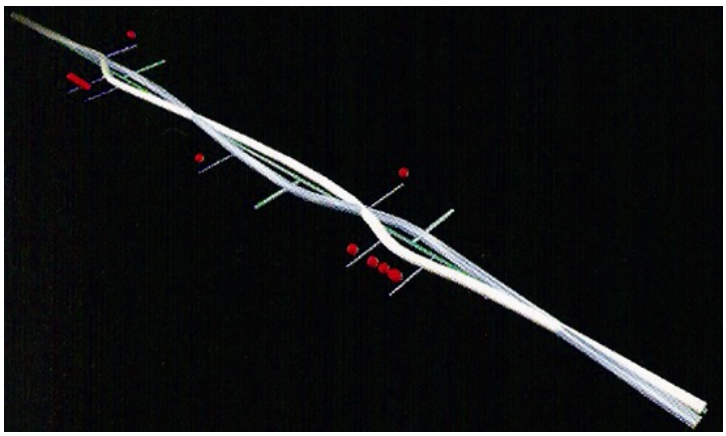


figure 5-3 Yokohama Port Terminal _ the generation of tubes

House Prototype in Long Island (New York, USA, 1994):

Various prototypes of a small weekend house are generated for a site in Amagansett Long Island. Each designed with a specific context; all prototypes

[182] Greg Lynn, "Animate Form," Animate Form, Princeton Architectural Press, New York, 1999, p 125
[183] ibid. Lynn, p 126
[184] ibid. Lynn, p 121

are formed in the same electronic topology. This topology is obtained by mapping the site according to “visual obstacles and visual attractors using forces of various shapes and configurations”.[185] Some environmental substances are construed as sources of distinct type forces:

> The foundations of the existing house are modeled using a gathering vortex force; the oak tree and the neighboring house are modeled using a repelling radial force; the existing driveway, with a gathering linear directional force; and the coastline with a strong gathering area force.[186]

Figure 5-4 illustrates the electronic phase through which these forces of the site are mapped. To read the effects of linear, vortex and radial directions of the forces, a three-dimensional grid of particles is introduced onto the site. The sequence in the figure depicts the movements of particles in the constructed field of attraction and repulsion.

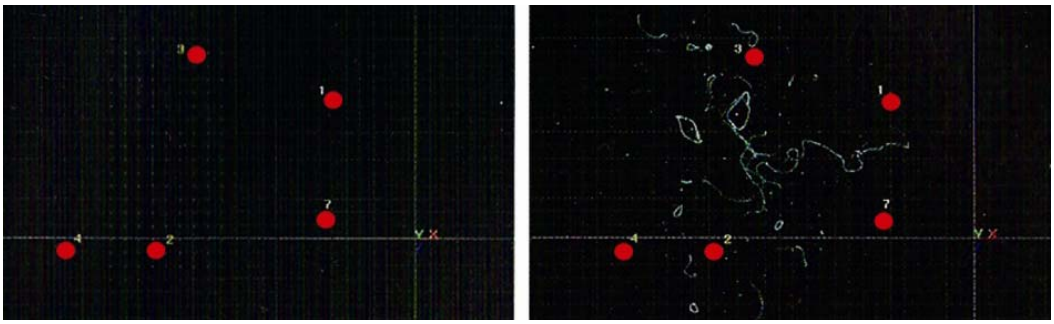


figure 5-4 House Prototype in Long Island _ mapping of the site forces in the three dimensional grid of particles, red points indicate the attraction positions: 1. the location of a neighboring house, blocking the view of the Atlantic Ocean, 2. a large tree also located in the same line 3. an existing foundation from the previous house 4. an existing driveway 5. an existing orchard on the site

There are four different prototypes generated in this constructed environment. First prototype has a rectangular volume. A skeleton system is set up in the volume to translate the forces coming from the site onto the surfaces. The generated forces in the design environment make the skeleton’s joints move. These moving joints create deformations on the outer surfaces. Hence, the volume takes its form through the movements generated virtually in the active design space. (figure 5-5)

---

[185] Greg Lynn, “Animate Form,” Animate Form, Princeton Architectural Press, New York, 1999, p 143

[186] ibid. Lynn, p 143

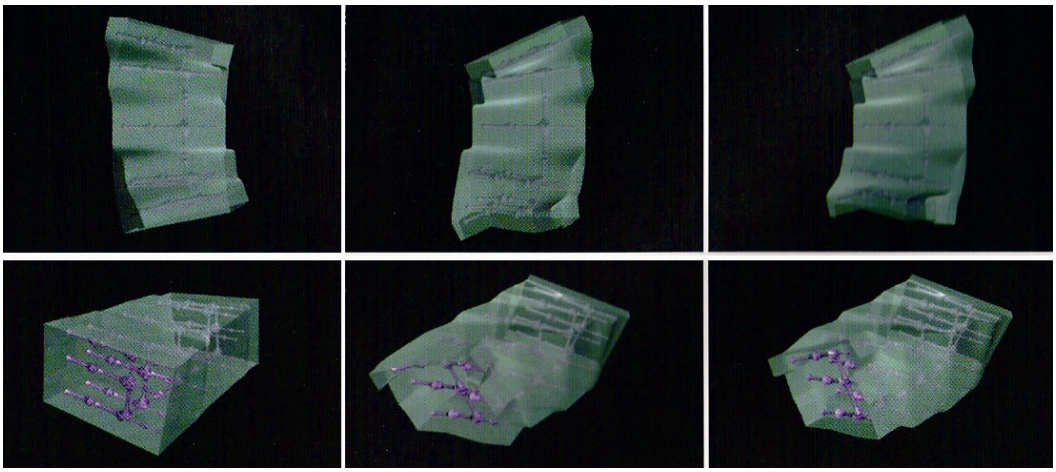


figure 5-5 up: House Prototype in Long Island _ prototype1 _ plan view
below: House Prototype in Long Island _ prototype1 _ perspective view

Second prototype has an H plan organization with a central main living space and two pairs of rooms at both sides. Again, skeleton systems are introduced in the volumes as the translators of generated forces. Moreover, two tensile structures are formed running along the front and back of the house. These structures act as transitional spaces between the interior and exterior area. Their reactions to forces are different than the skeletons and the overall volume since they are generated as lightweight tent structures corresponding to their functions. The sequence in the figure 5-6 illustrates the forming phase.

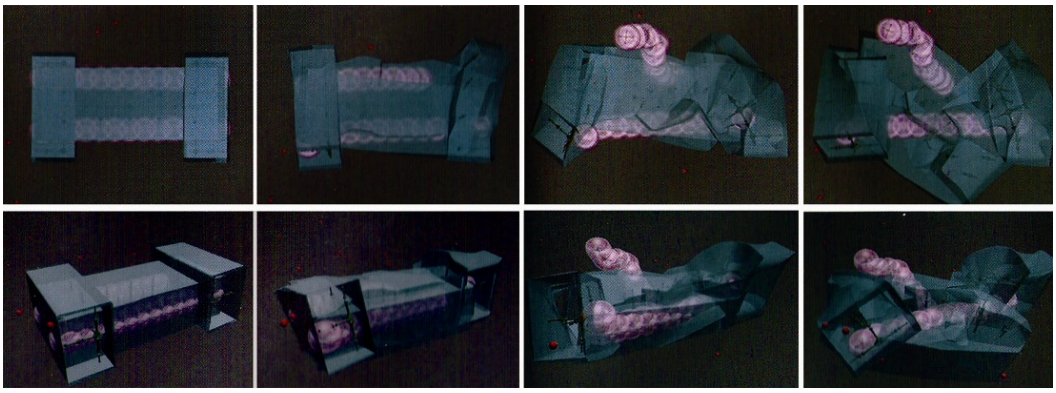


figure 5-6 up: House Prototype in Long Island _ prototype2 _ plan view
below: House Prototype in Long Island _ prototype2 _ perspective view

Third prototype differs from the second one with its arrangement of tensile structures. They are placed perpendicular to the main living space in this case. Moreover, two ending rooms are shifted forward and backward in accordance with the central space. Skeleton system remains as the translator. Figure 5-7

depicts the initial condition in a static environment and an intermediate position formed by the virtual forces.

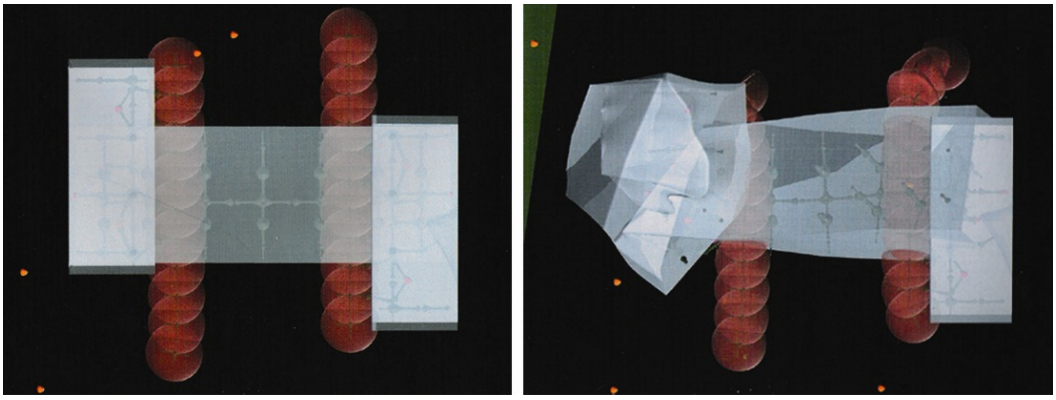


figure 5-7 left: House Prototype in Long Island _ prototype3 _ initial condition
right: House Prototype in Long Island _ prototype3 _ an intermediate position in the active design space

In the last prototype, the skeleton is simplified to a linear system to read the effects of the generated forces more clearly as Lynn claims. The surfaces enveloping the skeleton are also linearly organized. The center of the structure is attached to the driveway and the foundation whereas the longitudinal ends are connected to the ocean forces. The central part holds the surface of the main living space and the ends hold the tensile elements. The deformations generated from the movements of the joints are greater in the tensile elements due to their loose structures and more effective movements created on the ends of the skeleton. The electronic formulation phase is depicted in the figure 5-8.

figure 5-8 up: House Prototype in Long Island _ prototype4 _ plan view
below: House Prototype in Long Island _ prototype4 _ perspective view

As both projects demonstrate, the movements Lynn uses as his design tools belong to the larger contexts rather than to the structures. The topologies in which the structures will exist are depicted as spaces of distinct forces. These forces are sourced from various substances with particular alignments. Some translators such as “splines” or “skeleton systems” are introduced to the projects to transmit the forces onto surfaces of the structures. The forces move the surfaces and the structure gets its form. Hence, the movements, which define the design spaces, embody the structures. The last products are adaptable structures designed in accordance with the forces generated from the environment, similar to hulls anticipating different forces in the water.

“Virtual movement” as such a design method conceptualized by Lynn, evokes the particular Deleuzian comprehension that depicts movement as a way to describe figures. Similar to figures of cartoons that are exemplified by Deleuze as being embodied through movements, virtually moving structures are formed by motions.[187] Although the similarity in the presence of movement as the generator of forms for both cartoon figures and virtually moving structures, the theoretical conceptions of end products are very different. Cartoons are movements whereas virtually moving structures are stable objects. In both, the movement is the generator. Nevertheless, for cartoons; movement generates movements while for virtually moving structures; movement generates a stable end product. Lynn’s architectural products as “computer-generated architectural forms” can not achieve the status of architectural form that “appears as the ultimate result of a process” according to Antoine Picon.[188] Picon’s further comments on the computer-generated architectural forms are as follows:

> Even if it appears as the most satisfying configuration for its designer, it remains an arbitrary stop in an endless process of geometric transformation, the type of process that Greg Lynn calls “animation”. Architectural form becomes similar to a cross-section in a continuous geometrical flow.[189]

---

[187] Gilles Deleuze, “Theses on Movement: First Commentary on Bergson,” Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 5

[188] Antoine Picon, “Architecture, Science, Technology and the Virtual Realm,” Antoine Picon and Alessandra Ponte edit Architecture and the Sciences: Exchanging Metaphors, Princeton Architectural Press, Princeton, 2003, p 302

[189] ibid Picon, p 303

This discussion depicts that end products of Lynn are in fact arbitrary stops in endless processes. There is arbitrariness about the stage on which the designer stopped the process of geometrical transformation. This condition evokes Deleuzian idea of "immobile section". Lynn's structures are products of mobile sections of durations consisting of immobile sections.[190] End products are one of these sections chosen by Lynn. Hence, each virtually moving structure is an immobile section as an end product.

To sum up, Lynn's structures depict movements that describe figures and the Deleuzian formulation of Lynn's comprehension is "immobile sections + abstract time". Although this formula prescribes the end product instead of the production phase, virtually moving structures miss the movement to cite Deleuze. This is because the incapability of an immobile section to signify a movement. Movement is an inherent element in Lynn's structures but the end products are not sufficient to imply this comprehension, I think. Abstract time is not added back to them later but this cannot change their identification as an immobile section rather than a mobile one of duration. Lynn's structures do not appear as figures that involve movement or indicate motion. They are just arbitrary immobile sections of active phases.

These outcomes point that Santiago Calatrava is unique in his utilization of movement issue in his architectural thinking and production. His mobile structures are figures that become the creator of movements to quote Deleuze.[191] They are neither the figures described by movement nor the immobile sections picked from a phase. Actually, bodily and visually moving structures of Calatrava are architectural productions that conceptualize movement as a mobile section of duration that creates changes to cite from the Deleuzian ideology.

---

[190] Henri Bergson's analogy quoted by Deleuze:

$$\frac{\text{immobile sections}}{\text{movement}} = \frac{\text{movement as mobile section}}{\text{qualitative change}}$$

[191] Gilles Deleuze, "Theses on movement: First Commentary on Bergson," Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 5

CHAPTER 6

CONCLUSION

This study reintroduces the term “movement” as a design medium for producing architecture. In the history of architectural culture, the theme has been utilized as a design concept signifying distinct methodologies. The Deleuzian discourse on the concept comprises the theoretical base of this thesis.

All related formulations of Deleuze prescribing even reconstructions in which “we miss the movement” have been discussed as guiding conceptions. The comprehension of movement as “a mobile section of duration”, which is an approved understanding by Deleuze, has been chosen as the contextual perception of the theme in this study. Santiago Calatrava’s mobile structures have been analyzed as architectural products that embody this contextual perception.

The pragmatic base for this analysis was formed with a trilogy derived from Alexander Tzonis’s related statements on the works of Calatrava. This trilogy is a categorization of Calatrava’s finished structures. The methods used by Calatrava to conceptualize movement in his works were the guides for this categorization. Actual, bodily and visual movements constituted the sections of the trilogy. Each type has been explored through chosen projects of Calatrava both as a theoretical framework and a practical design technique.

These explorations have introduced some design tools utilized by Calatrava in the conceptualization and the production of his mobile structures. These design tools are apprehended as generators for methods of producing “other ways” of architecture. They are treated as elements of an extensive design culture.

“Unfolding”, “rising” and “revolving” are three of these design tools that are used to form actually moving structures. These three tools are primarily discussed by Tzonis in his related writings. Moreover, Calatrava’s particular remarkable

projects embody each tool and “become the creators of movement” to cite Deleuze. Calatrava’s actually moving structures have adaptable bodies. This condition is obtained through forms that can literally change. The actual movements transform the structures into different bodies to adapt the environmental changes. The Eastern entrance of Alcoy Community Hall transforms to a back wall for a circular pool when it is folded and becomes a secure surface for pedestrians when it is unfolded. Ribs of Kuwait Pavilion rise or fall to climate the plaza. Footbridge Puerto Mujer revolves to give passage for the mobiles on water. The design tools; unfolding, rising and revolving enable structures to response to changes occurring in the environment and in the time. Due to utilization of these tools, actually moving structures of Calatrava change their shapes to adapt altering pressures. Josè Luis Gonzàlez Cobelo comments on Calatrava’s such designs in his article published in *El Croquis*:

> The importance of introducing a kinetic component in his designs comes from the possibility of each stage of movement permitting a formal variant that is valid in itself. The building thus evolves as an organism whose form adapts to a changing environment.[192]

As a further contribution besides the ones made on the functional potential of the structure, unfolding characterizes the contextual definition of the work. Deleuze’s discussions explored on the second chapter introduce this characterization. Deleuze claims; “it can be stated that what is folded is only virtual and currently exists only in an envelope, in something that envelopes it.” [193] This understanding generates a remarkable shift in the conception of movement. Materialized as unfolding, movement is introduced as a feature that adds to the identity of a structure. Although they have not been conceptualized in any theoretical framework, rising and revolving can also be used as identifier features of structures.

Due to their generations of characteristic changes on the postures or the positions of the works and the resulted contributions made on the functional abilities of the structures, unfolding, rising and revolving are accepted as

---

[192] Josè Luis Gonzàlez Cobelo in “Mask and Vertigo: Engineering and Alchemy in the work of Santiago Calatrava,” El Croquis, vol.11, no.5, 1992, p 12

[193] Gilles Deleuze, “Theses on Movement: First Commentary on Bergson,” Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991, p 22

essential design tools that conceptualize actual movement. Although Calatrava's finished works depict only these three methods, other tools that embody real motions may be derived from further specific studies.

Explorations on bodily movement in Calatrava's works, on the other hand, have introduced two other design tools; "rhythm" and "shape". Both have been depicted to be used as distinct sources to embody motions in the structures.

Rhythm is explored as an articulation method that relates with movement in two ways. Firstly, movement is depicted as an essential issue to experience a rhythm when rhythm extends in space. Secondly, rhythm becomes a perception of movement as a transformation of conception. Derived from these relations, rhythm has been introduced as a flow that can be perceived by movement in this study. Such an articulation method has been highlighted as a design tool to embody movements in the structures. Rhythmical configurations of Calatrava have been explored as differentiated channels that cover various flows of mobile bodies. Repeated Y-shaped columns that carry cantilevered platform roof of Stadelhofen Railway Station are the traces for traveling people whereas rhythmical undulating concrete arches of the underground center become signs for the shopping ones in the same station.

Shape, on the other hand, has been highlighted as formal configuration that is capable of directing movements. Deliberately chosen shapes for "plates", "openings", and "silhouettes" in the architectural production turn into means for embodying motions through concretizing and even framing them. Triangle has been depicted as the shape that guides flows with its directional configuration and frames motions in the strong stability its articulation implies. Triangle "openings" and triangle "silhouette" of Lyon Airport Railway Station constituted references for this depiction. Nevertheless, other shapes can also be utilized with similar conceptions. Although discussed as a stable configuration, circle can become a form that directs movements towards its center. Square, even though depicted as having no preferred direction, can turn into an articulation embodying flows moving along its circumference. Hence, when comprehended as an outline that will embody movements through its formal configuration, shape turns to be a remarkable design tool for capturing bodily movement.

Other ways of producing bodily moving structures may be introduced through different studies. Capability to direct mobile bodies, capacity for differentiating particular flow paths, and potential for portraying movement constitute essential criteria for defining new design tools that conceptualize bodily movement in the architectural production.

Visually movement, as the last category of trilogy, reveals three more design tools. These are “structural illusion”, “representation of nature”, and “figura serpentinata”.

Optically unbalanced works of Calatrava have been discussed as forms that anticipate movements. Posts seeming as collapsing, arches seeming as turning and columns seeming as falling were the exemplary cases. These works were treated as innovative results of structural researches and expressive responses of formal concerns. Shifts in the particular comprehensions of issues like “force”, “gravity” and “balance” have been depicted as the essential criterion for achieving structural illusion. To grasp an architectural structure as a system consisting of counterbalancing forces rather than seeing it as a reaction to the force of gravity is the initial requirement for utilizing structural illusion tool. To eliminate the restrictive effect of gravity force provides the designer with an increase in the variety of possible structural configurations. Inclination becomes possible due to lapsing of the obligation of verticality. Inclined forms imply anticipatory movements.

Nature has been reintroduced as another source that implies movements. This implication has two reasons. First, there are natural creatures that can move, such as flying birds. Second, there is a concealed continuous movement in all natural organisms; to grow. This inherent mutuality brings the representation of nature a method to suggest movement. Calatrava’s representation deals with the essence of nature as well as its image. The moving natural organisms become models for Calatrava with both their systematical articulations and aesthetical configurations. His works resembles the images of birds as modeling their organic structures. His tree-like columns do signify mobility instead of stability since they branch in a system similar the one in the nature. The talent of natural

creatures to move is a fascinating criterion. To represent their essence as well as their image is a design tool to conceptualize these fascinating movements.

Figura serpentinata is the last design tool introduced in this thesis. The conception is based on the depiction of S-form as a way to imply anticipated movement like in the case of “the flame of fire”. Greek sculptures as well as Calatrava structures have been used to illustrate this depiction. High Rise in Malmö implies a twisting flow towards to sky whereas La Rioja Bodegas Ysios Winery involves an undulating one along the horizon. Nevertheless, the common feature both inherit is the continuity they indicate. S-formed architectural articulations suggest movements due to the endlessness implied from their outlines. The curvilinearity they are shaped of seems lasting to infinite. This generated illusion highlights figura serpentinata as a design tool in the conception of visual movement in architectural production.

Alternative methods for producing visually moving structures may be derived from distinct explorations. Nevertheless, Calatrava’s finished works that anticipate movements are systematized along with these three tools substantially.

Design tools; “unfolding”, “rising”, “revolving”, “rhythm”, “shape”, “structural illusion”, “representation of nature”, and “figura serpentinata” are derived from Calatrava’s architectural production that conceptualizes movement.

Movement, in the sense Calatrava conceptualizes it, is “mobile section of duration” to cite Deleuze. The theme is treated as a mobile duration, not as the superimposition or sequencing of distinct instances or phases. Motion is comprehended as a source of change in Calatrava structures, parallel with the ideas of Deleuze. All of actually, bodily, and visually moving structures of Calatrava are productions of such a comprehension. Explorations on “virtual movement” have emphasized this determination.

Virtual movement has been researched as a contemporary issue related with the concept of movement in the 20th century’s design culture. Studies of Greg Lynn constituted the base for this research. Lynn brings a different perspective to the

comprehension of movement idea in the realm of design by attributing motion to the design environment in which the structure emerges.

Movement is treated as a force sourced from the outer environment to generate forms. Lynn's productions do not depict this force through superimposing sequences or poses. Nevertheless, they "miss the movement" to cite Deleuze. There is a basic reason for this situation; virtually moving structures are immobile sections. Although Lynn's architectural thinking comprehends that movement is a mobile section of duration that creates changes, his architectural production do not imply this comprehension. The end products of his theoretical projections are arbitrarily chosen sections of such durations. Lynn's each project is an immobile section of a creative transition that generates it. The works are moulded in mobile sections of durations. Active forces generated in computers mould the forms as moving their skeletons and surfaces. Nevertheless, the arbitrariness in the ending phases of these durations prevents the products to imply the mobility they inherit. Lynn's works, as arbitrarily picked sections, make the observer to perceive the movement as created by disjointed immobile poses like the ones in cubist paintings. Hence, as being immobile sections, virtually moving structures do not depict an abstract time. They "miss the movement" as embodying Deleuze's second formula; "immobile sections + abstract time". This specific research on the particular comprehension of Lynn does not only provide plasticization of related Deleuzian idea but also prove that Calatrava is unique about the conceptualization of movement theme in the architectural production.

Santiago Calatrava's remarkable distinctness is previously discussed. To make a recall, his multi-disciplinary studies on specified fields, his sophisticated architectural background, and his creative personality can be counted as the derivations of his uniqueness. As an "engineer architect", Calatrava comes to the fore regarding both such previous designers and his contemporaries.[194]

Movement is a design tool for the architectural thinking and production. The application of the issue has remarkable contributions in Calatrava's profession.

[194] "Engineer architect" is a term introduced by Arzu Emel Yıldız in her unpublished text: Pier Luigi Nervi: Architect Engineer, Santiago Calatrava: Engineer Architect, for the course ARCH 513_ Architectural Research I, METU, Ankara, 2004

Similarly, Calatrava's mobile structures that are both aesthetical expressions and technological innovations improved the utilization of movement concept in the design culture. Together with the related studies on the issue realized by philosophers, critics, and other designers, actually, bodily and visually moving structures of Santiago Calatrava depict that the conceptualization of movement theme is an 'other way of producing architecture'.

BIBLIOGRAPHY

Arnheim Rudolf, Art and Visual Perception: A Psychology of the Creative Eye, University of California Press, Berkeley, 1974

Banham Reyner, Theory and Design in the First Machine Age, MIT Press, Cambridge, 1980

Beck John, "Buckminster Fuller and the Politics of Shelter," Hughes Jonathan and Sadler Simon edit Non-Plan: Essays on Freedom Participation and Change in Modern Architecture and Urbanism, Architectural Press, Oxford, Boston, 2000

Berkel Ben van and Bos Caroline, Move: v.1 Imagination, UN Studio and Goose Press, Amsterdam,1999

Berkel Ben van and Bos Caroline, Move: v.2 Techniques, UN Studio and Goose Press, Amsterdam,1999

Berkel Ben van and Bos Caroline, Move: v.3 Effects, UN Studio and Goose Press, Amsterdam,1999

Berkel Ben van and Bos Caroline, UN Studio- Unfold, NAI Publishers, Rotterdam, 2002

Blaser Werner, "Who is Santiago Calatrava?," Blaser Werner edits Santiago Calatrava, Gustavo Gili , Barcelona, 1989

Bridging the Gap: Rethinking the Relationship of Architect and Engineer, the proceedings of the Building Arts Forum/New York symposium held in April of 1989 at the Guggenheim Museum, Van Nonstrand Reinhold, New York, 1991

Buchanan Peter, “Santiago Calatrava,” Architectural Review, vol. 189, London, January 1991

Carpenter Rhys, Greek Sculpture, A Critical Review, University of Chicago Press, Chicago, 1960

Ching Francis, Architecture: Form, Space and Order, Van Nostrand Reinhold, New York, 1979

Cobelo Josè Luis Gonzàlez, “Mask and Vertigo: Engineering and Alchemy in the work of Santiago Calatrava,” El Croquis, vol.11, no.5, 1992

Davey Peter, “Poetry in Motion,” Architectural Review, vol. 197, London, February 1995

Deitz Paula, “Calatrava’s Creativity,” Architectural Review, vol. 209, iss. 1248, London, February 2001

Deleuze Gilles, Cinema 1: The Movement-Image, translated by Hugh Tomlinson and Barbara Habberjam, University of Minnesota Press, Minneapolis, 1991

Deleuze Gilles, The Fold: Leibniz and the Baroque, translated by Tom Conley, University of Minnesota Press, Minneapolis, 1993

Dorris Virginia Kent, “Seeking Structural Solutions,” Civil Engineering, vol. 66, iss. 11, New York, November 1996

Elias Helen, “Turning Torso Twists New Life into Cubism,” Architect’s Journal, vol. 220, no.8, London, September 2004

Erzen Jale Nejdet, Pictorial Movement: It’s Aesthetics and Mechanics, unpublished master thesis, Art Center College of Design, Los Angeles, California, 1973

Erzen Jale, “Nature, Its Aesthetic and Knowledge and Art,” Sargın Güven Arif edits Nature as Space (re)Understanding Nature and Natural Environments, METU Faculty of Architecture Press, Ankara, 2000

Frampton Kenneth, “Look No Hands – Santiago Calatrava and the Well-Tempered Reconstruction,” Blaser Werner edits Santiago Calatrava, Gustavo Gili, Barcelona, 1989

Frampton Kenneth, “Introduction,” Frampton Kenneth, Spector Arthur and Rosman Lynne Reed edit Technology, Place and Architecture, Rizzoli, New York, 1998

Giedion Sigfried, Space, Time and Architecture; the Growth of a New Tradition, Harvard University Press, Cambridge, 1967

Hart Sara, “Moveable Feast,” Architecture, vol. 89, iss. 5, Washington, May 2000

Hertel Heinrich, Structure, Form, Movement, Reinhold, New York, 1966

Hesselgren Sven, The Language of Architecture, Studentlitteratur, Lund, 1969

Hoberman Chuck, “Unfolding Architecture,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, 1993

Ivy Robert, “New Kind of Hero,” Architectural Record, vol. 192, iss. 9, New York, September 2004

Ivy Robert, “Calatrava Speaks... About the Genesis of His Work and the Influences that Shape His Singular Vision,” Architectural Record, vol. 188, iss. 7, New York, July 2000

Karchmer Alan, “Santiago Calatrava’s Lyrical Crossings,” Architectural Record, vol. 192, iss. 11, New York, November 2004

Lenoir Timothy and Alt Casey, “Flow, Process, Fold,” Picon Antoine and Ponte Alessandra edit Architecture and the Sciences: Exchanging Metaphors, Princeton Architectural Press, Princeton, 2003

Lynn Greg, Animate Form, Princeton Architectural Press, New York, 1999

Lynn Greg, “Architectural Curvilinearity: the Folded, the Pliant and the Supple,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, 1993

McQuaid Matilda, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993

Nicolin Pier Luigi, “Questions on Santiago Calatrava,” Blaser Werner edits Santiago Calatrava, Gustavo Gili , Barcelona, 1989

Picon Antoine, “Architecture, Science, Technology and the Virtual Realm,” Picon Antoine and Ponte Alessandra edit Architecture and the Sciences: Exchanging Metaphors, Princeton Architectural Press, Princeton, 2003

Powell Kenneth, “Unfolding Folding,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, 1993

Rajchman John, “Out of the Fold,” Architectural Design: Folding in Architecture, no. 102, Academy Editions, London, 1993

Richter Gisela M. A., The Sculpture and Sculptors of the Greeks, Yale University Press, New Haven, 1950

Sharp Dennis edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996

Sharp Dennis edits Santiago Calatrava, E and FN Spon, London, 1994

Seles Emre, Representation(s) of Topkapı Palace, unpublished master thesis, Department of Interior Architecture and Environmental Design, Bilkent University, Ankara, 2004

Tischhauser Anthony and Moos Stanislaus von edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998

Tzonis Alexander and Lefaivre Liane, Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995

Tzonis Alexander, Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999

Tzonis Alexander, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004

Virilio Paul, "Overexposed city," Leach Neil edits Rethinking Architecture: A Reader in Cultural Theory, Routledge, London and New York, 1997

Webster Anthony C., "Utility, Technology and Expression," Architectural Review, vol.191, no.1149, 1992

Zardini Mirko edits Santiago Calatrava: Secret Sketchbook The Monacelli Press, New York, 1996

Zuk William and Clark Roger H., "Kinetic Geneses," Kinetic Architecture, Van Nostrand Reinhold Company, New York, 1970

[http://de.wikipedia.org]

[http://en.structurae.de]

[http://en.wikipedia.org]

[http://www.artlex.com]

[http://www.brunelleschi.imss.fi.it]

[http://www.calatrava.com]

[http://www.designbuild-network.com]

[http://www.eyeconart.net]

[http://www.monticello.org]

[http://www.m-w.com]

APPENDIX A

SANTIAGO CALATRAVA_CHRONOLOGICAL BIOGRAPHY *

28 July 1951	born in Benimamet, Valencia, Spain
1959-1960	visited evening courses at the school for Arts and Crafts in Burjasot, Spain
1961-1968	graduated from high school in Valencia, Spain
1968-1969	attended the Art School in Valencia, Spain
1969-1974	studied architecture at the Escuela Técnica Superior de Arquietctura de Valencia, Spain
1974	graduated from Escuela Técnica Superior de Arquietctura de Valencia with a degree in architecture
1974	attended graduate courses in Urban Studies in Escuela Técnica Superior de Arquietctura de Valencia

* This biography is derived from a thorough synthesis from Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993; Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996; Dennis Sharp edits Santiago Calatrava, E and FN Spon, London, 1994; Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, Alexander Tzonis and Liane Lefaivre, Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995; Alexander Tzonis, Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999; Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004; Mirko Zardini edits Santiago Calatrava: Secret Sketchbook The Monacelli Press, New York, 1996; and the official website of Santiago Calatrava http://www.calatrava .com

1975-1979 studied Civil Engineering at the Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

1979-1981 received a Ph.D. degree with his thesis: 'On the Foldability of Frames', ETH, Zurich, Switzerland

assistant in the Institute for Building Statics and Construction, ETH, Zurich, Switzerland

assistant in the Institute for Plane Statics and Light Constructions, ETH Zurich, Switzerland

1979 founded his own architecture and civil engineering office in Zurich, Switzerland

1985 **exhibition** _ Nine Sculptures, Jamileh Weber Gallery, Zurich, Switzerland

1987 became member of BSA (Union of Swiss Architects)

became member of the International Academy of Architecture

participated the 17th Trienale, Milan, Italy

prize _ *Auguste Perret UIA (Union Internationale d'Architectes)*

exhibition _ *Santiago Calatrava*, Museum of Architecture, Basle, Switzerland

1988 **prize** _ *City of Barcelona Art Prize*, for Bach de Roda Bridge - Felipe II Bridge, Barcelona, Spain

prize _ *IABSE Award (International Association for Bridge and Structural Engineering)*, Helsinki, Finland

prize _ *FAD Prize (Formento de las Artes y del Diseño)*, Spain

prize _ *Fritz Schumacher Prize for Urbanism, Architecture and Engineering*, Hamburg, Germany

prize _ *Fazlur Rahman Khan International Fellowship for Architecture and Engineering*

1989 founded his second architecture and civil engineering office in Paris, France

became honorary member of BDA (Union of German Architects)

traveling exhibition _ New York, St Louis, Chicago, Los Angeles, Toronto, Montreal

1990 **prize** _ *Médaille d'Argent de la Recherche et de la Technique*, Académie d'Architecture Foundation 1970, Paris, France

1991 founded his third architecture and civil engineering office in Valencia, Spain

prize _ *European Glulam Award (Glued Laminated Timber Construction)*, Munich, Germany

prize _ *City of Zurich Award for Good Buildings 1991,* for Stadelhofen Railway Station, Zurich, Switzerland

exhibition _ *Santiago Calatrava*, Suomen Rakennustaiteen, Helsinki, Finland

retrospective exhibition _ *Dynamic Equilibrium*, Museum of Design, Zurich, Switzerland

1992 became member of the Real Academia de Bellas Artes de San Carlos, Valencia, Spain

became member of the European Academy, Cologne, Germany

prize _ *Gold Medal*, the Institution of Structural Engineers, London, England

prize _ *Brunel Award*, for Stadelhofen Railway Station, Zurich, Switzerland

prize _ *CEOE Foundation, VI Dragados y Construcciones Prize*, for Alamillo Bridge, Zurich, Switzerland

retrospective exhibition _ Dutch Institute for Architecture, Rotterdam, Netherlands

retrospective exhibition _ *Santiago Calatrava*, Royal Institute of British Architects, London, England

retrospective exhibition _ Arkitektur Museet, Stockholm, Sweden

1993 Doctor Honoris Causa, Polytechnic University of Valencia

became Hon FRIBA (honorary fellow of the Royal Institute of British Architects)

prize _ *Honorary Medal for the Fostering of Invention*, Foundation Garcia Cabrerizo, Madrid, Spain

prize _ *City of Toronto Urban Design Awards*, for BCE Place, Toronto, Canada

exhibition _ *Santiago Calatrava*, La Llotja, Valencia, Spain

exhibition _ *Santiago Calatrava*, Overbeck Gessellschaft, Lübeck, Germany

exhibition _ *Santiago Calatrava*, Gammel Dok, Copenhagen, Denmark

exhibition _ *Santiago Calatrava - Bridges*, Deutsches Museum, Munich, Germany

exhibition _ *Structure and Expression*, MoMA, NewYork, USA

1994 Doctor Honoris Causa, University of Seville

Doctor Honoris Causa of Letters in Environmental Studies, Heriot-Watt University, Edinburgh

exhibition _ *Santiago Calatrava*, Arqueria de los Nuevos Ministerios, Madrid, Spain

exhibition _ *Santiago Calatrava*, Sala de Arte 'La Recova', Santa Cruz de Tenerife

exhibition _ *Santiago Calatrava-Recent Projects*, Bruton Street Gallery, London, England

exhibition _ *Santiago Calatrava-Buildings and Bridges*, Museum of Applied and Folk Art, Moscow, Russia

exhibition _ *Santiago Calatrava-Dynamics of Equilibrium*, Mae Gallery, Tokyo, Japan

1995 Doctor Honoris Causa of Science, University College, Salford

prize _ *Canton of Lucerne, Award for Good Building 1983-1993*, for the railway station and square

exhibition _ *Santiago Calatrava*, Centro Cultural de Belem, Lisbon, Portugal

exhibition _ *Santiago Calatrava-Construir el Movimiento*, Fondazione Angelo Masiere, Venice, Italy

exhibition _ *Santiago Calatrava*, Navarra Museum, Pamplona, Spain

1996 Doctor Honoris Causa of Science, University of Strathclvde, Glasgow

prize _ *Medalla de Oro al Mèrito de las Bellas Artes,* Ministry of Culture, Granada

exhibition _ *Santiago Calatrava*, Sala de Exposiciones del Archivo Foral, Bilbao, Spain

exhibition _ *Santiago Calatrava: Opera e Progetti 1980-96*, Palazzo della Ragione, Padua, Italy

1997 Doctor Honoris Causa of Science, University of Technology, Delft

Doctor Honoris Causa of Engineering, Milwaukee School of Engineering, Milwaukee, Wisconsin

prize _ *European Award for Steel Structures,* Berlin, Germany

prize _ *Louis Vuitton – Moët Hennessy Art Prize,* Paris, France

1998 **prize** _ *Brunel Award*, for Oriente Station*,* Lisbon Multimodal Station S.A., Portugal

1999 Doctor Honoris Causa of Civil Engineering, Università degli Studi di Cassino

Doctor Honoris Causa of Technology, University of Lund

prize _ *Gold Medal,* The Concrete Society, London, England

2000 Doctor Honoris Causa of Architecture, Università degli Studi di Ferrara

prize _ *Gold Medal,* Circula de Bellas Artes, Valencia, Spain

prize _ *2000 Algur H. Meadows Award for Excellence in the Arts,* Meadows School of Arts, Dallas, USA

prize _ *"Das Goldene Dach 2000", The Golden Roof, Structural Completion of the "Pfalzkeller",* St. Gallen

retrospective exhibition _ *Santiago Calatrava: Artist, Architect, Engineer*, Palazzo Strozzi, Florence, Italy

2001 **prize** _ *Prize Exitos 2000,* for Science Museum in Valencia, Madrid, Spain

prize _ *Award for Excellence in for the Time Capsule,* American Museum of Natural History, New York, USA

prize _ *European Award for Steel Structures,* for Europe Bridge over the Loire River , Orleans, France

2002 **prize** _ *Best of 2001,* for Milwaukee Art Museum Extension, Time Magazine, New York, USA

prize _ *"Il Principle e L' Architetto",* for Quattro Ponte sul Canal Grande in Venice, Architettura e Design per la Città, Bologna, Italy

prize _ *The Sir Misha Black Medal,* Royal College of Art, London, England

prize _ *2002 The Best Large Structural Project,* for Milwaukee Art Museum Extension, The Structural Engineers Association of Illinois, USA

prize _ *The Leonardo da Vinci Medal,* for having made an outstanding contribution of international significance to engineering education, SEFI, Florence, France

2003 **prize** _ *Medalla al Mèrito a las Bellas Artes,* Real Academia de San Carlos de Valencia, Valencia, Spain

prize _ *Grande Mèdaille d'Or Architecture,* Acadèmie D'Architecture, Paris, France

exhibition _ *"Like a Bird"*, Kunsthistorisches Museum, Vienna, Austria

2004 Doctor Scientaiarium Honoris Causa, Technion (Israel's Institute of Technology), Haifa, Israel

prize _ *Golden Plate Award of the Academy of Achievement,* Chicago, Illinois, USA

2005 Doctor Honoris Causa of Arts, Southern Methodist University, Dallas, Texas

Doctor Honoris Causa in Engineering, Aristotle University of Thessaloniki, Thessaloniki

prize _ *2005 European Award for Steel Structures,* for OAKA Stadium's roof, Athens, Greece

prize _ *2005 European Award for Steel Structures,* for Harp, Zither, Lute: Three Bridges over the Hoofdvaart, Haarlemmermeer, Netherlands

prize _ *MIPIM Awards,* for Turning Torso as best residential building in the category "Residential Developments", Malmö, Sweden

prize _ *Eugene McDermott Award in the Arts,* Council for the Arts at MIT (Massachusetts Institute of Technology), Cambridge, London

prize _ *AIA Gold Medal,* American Institute of Architects, Washington DC, USA

exhibition _ *Santiago Calatrava: Sculpture into Architecture*, The Metropolitan Museum of Art, New York, USA

APPENDIX B

SANTIAGO CALATRAVA _ CATALOGUE OF WORKS *

1979 **WATER Sculpture,** ETH, Zurich, Switzerland, 1979-1980

IBA Squash Complex *(Project)*, Berlin, Germany

1981 **ZÜSPA Exhibition Hall *(Project)*,** Zurich, Switzerland
(Competition with Spühler _ 7th Prize)

1982 **WORK HALL, Commune of Wettingen,** Wettingen, Switzerland
(Competition with Betrix _ 1st Prize)

CITY Library *(Project)*, Thun, Switzerland
(Competition with Marbach and Ruegg _ 4th Prize)

LETTEN Bridge *(Project)*, Zurich, Switzerland
(Competition with Marbach and Ruegg _ 3rd Prize)

RHINE Bridge *(Project)*, Diepoldsau, Switzerland
(Competition with Weser _ 2nd Prize)

---

* This catalogue is derived from a thorough synthesis from Matilda McQuaid, Santiago Calatrava: Structure and Expression, The Museum of Modern Art, New York, 1993; Dennis Sharp edits Architectural Monographs No 46: Santiago Calatrava, Academy Editions, London, 1996; Dennis Sharp edits Santiago Calatrava, E and FN Spon, London, 1994; Anthony Tischhauser and Stanislaus von Moos edit Calatrava-Public Buildings, Birkhäuser Verlag, Basel, Boston and Berlin, 1998, Alexander Tzonis and Liane Lefaivre, Movement, Structure and the Work of Santiago Calatrava, Birkhäuser Verlag, Basel, Boston and Berlin, 1995; Alexander Tzonis, Santiago Calatrava: The Poetics of Movement, Thames and Hudson, London, 1999; Alexander Tzonis, Santiago Calatrava: The Complete Works, Rizzoli International Publications, New York, 2004; Mirko Zardini edits Santiago Calatrava: Secret Sketchbook The Monacelli Press, New York, 1996; and the official website of Santiago Calatrava http://www.calatrava .com

SCHWARZHAUPT Factory *(Project)*, Dielsdorf, Switzerland
(Competition _ 1st Prize)

1983 **ERNSTINGS Warehouse and Distribution Center,** Coesfeld, Germany, 1983-1985

JAKEM Warehouse, Münchwilen, Switzerland, 1983-1985

LUCERNE Station Hall, Lucerne, Switzerland, 1983-1989

PTT Postal Centre, Lucerne, Switzerland, 1983-1985

ST. FIDEN Bus Shelter, St. Gallen, Switzerland, 1983-1985

STADELHOFEN Railway Station,Zurich, Switzerland, 1983-1990
(Competition with Amsler and Rüegger _ 1st Prize)

WOHLEN High School, Wohlen, Switzerland, 1983-1988

1984 **BÄRENMATTE Centre,** Suhr, Switzerland, 1984-1988
(In association with Hertig and Partners)

DE SEDE Mobile Exhibition Pavilion, Zurich, Switzerland

DOBI Office Building, Suhr, Switzerland, 1984-1986
(In association with Peter Frei)

1985 **BACH DE RODA–FELIPE II Bridge,** Barcelona,Spain, 1985-1987

COBALLEROS Pedestrian Bridge *(Project),* Lerida, Spain
(Competition)

STATION Square Bus Terminus *(Project)*, Lucerne, Switzerland
(Competition _ 1st phase: 1st prize, 2nd phase: 2nd prize)

1986 **9 DE OCTUBRE Bridge,** Valencia, Spain, 1986-1990

AVENIDA DIAGONAL Traffic Signals, Barcelona, Spain
BLACKBOX Television Studio, Zurich, Switzerland, 1986-1987

CONCERT Room, St. Gallen, Switzerland

TABOURETTLI Theatre, Basel, Switzerland, 1986-1987

RESIDENZ NEUGEBAEUDE Bridge *(Project),* Salzburg, Austria **(Competition)**

1987 **ALAMILLO Bridge,** Seville, Spain, 1987-1992

BCE Place, Toronto, Canada, 1987-1992

OUDRY-MESLY Bridge, Paris, France, 1987-1988

BASARRATE Underground Station *(Project),* Bilbao, Spain

1988 **BAUSCHAENZLI Restaurant,** Zurich, Switzerland

EMERGENCY Services Center, St. Gallen, Switzerland, 1988-1998

LUSITANIA Bridge, Merida, Spain, 1988-1990

SWISSBAU Concrete Pavilion, Basel, Switzerland, 1988-1989

COLLSEROLA Communications Tower *(Project),* Barcelona, Spain **(Invited competition)**

GENTIL Bridge *(Project),* Paris, France

LEIMBACH Station *(Project),* Zurich, Switzerland

PRÉ BABEL Sports Center *(Project),* Geneva, Switzerland

WETTSTEIN Bridge *(Project),* Basle, Switzerland

1989 **BOHL Bus and Tram Stop,** St. Gallen, Switzerland, 1989-1996

BUCHEN Housing Estate, Würenlingen, Switzerland, 1989-1996

FLOATING Pavilion, Lake of Lucerne, Switzerland

LA DEVESA Bridge, Ripoll, Spain, 1989-1991

LYON Airport Station, Lyon, France, 1989-1994

ZURICH University – Law Faculty, Zurich, Switzerland

BAHNHOFQUAI Tram Stop *(Project),* Zurich, Switzerland

MIRAFLORES Bridge *(Project),* Cordoba, Spain

PUERTO Bridge *(Project)*, Ondarroa, Spain

1990 **SONDICA Airport,** Bilbao, Spain, 1990-1999

BELLUARD Castle Theatre *(Project)*, Filbourg, Switzerland

EAST LONDON River Crossing *(Project)*, London, England

URIBITARTE Bridge *(Project)*, Bilbao, Spain

1991 **ALAMEDA Underground Metro Station and Bridge,** Valencia, Spain, 1991-1996 **(Competition)**

CITY of Arts and Sciences in Valencia, Valencia, Spain, 1991-2004

KRONPRINZEN Bridge, Berlin, Germany, 1991-1995 **(Competition)**

KUWAIT Pavilion, Expo'92, Seville, Spain, 1991-1992

TENERIFE Opera House, Santa Cruz de Tenerife, Spain, 1991-2003

CALABRIA Football Stadium *(Project)*, Reggio Calabria, Italy

CATHEDRAL of St. John the Divine *(Project)*, New York, USA **(Invited competition)**

MEDOC Swing Bridge *(Project)*, Bordeaux, France **(Competition)**

SALOU Football Stadium *(Project),* Tarragona, Spain **(Competition)**

SPANDAU Railway Station *(Project)*, Berlin, Germany **(Invited competition)**

VALENCIA Communications Tower *(Project),* Valencia, Spain

1992 **ALCOY Municipal Centre,** Alcoy, Spain, 1992-1996

SHADOW Machine, New York, USA, 1992-1993

TENERIFE Exhibition Centre, Santa Cruz de Tenerife, Spain, 1992-1996 **(Competition)**

JAHN Olympic Sports Complex *(Project)*, Berlin, Germany **(Invited competition)**

LONDON Underground Modular Station *(Project)*, London, England

REICHSTAG Conversion *(Project)*, Berlin, Germany

1993 **ILE FALCON Motorway Bridge,** Sian, Switzerland

ORESUND Bridge, Denmark, Sweden

ORIENT Station, Lisbon, Portugal, 1993-1998
(Invited competition)

SONDICA Control Tower, Bilbao, Spain, 1993-1996
(Competition)

TRINITY Bridge, Salford, UK

ALICANTE Communications Tower *(Project)*, Alicante, Spain
(Competition)

HERNE Hill Stadium *(Project)*, London, England

1994 **MILWAUKEE Art Museum,** Wisconsin, USA, 1994-2000
(Invited competition)

MICHELANGELO Fair and Convention Centre *(Project)*, Fiuggi, Italy **(Competition)**

1995 **BILBAO Football Stadium *(Project)*,** Bilbao, Spain

KL Linear City *(Project)*, Kuala Lampur, Malaysia

SOUTHPOINT Pavilion *(Project)*, New York, USA

VELODROME Football Stadium *(Project)*, Marseilles, France
(Competition)

ZURICH Station Roof *(Project)*, Zurich, Switzerland
(Invited competition)

1996 **VALENCIA Opera House,** Valencia, Spain

CATHEDRAL Square *(Project)*, Los Angeles, USA
(Competition)

CHURCH of the Year 2000 *(Project)*, Rome, Italy
(Invited competition)

CITY Point *(Project)*, London, England

NEW Olympic Stadium *(Project)*, Stockholm, Sweden
(Invited competition)

1996 **LIEGE GUILLEMINS Railway Station,** Liege,Belgium, 1997-2002
(Invited competition)

PFALZKELLER Gallery, St. Gallen, Switzerland, 1997-1999

PORT DE LA SUISSE Service Area, Geneva, Switzerland
(Competition)

BARAJAS Airport *(Project)*, Madrid, Spain
(Competition)