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1 Introduction

Every project requires conceptual design. Taking the idea or problem from the imagination of the client, and creating a solution that is feasible. Asking lots of questions along the way.

Architects discuss the conceptual design phase like an artist. It is the creative spark. The moment of magic. When you read books about buildings, they never talk about the window schedules, the waterproofing details, the toilet setting-out drawings, and yet these represent a large proportion of their time and effort. They discuss the moment of inspiration, how the design has used the historical context for the building, or the abstract inspiration which has led to its curves or jagged design.

Engineers are the opposite. We talk about the detail. The trials of designing a 1m deep post-tensioned transfer beam for disproportionate collapse. We fail to talk so much about our involvement in the creative part of the project, the art galleries we visited, which inspired us to suggest a folded plate solution, or the book we read that created a reference to the rhythm of the structure, or the abstract maths equation we have been chewing over that created the sculptural doubly-curved roof of the building. However, engineering is required at the conceptual design phase on every project whether we talk about it or not.

On some projects the engineering conceptual design is done by the architect. The design is delivered fully-realised to the engineer, with the simple requirement to prove it stands up. We have all worked on these projects. At best, they are dull to work on as all we have to do is crunch the numbers. At worst, the design is flawed, and the engineer becomes the enemy of creativity as they start to add columns to support 20m cantilevers, in the process ruining the ‘Parti’ (the central idea or concept)[1] of the building.

It is always more fun to work on projects where we get to play with the architect, or even on our own, allowing our technical ability to be used in creative and unusual ways. Solving complex problems through divergent thinking. These are the projects we remember working on for all the right reasons and the projects we feel most proud of.

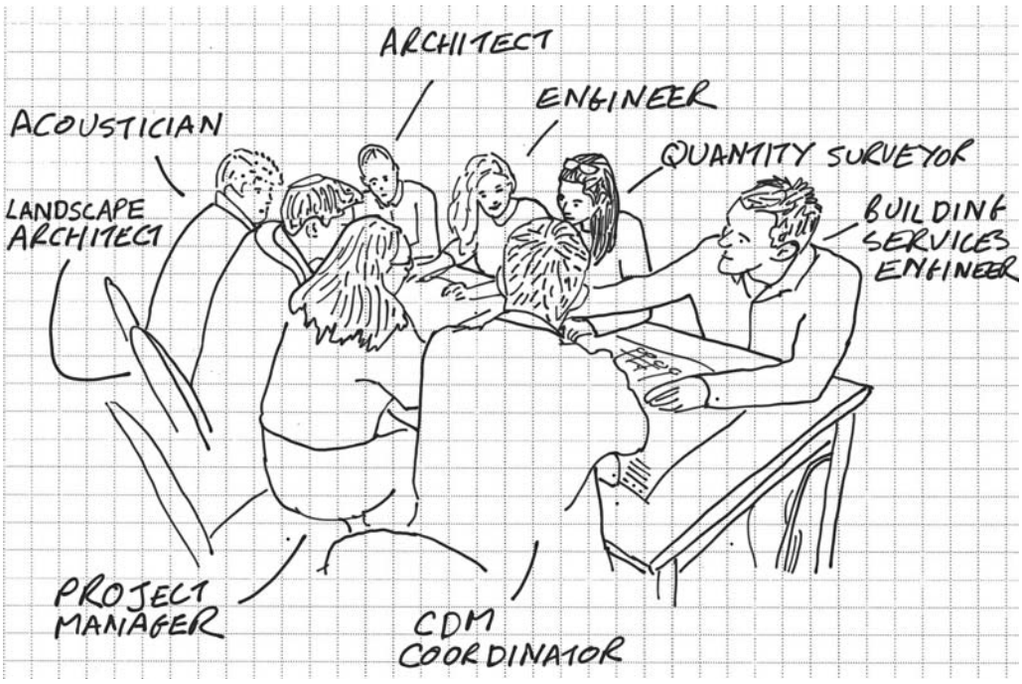
So, if you are a graduate engineer who has carried out multiple load-takedowns, and designed numerous beams and columns, then this book is for you. It is designed to help you engage in the next step of your design career, the conceptual design. It will build on your innate understanding of how buildings work and your library of solutions to design problems, but hopefully it will also challenge you to both draw inspiration from further afield and learn to communicate your ideas. This book is designed to be used by anyone, anywhere. We are aware that our collective personal experience is based mostly from designing buildings in the UK, but hopefully the book is universally applicable. However, some examples and finer details (such as codes referenced) are UK-specific.

If you are a student, we hope that this book will also be a great aid for you. While your ability to carry out conceptual design grows as you experience more design, it is never too early to start practicing, and we hope this book will offer helpful advice.

1.1 From blank page to complete building

Every project starts off as a blank page. It may first exist in the client's head. A desire or business need that has to be fulfilled. At some point the client decides to take the plunge and employs some professionals. An architect. An engineer. A quantity surveyor. A building services engineer. Maybe an acoustician. A landscape architect. A project manager. A CDM coordinator. The list goes on. Generally, these people are referred to collectively as the 'design team' (Figure 1.1), as designing large complex projects is always a team activity. The design at this point may be a set of business needs, or it might be a sketch on a napkin. It may be fully realised in the client's head, or there may be a problem that needs solving without a preconceived idea of what the solution should be.

Figure 1.1: A typical design team

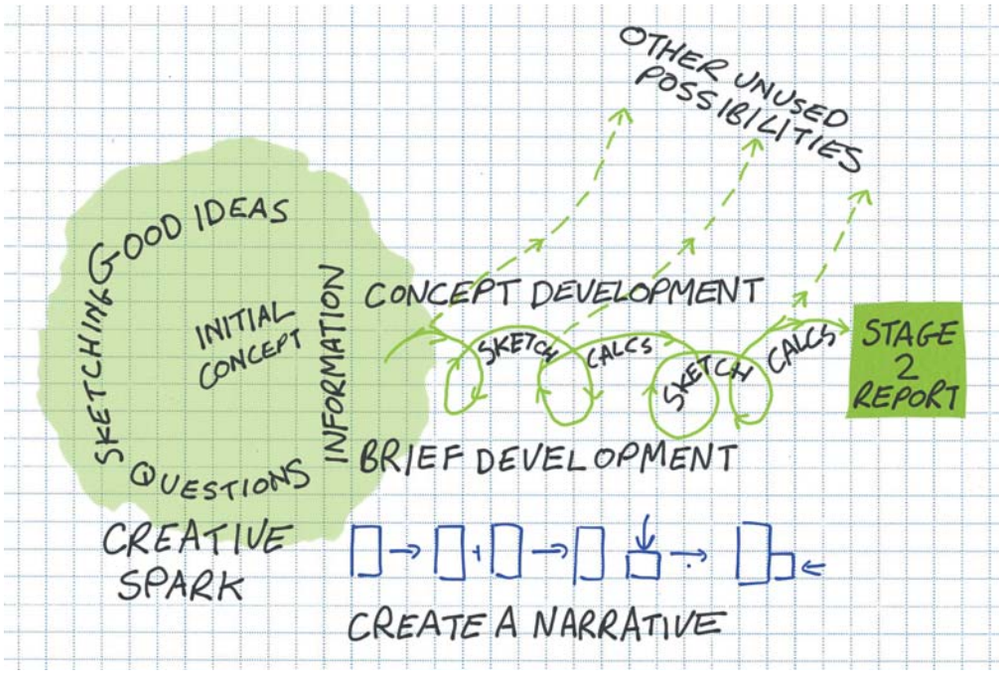


The conceptual design stage is the most creative, most fast-paced and most ill-defined of any stage of a project. As an engineer, we may be involved from the very beginning, or we may be involved long after the initial conceptual design has been completed. Whatever stage the project has reached, we will need to start to create a structure that will support the building and prove it will stand up.

This book is designed to help you successfully navigate, and make the most of, the conceptual design stage. The conceptual design stage itself (Figure 1.2) is very short – and the moment when key decisions get made often lasts just a few hours compared to a project that could last for years. When it happens, you will not have time to learn to draw, read widely, create narrative or carry out detailed design of sections. You will either be ready, or you won't! The aim of this book is to make sure you are ready. To prepare you for the moment an architect pops by to discuss a project they've been thinking about. To prepare you for when a client mentions in passing about a new project they've been dwelling on. To prepare you for when you sit your IStructE Chartered Membership exam. The aim of this book is to prepare you, as best we can, for these moments. These are milestone events in your career, for as you move on from just being able to carry out detailed design and become a competent conceptual designer, your skill set becomes bigger, the opportunities ahead of you become greater and you are ready to be a chartered structural engineer.

A small note of advice right at the very start. When you start a conceptual design, you are frequently confronted with a blank page. It can feel daunting to put a mark on it, to come up with a design. But as with any creative endeavour the best way to overcome the blank page is to start. Start drawing. Start making models. Start asking questions (and never stop). Start researching. Start spending time in the space where the building will be. Start talking to people. The (possibly metaphorical) blank page should not stay blank for long.

Figure 1.2: Concept design process



1.2 The importance of ‘good’ concept design

There is a phrase bandied around in some design offices:

‘Right first time’

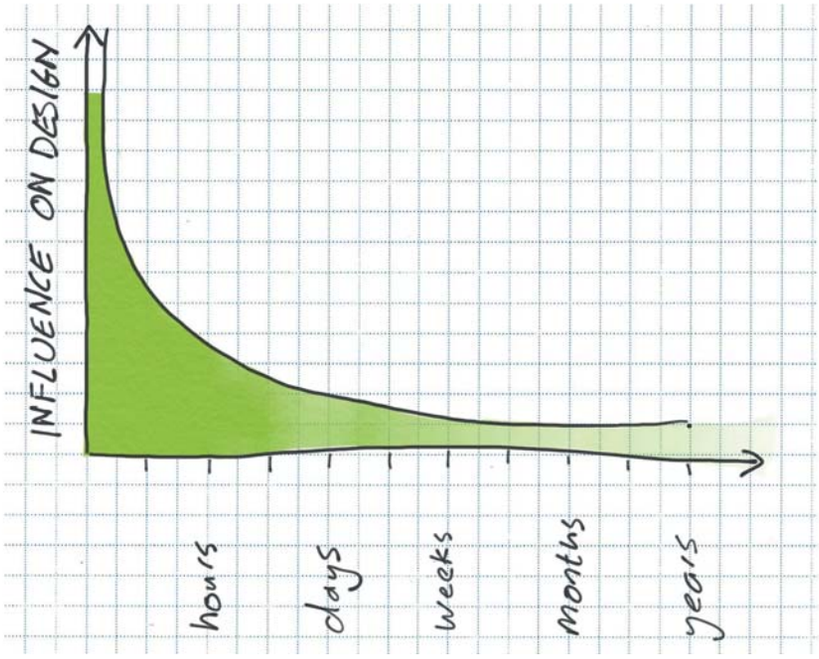
The idea is that you do everything once and only once. If you have worked on a design project you will have designed the same beam a number of times as the loading changes, or the column position moves, or the cladding changes. This is all a natural part of the design process, and on large and complicated projects it is inevitable that the design iterates and converges on the right solution. It is not possible to get the full design right first time. It is too complicated a system.

However, I am also sure we have all worked on projects where it feels like decisions made earlier could have made the project so much simpler. From an ill-conceived stability system to an irregular grid which feels like it could/should be rationalised — but the design has got so far down the line, that to change now would jeopardise the project. I am sure we have all scratched our heads and wondered how have we got here? If you have never had this experience, someone in your office is getting the conceptual design right.

A good conceptual design should offer flexibility without needing to start all over again. It should offer a rational solution that works not just for the engineer or for the architect, but for everyone. Sometimes this design is not easy to come by. The requirements of the client mean that finding a rational grid requires much thought and problem-solving. But if you get it right, the benefits further along the design process are huge (Figure 1.3).

Occasionally we will be carrying out the design process on our own, as the only professional involved in the project, but more often than not we will be working as part of a team. As part of a team, it is not only important to get the conceptual design right, we need to be able to communicate it. This communication will be verbal, written and through drawings. Drawings often form the heart of the conceptual design, reflecting the requirements of the client, and articulating a solution that fulfils a client’s brief. As engineers, we need to be able to draw in a number of ways, from rapid sketching to transferring ideas during a meeting, to more considered sketches being bounced backwards and forwards by email, as we try and converge on a solution, to neat and detailed sketches, or even CAD drawings, issued at the end of the conceptual design process. Often it is the information on these early drawings that defines the success of the project and removes the complicated negotiations later on in the design. Making drawings

Figure 1.3: Degree of influence on design versus how long the project has been running



rich with information, may feel time consuming when all you have been asked for is a beam size, but articulating key information, like expected deflection and connection sizing and tolerance can help solve many problems later on.

You may be wondering where BIM fits in with this process. And the simple answer is, it doesn't! Up to the end of the conceptual design process, drawings are sketches, the information is in constant flux and a fat felt tip pen is your friend as its lack of accuracy leads to a sensible level of approximation. As you converge on a solution and prepare to issue information at the end of conceptual design, it is quite possible that you will issue 3D drawings, often based on overlays from other practices. At this stage, it is unlikely that you are formally achieving BIM standards, but at the same time it is quite probable that you will be considering this for the next step as you enter detailed design. As we said, ideally it is best to get it right first time and, as such, you may well work closely to BIM protocols. This avoids having to do everything again at the next stage. As a result, while BIM is only mentioned in passing in these pages, it is worth considering it, just as you would the detailed design of your stability.

In every aspect, a successful conceptual design will make the later stages of the design process easier, but it cannot completely remove the risk of the brief being changed later, and will hopefully lead not just to a great design but also a happy client and architect, increasing your chances of working with them again in the future.

The term 'great design' is used here rather flippantly. The successful outcome of a design is complex and multi-faceted. Defining what we are trying to achieve is often key to this and we look at 'developing the brief' in Chapter 5.

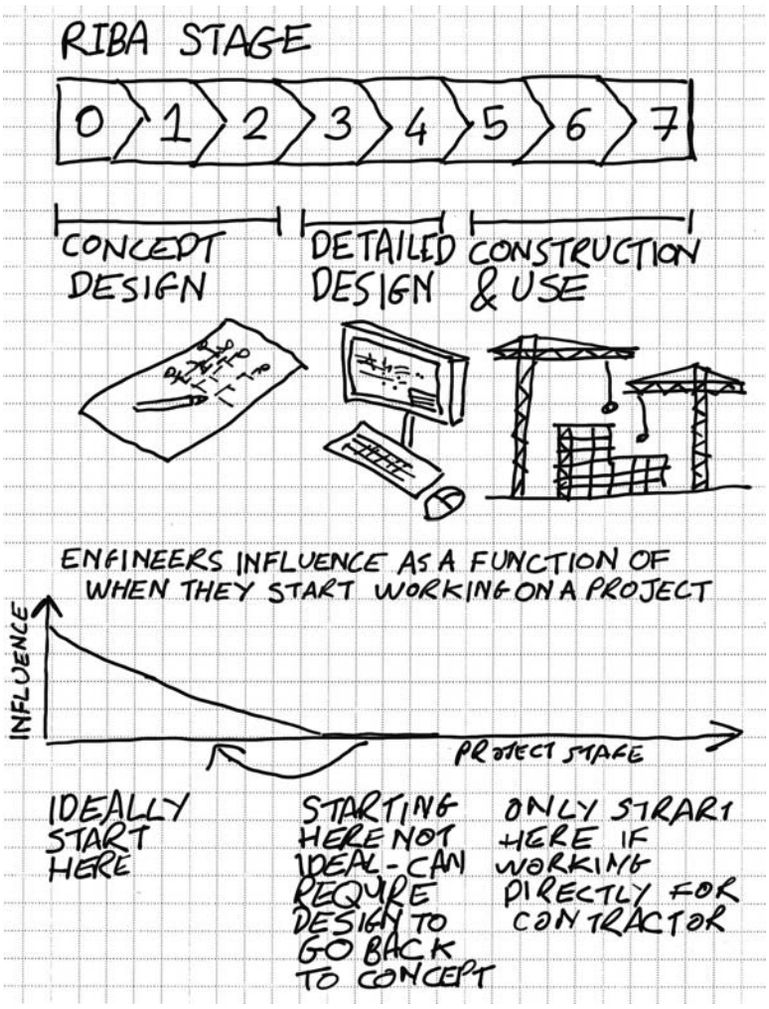
1.3 Building design process and the RIBA stages

The Royal Institute of British Architects (RIBA) Plan of Work 2020[2] reflects the different stages of a design project. These stages can be loosely described in three sections (Figure 1.4):

- Conceptual design stage (Stage 0–2)
- Detailed design stage (Stage 3–4)
- Construction and use (Stage 5–7)

If you are not already familiar with the Plan of Work, it is free to download from the RIBA website.

Figure 1.4: The RIBA design stages and the degree of influence an engineer can have at each stage



The conceptual design occurs between Stages 0 and 2. Stages 0 and 1 are the 'Strategic definition' and 'Preparation and briefing' and are covered in detail in Chapter 5. Stage 2 is the 'Concept design' and is covered in more detail in Chapters 7–11. At the end of this phase, the design team is normally required to produce a report and a set of drawings.

It is possible that the project has gone beyond Stage 2 before you are approached to work on the job. This does not mean that you are no longer required to carry out the concept design — you still need to go through the process, it just means that the design is far more constrained and that your options may well be limited. The frame may already be a steel frame with precast planks. However, there is a risk that the design is so constrained that a solution is not possible, forcing the design back into Stage 2 before it can develop.

It is our belief that the earlier the engineer is involved in the project, the better both for the client, who will get a better building with less problems later on, and for the engineer who will enjoy working on the job far more. However, there are some architects who are very good at considering the engineers needs without involving an engineer. At times in these situations, it may feel like the engineer is adding little value to the process.

1.4 How to use this book

This book is here to act as a guide. To challenge you to ask questions you may not have thought to ask, but to also have the confidence to make decisions you may not have felt confident making. However, it is very important to state that this book does not replace both your own experience and the experience of your colleagues. Every project is

different and while the authors have, in our combined 100 years of design experience, seen many different situations, we haven't seen them all.

We would recommend you view this book as being similar to the advice you might get from a senior engineer. You'll still want to weigh it against your own experience, and you should still have your information reviewed by someone more senior, such as a director or chartered engineer, prior to issue. Ultimately, talking your design problems through with someone, especially someone more knowledgeable than yourself, will always be more helpful than reading a book.

It is also important to be aware of your employer's attitude to risk. Different organisations have different approaches to risk and the attitude of yours may be affected by previous issues they have encountered. This may also depend on where the liability lies regarding the design. If your director's house is at risk if there was a problem, they may have a different attitude to risk than that of an employee of a limited company. These different views of risk do not mean that the building itself will be more (or less) safe, rather that different solutions may be viewed with more, or less, scepticism. With all conceptual design, there is a risk that things might need to change later on.

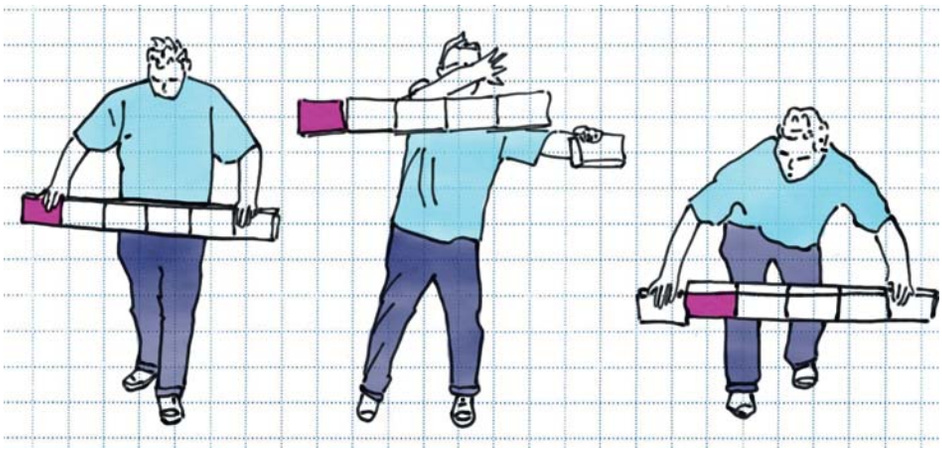
The book should be viewed in three ways:

Linear
It is written to be read linearly and is divided into three sections.

The first part looks at idea generation (Chapter 2), communicating and developing ideas through both drawing (Chapter 3) and writing (Chapter 4), developing a brief (Chapter 5) and the questions we must ask (Chapter 6).

The second part looks at the concept design process, taking you through the site constraints and ground conditions (Chapter 7), developing a structural scheme (Chapter 8), robustness and stability (Chapter 9), the quick sizing of elements (Chapter 10), and finishing with some worked examples (Chapter 11). It should be noted that the conceptual design process (Chapters 7–9) should not be seen as a linear process. Instead, the consideration of site constraints, geotechnical issues, structural solutions, materials, construction considerations, stability, prefabrication and all the other rich questions you might want to ask about the design should be seen as acting simultaneously. In many ways, we will gather as much information as possible and then throw it all up into the air and grab hold of the solution in one rapid movement, much like a skilled circus trick (Figure 1.5).

Figure 1.5: The early concept design process involves throwing everything in the air and catching it all at once



The third part (Chapter 12) looks at how we communicate the brief, design process and proposed solution/s and the other deliverables we may want to produce at the end of the conceptual design process.

For reference
The book is also designed to be a reference. If you want to choose a location for concrete shear walls or want to get a quick idea of the advantages of different materials, you can dive straight in. Every section is written to be self-contained, but it may occasionally refer to ideas contained elsewhere.

As part of a building designer's library

Finally, this book is not designed to provide all the information you require to carry out concept design. Instead, it is intended to supplement and support a number of excellent texts which already exist. We would suggest that every engineer should have access to the items in Table 1.1.

Table 1.1: Suggested books to have in your library

Title	Comments
Structural engineer's pocket book: Eurocodes (3rd edition)[3]	This book is a toolbox containing a vast array of useful information in one place
Structural timber elements: a pre-scheme design guide (2nd edition)[4] *Steel building design: design data (SCI Publication P363)* [also known as the 'Blue book' and freely available as a fully interactive version][5] *Economic concrete frame elements to Eurocode 2: a pre-scheme handbook for the rapid sizing and selection of reinforced concrete frame elements in multi-storey buildings designed to Eurocode 2*[6]	These three books all deal with rapid sizing of elements in their selected material. They provide a large array of data covering beams, slabs, columns and walls in timber, steel and concrete respectively There is also a plethora of load span tables available online. We have avoided specifying brand-specific tables but if you require load span tables for precast concrete planks, a simple web search will give you all the information you require
Conceptual structural design: bridging the gap between architects and engineers (2nd edition)[7]	This book is aimed primarily at architects and what architects need to know about the engineering side of conceptual design. However, it is also a useful reference for engineers
101 things I learned in architecture school[1]	This book is short and sweet, but will introduce you to some architectural ideas such as the 'Parti' and shape-space theory, which will help you in better understanding what the architect is thinking and will enable you to communicate more freely with architects. It should be seen as a very small introduction and we would recommend delving deeper into architectural literature as part of your own development in conceptual design

1.5 One hundred years of design experience

This book is written by a group of engineers who have gathered over 100 years of design experience between them. Each chapter includes personal experience and anecdotes. With concept design there is no right answer, just experience. Don't be surprised if we provide occasionally conflicting opinions. While this at first may be frustrating, in time you will discover a richness to this discourse. I can recall a number of times when my colleagues at work disagreed on the approach to a problem and, as the engineer, I had to work out the best way forward. I also wouldn't be surprised if you and your colleagues don't always agree with us either. That's fine too. Ultimately, as a practicing engineer, it is your responsibility to make the best decision you can, based on the available information.

1.6 'Good enough'

The information provided in this book is designed to be used for quick conceptual design calculations only. As a result, much of the information is 'good enough' for this purpose but should *never* be used for detailed design of buildings. For all design post-Stage 2 of the RIBA Plan of Works 2020, the latest codes of practice and most up to date information available at the time should be used.