Model Perspectives

Structure, Architecture and Culture

Mark R. Cruvellier
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ROUTLEDGE

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2017
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

Publisher's Note:
This book has been prepared from camera-ready copy provided by the authors.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Cruvellier, Mark, author. | Sandaker, Bjørn Normann, 1954- author. |
Dimcheff, Luben, author.
Title: Model perspectives : structure, architecture and culture / Mark R. Cruvellier,
Bjørn N. Sandaker and Luben Dimcheff.
Description: New York : Routledge, 2016. | Includes bibliographical
references and index.
Identifiers: LCCN 2016003816| ISBN 9780415731935 (hb : alk. paper) | ISBN
9780415731942 (pb : alk. paper)
Subjects: LCSH: Architecture--Themes, motives.
Classification: LCC NA2540 .C78 2016 | DDC 720--dc23
LC record available at http://lccn.loc.gov/2016003816

ISBN: 978-0-415-73193-5 (hbk)
ISBN: 978-0-415-73194-2 (pbk)

Typeset in Adobe Garamond
Printed and bound in India by Replika Press Pvt. Ltd.

Model Perspectives

Structure, Architecture and Culture

This book contains a unique collection of various perspectives on the relationship between structures and the forms and spaces of architecture. As such it provides students and professionals alike with an essential sourcebook that can be mined for visual inspiration as well as for textually rich and authoritative insight into the links between structure, architecture and cultural context.

The chapters address fundamental structural elements and systems: columns, walls, beams, trusses, frames, tensile structures, arches, domes and shells. Each chapter is subdivided into two parts:

• The essays – introduce the chapters with the reprinting of a curated set of essays and excerpts by various authors that uniquely address how particular structural elements or systems relate in essential fashion to architectural design concepts.

• The model studies – physical models of the overall structural systems of several notable contemporary buildings from Europe, North and South America, Africa and Asia are illustrated with large photographs, detail close-ups and views of their external forms and internal spaces that establish the exceptional qualities of these projects in connecting structural form to architectural design objectives. Mosaic layouts complete the chapters with a collection of photographs of yet more models whose particular details and unique features serve to extend the visual repertoire of the structural type being considered.

The combination, juxtaposition and mutual positive reinforcement of these two collections, one largely textual and the other image-based, provides the reader with unique and multifaceted insights into how structural forms and systems can be related to architectural design intentions. Conveyed by a strong and deliberate graphical design format, this assembly of materials gets to the very essence of structures within the context of architecture, and will inspire students and practitioners alike to make strategic design decisions for their own projects.

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Some books are treasure troves – ensembles of deep human experiential research – which need to be kept close to hand. This book is one such treasure. The combination of selected texts with the constructed models becomes the thoughtfully constructed intellectual structure within which to navigate these essential topics.
– Yvonne Farrell & Shelley McNamara, Directors, Grafton Architects

During the past decades, architecture has been dominated by an interest in expressive singular forms, often facilitated by computerized design and methods of calculation, novel material technologies, and robotic methods of production. The book Model Perspectives: Structure, Architecture and Culture returns architectural thinking back to its tectonic principles and elementary syntax. It also emphasizes the essential cultural connectedness of the art of building; architectural meaning cannot be invented, as it is bound to reflect the human existential and mental reality. All true architectural meaning echoes tradition, and the most radical artistic innovations become part of this esteemed continuum of tradition.
– Juhani Pallasmaa, architect, writer, professor emeritus, Helsinki University of Technology (Aalto University, School of Art, Design and Architecture), Finland

Preface

A passion for structure – from its overall forms and physical behaviors to material choices and connection details. A passion for architecture – from its external shapes and interior spaces to conceptual inspirations and aesthetic preferences. A passion for culture – from the artistic and literary to the social and technological. These are the things that have motivated this book – especially when considered as closely intertwined topics. Other passions are behind it as well: for the written word, for the photographic image, and for *making*, whether at full scale or one much reduced.

Structure, architecture and culture; these topics can be considered in relation to one another in multiple ways, but two perspectives in particular are used here: one is a collection of essays/text extracts, and the other an archive of photographs of models. For the first, text is premiated for inherent quality and embedded message; for the latter, the image is the focus. In both cases, the intention is to dwell on things for a while, to contemplate them, to luxuriate in generous treatment. Furthermore, this book is organized into seven chapters that each covers a quintessential structural element or basic system type; columns start things out, followed by walls, beams, trusses and so on. These fundamental building blocks of structure have already been well covered in books elsewhere, including by two of the present authors in *The Structural Basis of Architecture, 2nd ed.*, but here they are considered afresh in what is regarded as a mutually productive and complementary manner. Whereas structures textbooks generally approach the topic through explanations of systems of forces and analytical descriptions of responsive behaviors (i.e., the "*how things work*" aspect of the subject), here broader cultural themes are fleshed out and considered equally relevant to address the "*why things are the way they are*" facet of the argument. Moreover, photographs of three-dimensional systems demonstrate in ways that words simply can't the "*how do these things look?*" aspect that is so critical to being able to appreciate – and incorporate – structures as an integral part of architectural design.

With regard to the collection of essays/extracts: each one addresses, in a way that we feel strikes a resonant chord, the interconnections between the topics of central concern here. Sometimes this has been done intentionally by the author, as in the case of Peter Collins' description of the dilemma Auguste Perret confronted when columns had to be fashioned from the newly developed material of reinforced concrete. In other cases, the idea of addressing the topic of *structure* may not have been there to begin with, but when read with this in mind the words take on new relevance; Gottfried Böhm's text about the deeply sensed impact of Richard Serra's sculptures, for instance, could not better embody the essence of walls in architecture. Other entries address familiar buildings, but in perhaps unexpected ways, such as the Munich Olympic Stadium, Miami's 1111 Lincoln Road, or the Sendai Mediatheque. Several of the authors might be anticipated: Cecil Balmond is here *informally* as is Robert Silman recounting his experiences in strengthening Fallingwater; Colin Rowe and Roland Barthes are present with their respective essays *The Chicago Frame* and *La Tour Eiffel*, which are included for their eloquence and engagement of structure alike. Other writers will likely be more unexpected in the present context, such as

Donald Ingber with his description of living cells' cytoskeletal structures and their tensegrity characteristics, or installation artist Sanjeev Shankar's recounting of the communal building project for a suspended canopy made using discarded cooking-oil cans. The list of entries on the preceding four pages indicates the range of what has been collected in this book; but this is not to imply that this is *the* definitive collection of such essays/extracts. Rather, it is hoped that it will act as more of a prompt for other such texts to be researched, gathered, shared – and written too!

The collection of images of models forms the complementary lens through which the topics of structure, architecture and culture are here explored. This is derived from a collection of well over 750 unique and often exquisite models that have been built by architecture students at Cornell University for over the past twenty years. This approach to the teaching of structures was in part inspired by the earlier work of Professor Steinar Eriksrud and his students at The Oslo School of Architecture and Design (AHO) who built up a unique model culture there. Among other things, this led to the substantial collection of stave church models that still exists at the school today, inspired by the interests of Professor and colleague Arne Eggen.

So why this particular focus on models? Because they are a highly effective and engaging way of teaching and conveying the subject matter of structures when considered in the context of architecture's conceptual ideas and design objectives. Certainly the models' conception is in and of itself an artistic/creative act. And with their assembly there are plenty of "Ah-hah!" moments that signal critical understanding; when a diagonal brace all of a sudden "locks" into place a previously flimsy frame, for example, or when the anchoring of a tension ring enables a set of radial ribs previously lying flat and without purpose to form into a dome and hold it in place. In models' final realization space and form are created and the sense of "inhabiting" such space comes to life. Moreover, how the structural skeleton is modeled relates in fundamental ways to the conceptual, formal, spatial and material ideas that are embodied in the "real" structure from which the lessons are being learned. But also, at some point these projects take on a life of their own; not as precious miniatures of the actual buildings but as their own entities – no less real, no less "accurate" for the translation of authorship; the lessons are still embedded, and often self-created. And finally, if many of the essays/extracts are inherently more historical in character, the complementary models are purposefully mostly of contemporary structures – thus emphasizing the ongoing and ever-present relevance of the theme of this book.

The late architect Sverre Fehn liked to read novels collected here and there, perhaps received as gifts or picked up at a bookstore on his way home; in these he found particular sentences or phrases on which he reflected deeply, becoming engrossed in them before eventually turning the words into architectural content.[1] That is the analogous objective here as well. Each of the text entries or model studies can be approached individually and at random. Or they can be gone through in sequence, as the introductory paragraphs connect and put them into context with each other. One could instead start by just deciding to read the essay introductions and model study texts to get an overall sense of what is contained in this book and then decide what to come back to, but it is likely that along the way one would have become engrossed in something, akin to Fehn's approach for broadening his intellectual horizons and inspirational repertoire – which is, of course, just the intent.

1. Fjeld, Per Olaf. *Sverre Fehn: The Pattern of Thoughts.*

Acknowledgments

A book like this does not come together without significant and critical assistance. The following individuals have all been key contributors: Mia Kang, who lent this project her keen design skills from the start; Katayoun Amirmoeini and Cora Visnick, who with great care and patience waded through a permissions process that was as extensive as it was complicated; also, Michael Babcock and Ethan Davis whose help with text transcriptions and proofreading was both essential and timely. Others have also contributed in various ways: Juan Carlos Artolozaga, Nicholas Cassab-Gheta, Alberto Embriz de Salatierra, Iroha Ito, Daniel Toretsky and Mariya Tsvetkova. Too many to name are the structures teaching assistants at Cornell over the years, whose overall support and photographic expertise have made this project come to life. And clearly this book would not have been possible without the many former students who have so effectively contributed to it through their model building skills, creativity, ambition and perseverance; it is to them, therefore, that we dedicate this work.

We also wish to recognize the creative flair and contribution of faculty colleague Mark Morris, whose final essay *A Model Curriculum* so ably helps tie together some of the many threads of this endeavor, both in spirit and over time.

To the many authors, publishers, photographers, architects, engineers, librarians, curators, archivists, etc. who either individually or on behalf of their respective practices/institutions provided the permissions necessary to reproduce the various texts and images contained herein, we express our sincere gratitude.

The support of the many dedicated staff members, faculty colleagues and administrators alike at our "home" institutions of Cornell University's College of Architecture, Art, and Planning and The Oslo School of Architecture and Design (AHO) is gratefully acknowledged, as is these institutions' generous financial support for the endeavor.

And lastly, at Routledge publishers, we are very grateful for the support and encouragement of Editor Fran Ford, Editorial Assistant Trudy Varcianna, and Production Editor Christina O'Brien for seeing this project through to being realized in the way that we had envisioned it at the start.

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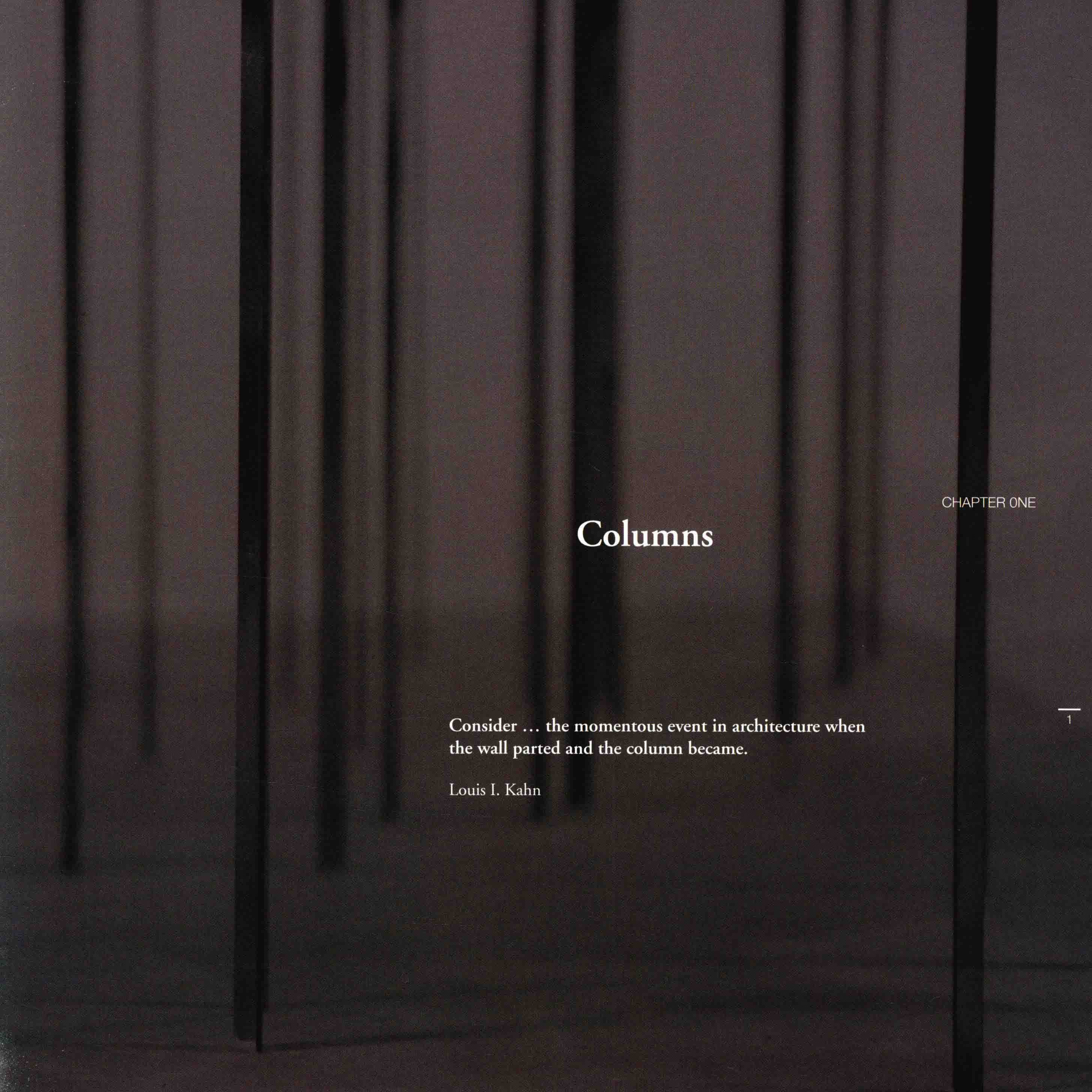

CHAPTER ONE

Columns

Consider … the momentous event in architecture when the wall parted and the column became.

Louis I. Kahn

Musée des Travaux Publics, exhibition hall

The column is commonly understood to be a structural element that is subject to compressive load – perhaps caused by the weight of a roof held aloft, or other story levels and occupants in a multi-story building. As such, columns are essential to the creation of occupiable space; moreover, the details of their design have varied greatly over time according to changing architectural styles and material advancements. One such notable material development in the early 20th century was the widespread introduction of reinforced concrete construction, leading to the struggle of architects and engineers of that era to adapt not only to its load-bearing capabilities but also to the new possibilities it provided for form-making – whether for its base, shaft or capital. As described in the following extract written by Peter Collins in his seminal book *Concrete: The Vision of a New Architecture*, Auguste Perret was a Parisian architect who took this challenge to heart with his innovative and evolving designs for columns in such notable buildings as Notre Dame de Raincy and, of primary focus here, the Musée des Traveaux Publics.

Auguste Perret and the Concrete Column

from *Concrete: The Vision of a New Architecture*
Peter Collins

In examining Perret's doctrine in detail, it will be convenient to begin with his attitude towards the design of columns, the element in his vocabulary to which he attached the most importance. Columns have traditionally been regarded as the very symbol of architecture, since they express more forcibly than any other element the peculiar dignity of the architect's achievement, and it is only within recent years, mainly as a result of their abuse in the nineteenth century, that their use on façades and in interiors has been looked upon with mistrust. As we have seen, Perret's substitution of reinforced concrete columns for load-bearing partition walls at 25b rue Franklin was interpreted by the younger generation as an invitation to do away with visible supports altogether, and this attitude became more and more pronounced as the new concepts of spatial integration spread, and the desire to exploit the slenderness of new structural materials increased. The traditional idea of a colonnade, with its rhythm of vertical supports forming imposing perspectives throughout interiors and across façades, was discarded as both structurally unnecessary and inappropriate to modern planning, so that the columns themselves, which at the beginning of the century were already being disguised by Art Nouveau decorators as naturalistic stems, were now reduced to their minimum frequency and dimension so as to be as unobtrusive as possible, if not completely unseen.

Auguste Perret liked columns, and proliferated them with all the enthusiasm of the architects of the past. It was not only the inherent structural dignity of the column itself which captured his imagination but the powerful emotional effect created by receding ranks of columns, and the optical function fulfilled by such rhythmic sequences in creating an awareness of scale beyond the effective bounds of stereoscopic sight. However much the Renaissance principles of perspective might be outmoded as a means of pictorial representation, the abiding reality of its laws as a means of apprehending spatial relationships seemed to him incontestable, and instead of diminishing or camouflaging his structural supports, he sought every means at his disposal to isolate them in space, and make their rhythm provide the dominant unifying element of his designs. This did not mean that he limited himself on principle to spans only possible in older types of construction, or multiplied columns unnecessarily where they were not structurally required; but it did mean that instead of feeling morally bound always to use the maximum spans obtainable by civil engineering, he considered himself free to use intermediate supports whenever desirable, and saw no objection to dividing a large hall with interior colonnades, provided that these were not in any way detrimental to its use.

In order that full aesthetic advantage could be taken of these structural columns, it was necessary to ensure that each would be a pleasing object in itself. Pride in his new material, and a growing contempt for veneers and renderings, made him seek beauties inherent in concrete, but unlike most of the early theorists, he was not rash enough to assume that the resultant shapes must be of a kind never seen before. On the contrary, he based his researches on those inalienable characteristics, derived from structural and optical laws, which all vertical supports must have in common, and being a building contractor, he perceived that it would be the methods of casting the material, rather than the nature of the material itself or any presupposed theoretical analyses and calculations, which would be the cause of such modifications as might distinguish concrete from worked stone.

The engineers of the period, who had had no reason to abandon the conventional theoretical assumptions of steel frame construction, designed each stanchion as one continuous support rising from floor to floor, and considered the most distinctive characteristic of reinforced concrete frames to be the 'haunches' of the beams, namely the flared ends of the beams which increased the area of concrete under compression near the vertical supports. It soon became apparent to Perret, however, that despite the effective continuity of such columns from the point of view of theoretical calculations, they were not in fact constructed continuously, but were cast independently in sections one storey high. Similarly, though the beam might be conceded theoretically as requiring an increased amount of concrete at its extremities, it was in practice more efficient to make the form-work completely regular, and hence horizontal at its lower edge. In consequence, Perret reversed the normal conception of a reinforced concrete frame. The columns now butted into the beams, and the latter formed a simple grid pattern on a level plane, so that henceforth continuity was horizontal and hence also visible, and each internal column appeared as a distinct element, expressing the way it was cast. It was as if the standard Hennebique diagram had been turned on its side.

The next stage was to consider the character which the form-work should take. In Hennebique's earliest industrial buildings, the columns had been of simple rectangular section, which was logical enough, since this was the cheapest way of assembling timber planks, and Perret himself had used a similar method in the garage in the rue de Ponthieu, where the only major modification was the introduction of diminution and entasis in the columns of the façade. He did not have any occasion to experiment with the shape of vertical supports in monumental buildings during the ensuing twenty years, for the columns of the Théâtre des Champs-Elysées had had to be veneered with marble or plaster, and his other private commissions were mainly for the most utilitarian kind of industrial building, where such refinements would have been extravagant, if not out of place. In 1922, however, an unexpectedly favourable opportunity presented itself when he was commissioned to build the church of Notre Dame du Raincy, for the propaganda of Viollet-le-Duc had disposed the public to accept the idea of ecclesiastical architecture as structure unadorned, and it was thus possible to concentrate here on the refinement of bold and original structural methods without the risk of outraging popular taste, or inviting unfavourable comparisons with the processes of factory design.

The result was undoubtedly the most revolutionary building constructed in the first quarter of the present century, and it justly occupied the place of honour in the first issue of the first magazine specifically devoted to the New Architecture: *L' Architecture Vivante.* The design comprised four rows of free-standing columns 37 ft. high, spaced 33 ft. apart along the length of the nave, and diminished from 17 in. at the foot to 14 in. at the summit. Being free-standing, and thus unaffected by the normal need to receive the abutment of intermediate beams or partitions, there was no practical obligation to make the columns rectangular in section, and therefore, despite the increased cost of the form-work, Perret made them round. This shape was preferred for two reasons; firstly, because it was most economical (in the structural sense of the word), in that it provided constant rigidity from every angle, like a tree trunk, and was, as he himself pointed out, 'best adapted for a member subjected to compression'[1]; secondly, because it was more satisfactory optically as a result of the gradations of shadow and constancy of silhouette. The architects of the eighteenth century, like those of antiquity, had studiously avoided free-standing square columns (or 'pilasters' to give them their correct, though now misapplied name), because apart from their clumsiness, their apparent width varied according to whether they were seen diagonally or from the front. As geometric projections or drawings, a series of pilasters might well appear similar in appearance to columns, but when viewed in perspective, the width of each pilaster would seem to increase as the angle of vision became more oblique. It was thus not merely in obedience to Platonic ideals (whereby the circle was regarded as the configuration of perfection), or in obedience to the belief that the most 'natural' architectural forms were those found in natural organisms such as trees, that the Greeks used cylindrical columns; it was also in obedience to visual experience and optical laws, which demonstrated that rhythms discernible on plan did not necessarily produce the same rhythmic effects when projected into three-dimensional space.

To give greater elegance to the columns of Notre Dame du Raincy, and also (since this was his first attempt to give entasis to round columns) to make provision for any inaccuracies in casting, Perret modelled the surface of the form-work with a series of flutings. These were not regular segmental grooves, as in antique columns, but an alternation of curved projections and angular fillets more suggestive of Gothic composite piers. Similarly, by applying diminution and entasis to columns twenty-three diameters high, Perret showed that the forms were in no sense dictated by a subservience to either Greek or Gothic prototypes, but were on the contrary an attempt to extract the most rational elements from both. Nevertheless, it is clear that although he scrupulously observed the structural characteristics of the new material as he then understood them, Perret was still, like Labrouste before him, unable to free his mind entirely from standard historical conventions, and although he must have known, from reading Choisy, that Mycaenean columns tapered in the opposite direction,* he as yet saw no cause to modify the traditional assumption that a column must always derive its stability from being narrower at the summit than at the base.

It is not known precisely when he first began to question this assumption, but his first radical modification of the traditional lithic shape seems to have been introduced when designing the new Palais de Chaillot in 1934 for the 1937 Paris Exhibition. The authorities had decided to demolish the old Trocadéro Palace, built by Davioud as a temporary centre-piece for the 1878 exhibition, and to substitute a new monumental group of permanent buildings on the same site (the Mont de Chaillot) which would fulfill the same function of housing exhibition and concert halls, and would also terminate effectively the splendid axial vista extending through the Eiffel tower from Gabriel's École Militaire. Perret, who had been entrusted with the commission, abandoned the earlier Baroque composition, with its dominating central structure and curved concatenated wings, and substituted two symmetrical groups of museum buildings linked by an open colonnade. The resultant composition was, in character, reminiscent of Jules Hardouin-Mansart's Grand Trianon at Versailles, but the difficulty here was to design a colonnade appropriate both to the new material and the vastly increased scale. Perret finally decided to arrange giant columns, 83 ft. high, in four rows, making a hundred and four in all, across the whole width of the Place du Trocadéro, and roof them at the same height as the four-storey museum blocks on each side.

The task of designing an open colonnade 17 ft. higher than that of the Madeleine presented aesthetic problems of the greatest delicacy, since the whole visual effect of the *ensemble* depended on the success of this focal element of the design. The columns could conceivably have been designed as simple cylinders, like those of the nearby Musée d'Art Moderne to be built contemporaneously as part of a similar though much smaller composition, but the harshness of such a rigid silhouette would, at this scale, have created an effect so brutal that even the most uncompromising advocates of elemental geometric forms might have hesitated before taking such a drastic step. Alternatively, they could have been tapered and fluted in the traditional manner to produce a solution which, provided that the columns were proportionately as slender as at Notre Dame du Raincy, would have had the advantage of combining classical precedents with the expression of a new structural technique. It had become apparent to Perret, however, that in spite of the elegance and apparent rationalism of the columns at Notre Dame du Raincy, there was a fundamental illogicality in monolithic columns which tapered upwards, since although the convention was justifiable enough in Greek architecture, where the shafts were composed of isolated drums, and even in Roman architecture, where the columns, though monolithic, were unsecured at the ends, the laws of gravity did not apply in the same manner to columns of reinforced concrete, which were rigidly secured at the top by a monolithic framework of interlocking beams, and could, if necessary, be free at the base. The proper analogy, if analogy were needed, was thus not with stone trabeated structures, such as Doric temples, but with timber trabeated structures, such as tables and chairs. Just as table legs, deriving their stability from the rigidity of the upper joint, were traditionally considered more elegant when tapered towards the bottom, so concrete columns might logically be shaped in a similar way; an argument which was especially valid when the columns did not form part of a continuous frame, but were, as in this instance, only one storey high.

Another justification for this shape was that it also corresponded more accurately to the system of reinforcement. In the 40 ft. high free-standing columns supporting the roof of Perret's Musée des Travaux Publics, the reinforcing rods gradually increase in number upwards, so that there are six times as many in the top sixth, where the diameter is 3 ft. 5 in., than at the bottom, where the diameter is 9 in. less. Indeed, the logicality of the shape was so apparent that it soon became an accepted form for reinforced concrete *pilotis*, even though most architects still preferred cylindrical columns for the intermediate floors of a multi-storey frame. There is however no reason why a multi-storey building should not be considered as a series of single-storey structures stacked one on top of the other, unless there are over-riding reasons for expressing the invisible continuity of the internal vertical supports.

Once Perret had accepted a general shape for his columns in principle, the next step was to determine the profiles they could most logically be given. Until that time, it had generally been assumed by classical architects that the basic plan of a column was a circle, since the stonemason's method of carving each drum was to inscribe a circle on the lower bed, and then cut back to form a rough cylinder before finally making it polygonal so as to carve the fluting. Perret perceived, however, that the most logical way of casting a reinforced concrete column was to make it polygonal in the first place, since the most direct way of creating the form-work would be to assemble flat strips of planking, in the same way that staves are assembled to form a barrel. It was not feasible to shape the form-work in such a way as to produce classical fluting, for without using plaster of Paris moulds ... it would have been necessary to carve each plank at enormous expense. However, neither process would have produced any real advantage, since it would not have been possible to remove the cement film by bush-hammering without at the same time destroying the precision of the lines. To obtain the optical advantages of fluting, Perret therefore considered it sufficient and more logical merely to remove the cement film from the centre of each face, and leave the arrises untouched,

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* No archaeologist, as far as I know, has ever given solid reasons why the shaft should have been thus inverted. I suspect, for reasons which will be clear later, that the original timber prototypes, though standing freely in the normal way on stone discs, were rigidly tenoned or pegged to the wooden architraves at the top.

thus producing slight concavities which, though not possessing the accuracy of Greek fluting, seemed more in keeping with modern reinforced concrete techniques.

The problem of deciding whether or not to give entasis to these new forms was more delicate. Perret felt very deeply the inconsistency of paying lip service to Greek optical refinements whilst at the same time disregarding them in contemporary design, and considered that if a slight curve was necessary to correct the illusion of attenuation in the silhouette of Greek columns, it must be equally necessary in those built today. He therefore designed his columns so that instead of diminishing regularly, their silhouette deviated imperceptibly from a straight line by an amount comparable to that of the Parthenon, i.e. a radius of about half a mile. In concrete this can be achieved with the greatest simplicity, since the form-work is built by nailing tapered boards to the inside of stiffening rings placed at regular intervals along its length. Thus instead of diminishing the diameters of these rings by equal amounts, the diminution is varied to produce the curvature desired. 'It is not to be supposed that the architects ever troubled to calculate the radius or to establish the form of an arc of such a theoretical circle,' wrote Professor Dinsmoor, with reference to the entasis in the Parthenon. 'Their system consisted rather in deciding first the maximum increment of curvature desired, and then selecting any convenient arbitrary number of equal intervals between the beginning and apex of the proposed curve. The maximum increment of curvature was then divided by the square of the above-mentioned number of intervals, thus determining the size of the fractional parts.'[2] The same method was pursued by Perret, with even greater constructional logic, since the 'convenient number of equal intervals' was already constituted by the stiffening rings which kept the form-work in place. Expert craftsmanship was indeed demanded in tapering each plank or stave to ensure that it curved regularly, but this, far from being regarded by him as a demerit of the system, was the guarantee that he was pursuing the right path.

In practice, the number of facets and the amount of entasis varied according to the position occupied by each colonnade, the size of each column, and the incidence of light. These variations are not obvious, simply because we are not trained to look for such minutiae today, but if evidence were needed of Perret's complete integrity in the pursuit of classical ideals, nothing could be more conclusive than his tireless search for perfection in these elemental forms, and the care with which he adjusted his standard elements to accord with each individual design.

In addition to determining the correct form and most effective silhouette for the shafts of his columns, it was necessary to decide how they should terminate at each end. A base could be readily dispensed with, as in Greek Doric architecture, but it seemed clear that some change of shape at the top was desirable if the transfer of reinforcement was to be effected smoothly between the round columns and rectangular beams. Perret had at first avoided this problem altogether; at the Théâtre des Champs-Elysées he had merely emphasized the upper termination by a narrow decorative band, whilst in the church of Notre Dame du Raincy he achieved a similar effect by placing the consecration crosses in the spandrels of the shell vaulting immediately above the shafts. Yet even at that time, he realized that such decorative expedients could not be resorted to indefinitely, and publicly stated his intention of seeking the logical transition from a circle to a square appropriate to reinforced concrete as soon as time and money would permit.[3]

Little guidance as to the correct means of terminating the shafts of a monolithic frame was offered by historical precedents, whilst even carpentry techniques offered few hints apart from a general indication of what to avoid. In trabeated masonry construction, the problem of transferring the load from a square beam to a circular shaft was solved by separate blocks of stone, which also had the function of minimizing the span. In mediaeval timber construction, as in furniture design, no termination was considered necessary (apart from carved or applied ornament), since both the posts and beams were usually square in section. Perret never regarded the need for some visible token of transition as absolutely essential, and frequently, even in his later works, butted shafts directly against the rectangular beams above, as in the colonnade of the Mobilier National, or the interior of the Musée des Travaux Publics. But he felt that if there was in fact some way of creating a transition which would be both structurally logical and aesthetically advantageous, he was under a moral obligation to find it, and there is no clearer evidence of his painstaking and idealistic intellectualism than in the way he devoted his time and energy to this abstract geometric task.

His first executed attempt to achieve a satisfactory transition may be seen in the monumental façade of the Musée des Travaux Publics, built just before the second world war, where the shafts were gradually widened and transformed to a square by an imbrication of leaf-like or scale-like projections. Technically, the method was perfectly justifiable, since the form-work could be assembled like roof shingles, and overlapped to form a kind of hollow cone; but in appearance the result was too reminiscent of conventionalized plant forms such as we find in Egyptian architecture, and as a result it did not affirm sufficiently clearly the essential qualities of the material employed. The method was therefore superseded by a more geometric solution, developed after the war when making studies for the reconstruction of Le Havre, whereby the transition was effected by a series of prismatic modulations developed progressively from the faces of the polygonal shafts direct. Thus, since the 'capital' was composed entirely of plane surfaces, the form-work could be built as an assemblage of flat pieces of wood, and once the minimum number of facets had been determined mathematically, the only arbitrary choice left to the designer consisted in determining the most suitable proportions for each particular case.