

Design-Tech

Building Science for Architects

Second Edition

**Jason Alread, Thomas Leslie, and
Rob Whitehead**

DESIGN-TECH: BUILDING SCIENCE FOR ARCHITECTS

2ND EDITION

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DESIGN-TECH: BUILDING SCIENCE FOR ARCHITECTS

2ND EDITION

Design-Tech is an indispensable, holistic approach to architectural technology that shows you in hundreds of drawings and tables the *why* as well as the *how* of building science, providing you with a comprehensive overview. In this expanded edition, measurements and examples are listed in both metric and imperial units to reflect the global reality of architectural practice. The authors also address digital fabrication, construction documentation, ultra-high-rise structures, and zoning codes. And there's more in-depth coverage of structural design and greater emphasis on environmental forces. Numerous case studies demonstrate real-world design implications for each topic, so that you can integrate technical material with design sensibilities.

Short chapters explain each topic from first principles in easy-to-reference formats, focusing on what you need to know both at the drawing board and in future discussions with engineers, contractors, and consultants. This new edition incorporates material from continuing curricular experimentation in the SCI-TECH sequence at Iowa State University, which has been recognized with awards and funding from the American Institute of Architects, the U.S. Green Building Council, and the National Council of Architectural Registration Boards.

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INTRODUCTION AND ACKNOWLEDGEMENTS

The second edition of *Design-Tech* reflects changes in both the profession and in our teaching since the first edition was published in 2007.

Developments in design and construction have moved very quickly in the last seven years, and we have seen the effects of new digital tools, newly urgent emphasis on efficiency and performance, and the popularization of digital fabrication techniques change both building realization and studio teaching since the first edition. More difficult financial times have forced a leaner approach to design and construction, and technology has played an even greater role in how architects, engineers, and contractors conceive and execute buildings. At the same time, the worsening effects of global climate change have produced a greater—though, in our minds, still not great enough—urgency in developing strategies for buildings that use less energy, that work with flows of wind, solar energy, and water on their sites, and that take Buckminster Fuller’s prescient charge to “do more with less” seriously. These seemingly dire influences are matched, however, by brilliant developments in programs such as Ecotect, Revit, and even Sketchup, all of which give designers the ability to think about the multiple forces acting on their designs—ecological, economic, structural, etc.—in integrative, fluent ways. If the problems designers face have grown over the last seven years, so have the tools to solve them that we have at our disposal. We have tried to cover these developments in expanded or new chapters that reflect the way young designers, in particular, will need to think and the skills we think they will need in the next few years.

We have also taken the opportunity to rewrite substantial portions of the book to reflect developments in our own teaching. SCI-TECH, the graduate technologies sequence at Iowa State from which this book grew, has evolved as we have taught these subjects again and again. Teachers learn too, and since the first edition came out we have kept dog-eared copies of the first edition of *Design-Tech*, making notes where we felt things could work better, correcting minor errors, and finding gaps that needed addressing. We have added new chapters on digital fabrication, high-rise structures, and zoning, along with a new chapter on specifications.

This edition also features a substantially rewritten section on structures written by our longtime colleague Rob Whitehead, whose research on struc-

tures teaching has transformed the way we teach the subject in our graduate and undergraduate programs. These sections offer an even more intuitive approach, one that we've seen at work in Rob's classes, and one that should prove valuable to students encountering structures for the first time as well as for professionals who need a reminder or two about some basic principles. While making this chapter more logical and understandable, we have kept the data tables and basic mathematical background that give valuable backup to the more conceptual elements of this section.

In spirit, however, *Design-Tech* retains substantially the same approach as it did in the first edition. We have still tried to channel the voice of the grizzled veteran in the back of the office, quietly dispensing advice and mentoring young architects, and while we can still only aspire to the breadth and depth of knowledge that these figures seemed to have in our experience, a few additional years have brought us a bit closer to that level. We still believe the time is right for a reassessment of what "tech" means in architectural curricula. This discussion has been led recently by an upstart group of young faculty, the Building Technology Educators' Society, and it has enjoyed the quiet and patient sponsorship of Ed Allen, whose inspiration permeates these pages. Some of these programs have adopted *Design-Tech* as a standard text, and more than anything we're pleased to see the book's ethic springing up throughout the field—namely that understanding how things are built, and how they perform, gives designers a fundamental grammar that can work with other important socio-cultural vectors in creating humane, appropriate, and efficient buildings.

We remain deeply indebted to a generation of technology educators who have gone before us, and whose books have inspired and been constantly used by us. *Design-Tech* is, we think, best seen as an addition to important, vital books such as Ed Allen's *Fundamentals of Building Construction* and (with Joseph Iano) his *Architect's Studio Companion*, Francis D. K. Ching's *Building Construction Illustrated*, Mario Salvadori's *Structures for Architects*, Rowland Mainstone's *Developments in Structural Form*, Harry Parker's *Simplified Engineering for Architects and Builders* (improved and expanded by James Ambrose), Victor Olgyay's *Design With Climate*, Charlie Brown and Mark DeKay's *Sun, Wind, and Light*, Ernst Neufert's *Architect's Data* and the perennial *Architectural Graphic Standards*. We have referenced these books, among many others, throughout our work, and have noted at the end of each section where one might turn for further information or elucidation.

Likewise, our careers have been informed by important mentors and teachers. Professor Leslie owes much of his technical background to teachers at Illinois and Columbia, especially Mir Ali, Tony Webster and Robert Silman; colleagues at Foster and Partners and Ove Arups, in particular David Nelson, Nigel Dancey, Peter Lassetter, Kevin Dong, Eric Ko, and (fondly remembered and greatly missed) Jon Markowitz; and a raft of collaborators on the Stanford University Center for Clinical Sciences Research project. Finally, Professor Leslie would like to particularly acknowledge the teaching and guidance of the late Don Bergeson at Illinois. It is, sadly, too late to propose this book as extra credit for Prof. Bergeson's Environmental Systems class, but Leslie wishes (for many reasons) that this was still possible.

Professor Alread thanks his good fortune for having started his education under the guidance of Martin Gundersen and Bernard Voichysank at the

University of Florida, and later to have the mentorship of Thomas Beeby at Yale. Mentors in practice have continued that education with firm and patient guidance, in particular Rick Rados, John Locke and Mark Schmidt. Professor Alread must also thank his longtime collaborators, Paul Mankins, Tim Hickman and Todd Garner, who keep him ever mindful of the need to be humble and relentless in the pursuit of good work.

Many of Professor Whitehead's most influential teachers from Iowa State and University of Texas at Austin have also become colleagues in practice, in teaching, or in many cases, both. Andy Vernooy is remembered for instilling the importance of always connecting technical information with its cultural significance; Mark Engelbrecht for his insistence on seeing what's possible, not just what's difficult; Kate Schwennsen for her inspirational professionalism and infectious laugh; Rod Kruse for his tireless pursuit of refined designs at all scales; Cal Lewis for demonstrating that design excellence comes from a comprehensive clarity of thoughts and diagrams; and Gregory Palermo for showing how an encyclopedic knowledge of design and a nurturing soul can produce a passion for work and life.

Our teaching at Iowa State has been influenced and supported by colleagues who have welcomed our attempts at innovation, offered commentary and suggestions for our coursework, and reviewed elements of this book. Clare Cardinal-Pett deserves the distinct credit for giving us the chance to re-write the tech curriculum within the friendly confines of our Master's program, and for constantly pushing us toward experimentation and innovation. Jamie Horwitz, Marwan Ghandour, Karen Bermann, Kimberly Zarecor, Ulrike Passe, Nadia Anderson, and Mikesch Muecke have welcomed the development of our coursework as the Graduate Faculty, and the graduate students who have gone along for this ride deserve special mention for their willingness to serve as guinea pigs, and for their constructive feedback and productive energy. The Technology Faculty in the Department have also been valuable resources and have supported this project, and we're grateful for the support of David Block, Bruce Bassler, Matthew Fisher, Gregory Palermo, Ulrike Passe, and Jim Bolluyt. Cal Lewis and Gregory Palermo, the Chairs of the Architecture Department over the last 12 years, have given us the academic space and resources to turn our scrappy class notes into this book. A sincere thanks to Deans Mark Engelbrecht and Luis Rico-Guitierrez who have made sure that the College of Design remains an energetic environment in which teaching and technology are taken as seriously as research and design.

A generous Subvention Grant from Iowa State's Vice Provost for Research's office provided funding for many illustrations and graphics. These clear, interesting, and occasionally humorous graphics were developed by Anna Aversing, Sade Reed, and Isabelle Leysens from several napkin sketches and post-it notes. We are quite grateful for their dedicated work. Finally, a special thanks goes out to Heidi Hohmann and Ann Sobiech-Munson for contributing incredibly instructive chapters in their respective fields of expertise—landscape architecture and specification writing.

Technology, for all the hype, is essentially an explanation of *how* things work. Design is a much higher calling, since it builds and expands upon how we do things to consider *why* we do certain things—often resulting in bigger statements that involve the experiential, societal, and cultural issues alongside

basic spatial and volumetric considerations. We hope this book helps everyone (students, educators, practitioners, etc.) understand more about the critical relationship between how and why buildings are built by seeing the connections between design and technology.

A NOTE ON MEASUREMENT

Throughout this book, we've used both metric and imperial (American) units in parallel. Our hope is that it can be used equally well for both systems.

To do this, we've gone beyond standard conversions and instead tried to translate meaningful units of measure back and forth. In our view, it's not been enough to say—accurately—that a 12-foot span is equivalent to a 3.6576-meter span. That may be true, but no metric designer would start with a number like this. Both systems have their “idioms,” or standard basic dimensions. So, in situations like this, we've gone for easy comprehensibility over dead accuracy, and called 12-foot spans 3.5 meters. Occasionally this gets us into a slightly awkward situation in examples, where translation errors pile up, and we've been forthright about where this happens and about the minor adjustments needed to get things back on track.

That principle applies generally to the mathematical examples throughout the book. This isn't intended as an authoritative reference, and where we have faced the choice between absolute precision or general understanding we've opted for the latter. One of the great joys of architecture is working with expert consultants, gaining a bit of insight into their field, and assimilating their advice and work. We've intended this book to be an introduction to the various specialties included, and a general reference. In part because of its global scope, the information here is necessarily subject to a wide range of local conditions, and professional consultants should be engaged for any project of reasonable size.

To all our kids at home,
Olivia & Calvin, Adrian & Finnegan, Theo & Sophia
And to all our kids at school

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PART 1

DATA

HUMAN FACTORS: ANTHROPOMORPHICS

The body	Range of motion Human scale The 95th percentile
Ergonomic/ anthropometric design	How we fit into a built environment Human productivity Hazards to well-being

DESIGN FOR PEOPLE

One of the main issues designers face when approaching a building project is, “How big should it be?” This is determined by the intended use, number of users, circulation needs, furniture, and equipment requirements. Once these are accounted for the question becomes, “How much individual space do the people need?”

There are resources that can assist in determining the typical size and arrangements of people, furniture, and spaces. The human body has been measured and statistically averaged to provide information that can accommodate most of the population. This does not mean you shouldn’t measure your own surrounding environment and decide whether or not you think it’s adequate, but these resources can help with understanding how others have solved these same problems.

Another primary issue that designers face is when it’s appropriate to “re-design the wheel”. There are arguments for re-examining problems without knowing the standard approach, because that allows for new ideas to emerge. Many times, however, these are problems that have been considered many thousands of times and those solutions are available for your review. Always starting from scratch is impractical; always using the standard approach limits creativity and progress. Be aware of what information is available, and then decide what to use and what to discard.

THE BODY

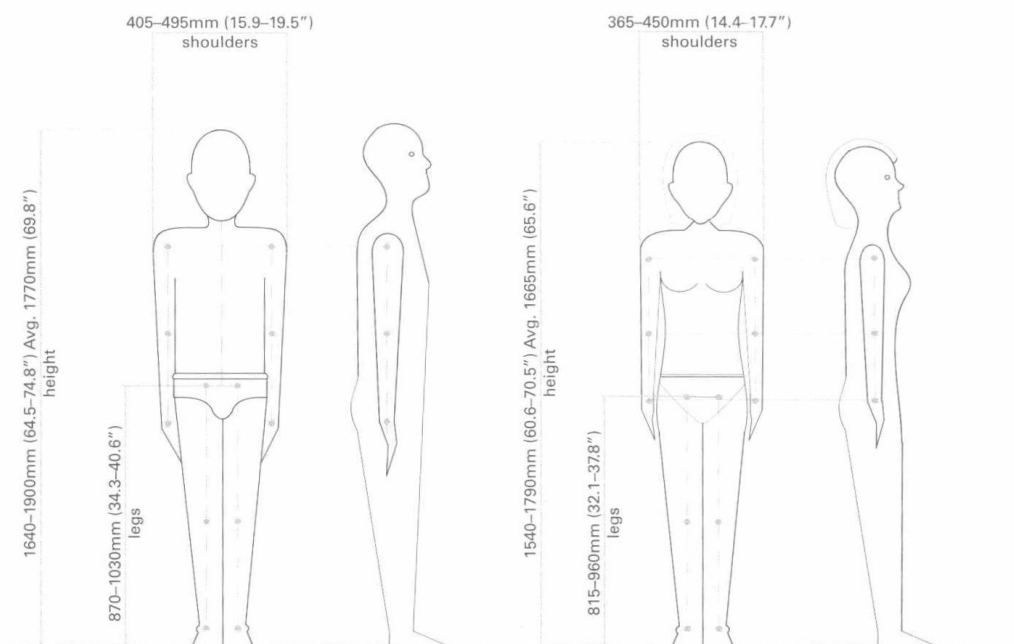
The laws of physics and the mechanics of the body govern human movements within buildings. We balance in certain ways, walk within a small range of speed, sit comfortably based on our pressure points, and can reach things based on predictable sets of movements. Designing within the tolerances of most people requires an understanding of two issues:

The *95th percentile* is the range of human sizes that are accommodated within typical structures. A 2.1m (7') tall person falls outside of this range, as does a 180kg (400lb) person. A 0.9m (3') tall person may or may not, depending on whether you are expected to accommodate children. Sometimes it is necessary to duplicate functions at different heights or spacing in order to serve all users. The sizes also evolve as the averages change over time and cultural differences are taken into account (Figure 1.1).

Range of motion covers how a body can maneuver from a position in space. Reach, rotation, sight lines, standing and sitting positions all factor into the range of motion.

REFERENCES/MEASUREMENT CHARTS

Building guides such as *Timesaver Standards*, *Architectural Graphic Standards*, and *Neufert's Architects Data* give you building and furniture configurations with the average sizes of the occupants already factored in. References like Diffrient's (1982) *Humanscale* and Dreyfus' (2001) *The Measure of Man and Woman: Human Factors in Design* allow you to see the detailed dimensions of the body, which provides the opportunity to decide for yourself which layouts work. Typically, the general planning information is adequate unless you're designing furniture or equipment that requires customizing how a person interacts with it. Codes also have requirements for minimum sizes, in the case of



1.1

Typical body measurements.