Udvikler og bevarer

Realdania By & Byg

MINICO2 ETAGEHUS BETON

Realdania By & Byg

VI SKABER LIVSKVALITET I DET BYGGEDE MILJØ GENNEM EJERSKAB

Udvikler og bevarer

Realdania | Realdania By & Byg

TEAM

BYGHERRE

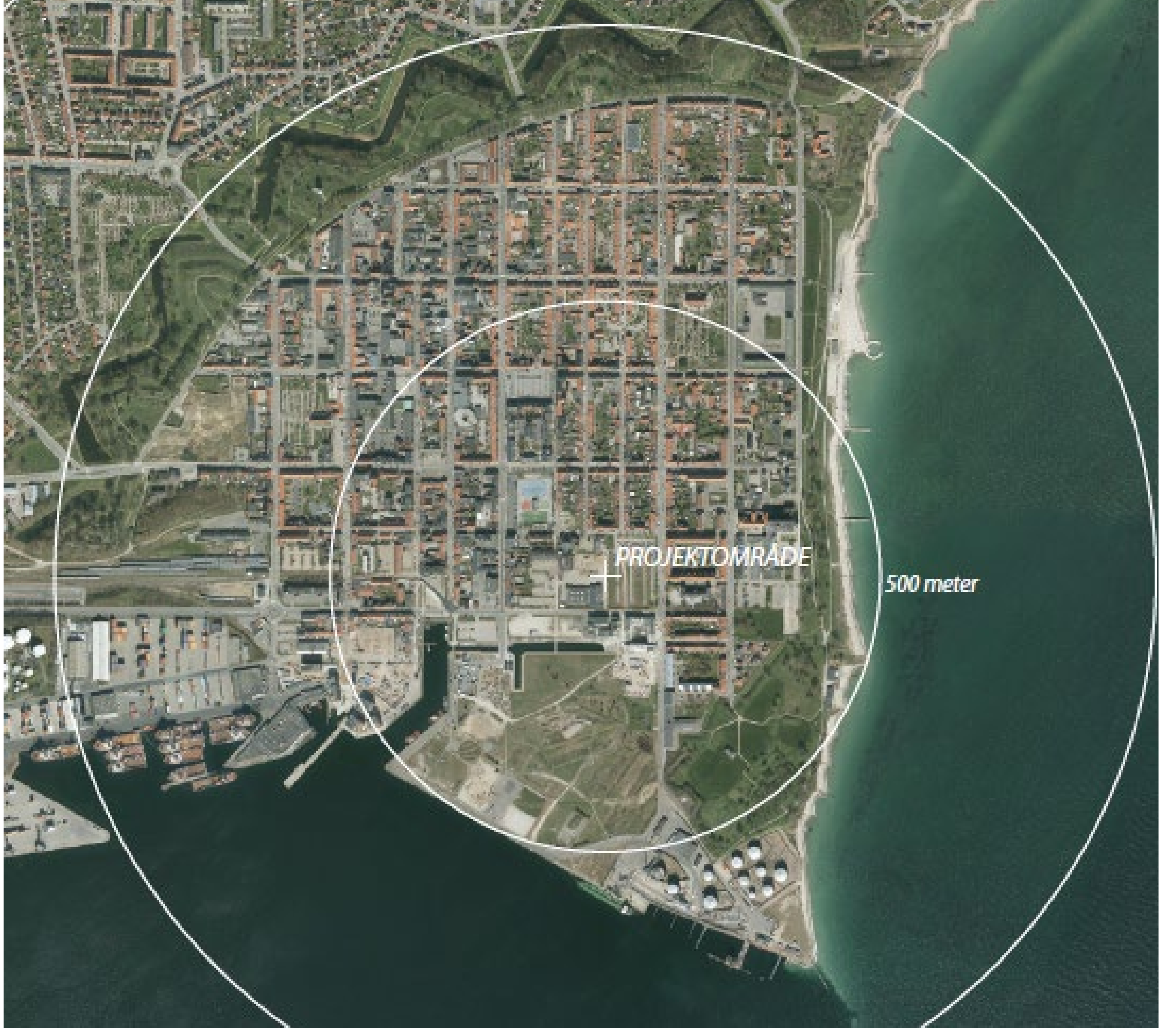
INGENIØRER

ARKITEKTER

HOVEDENTREPRENØR

STED

KONGENSSTRÆDE 88
KANALBYEN FREDERICIA



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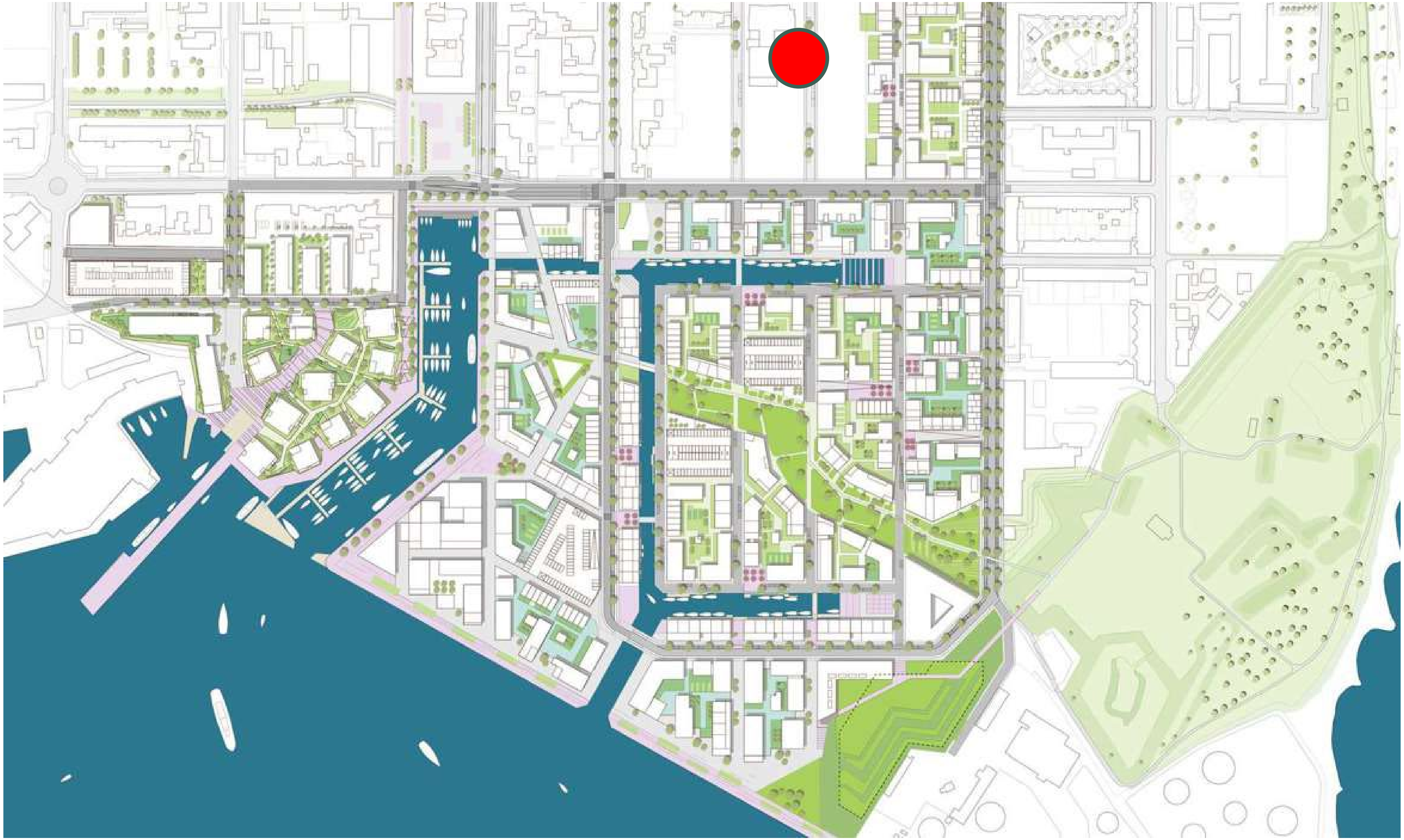
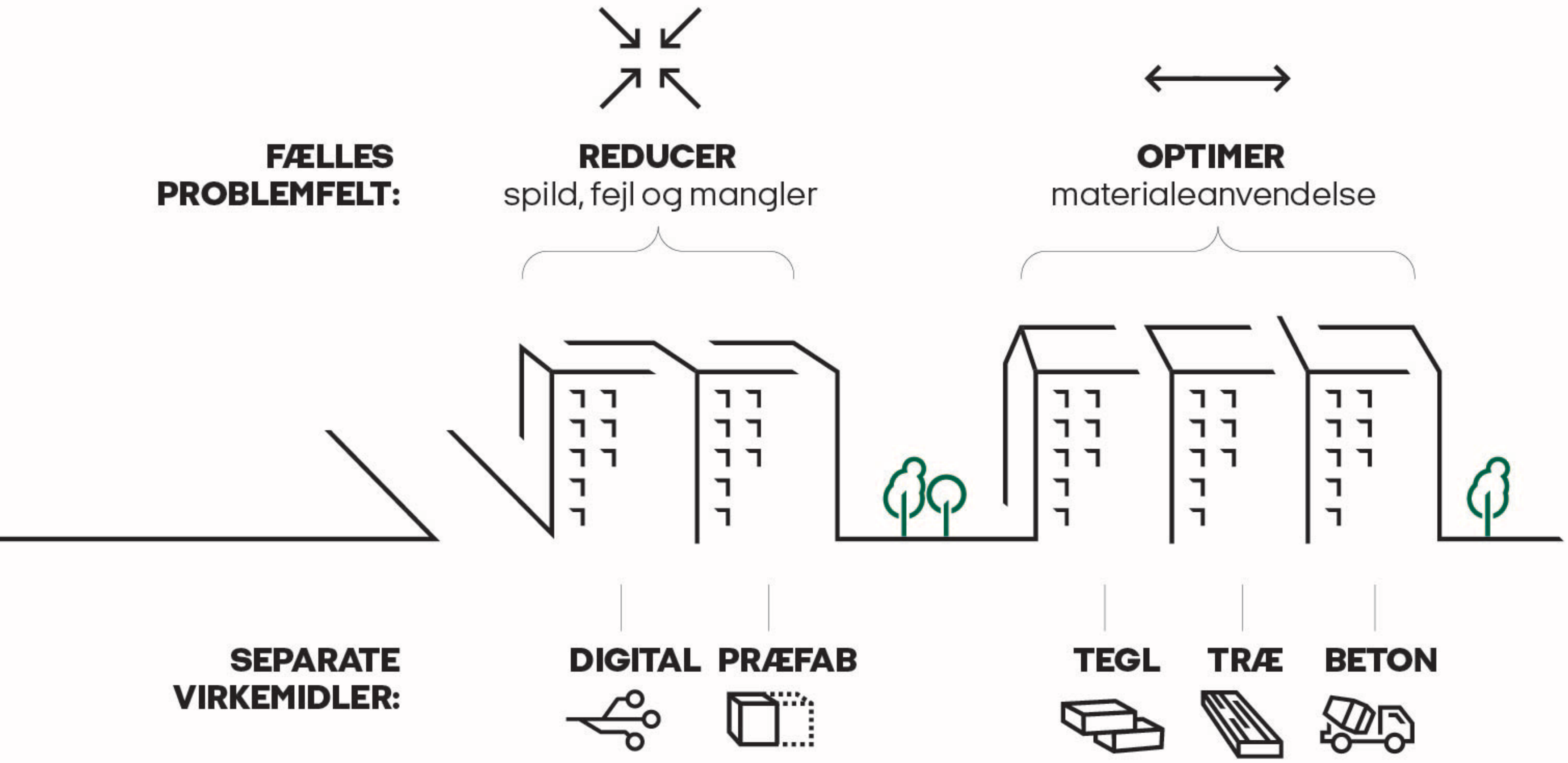
KANALBYEN, FREDERICIA



MINICO2 ETAGEHUSENE – ET KOMPARATIVT STUDIE

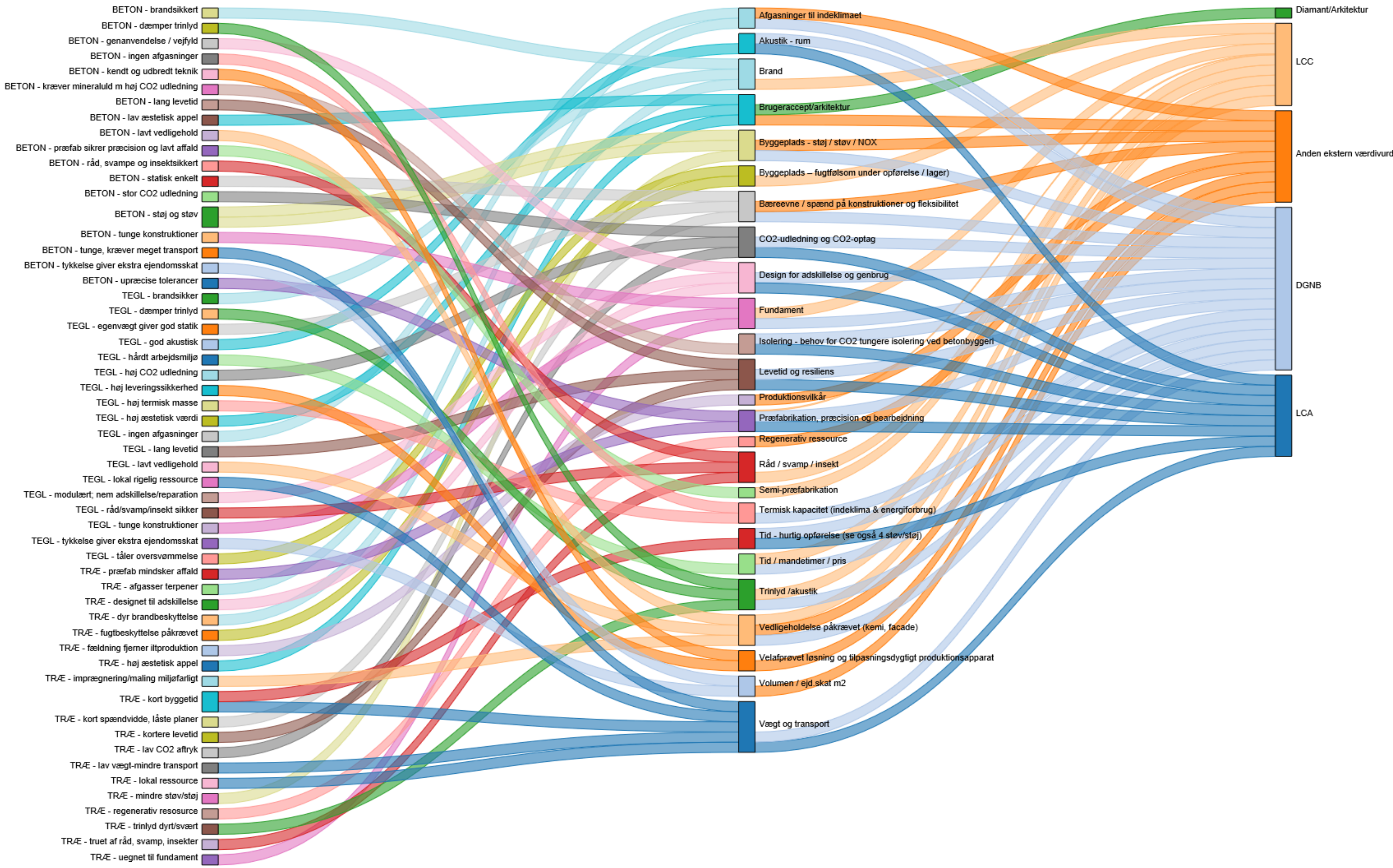
Udvikler og bevarer



- 5 ETAGEHUSE
- 1 GADESIDE
- 5 ETAGER
- 600 M2
- SAMME VOLUMEN
- SAMME BOLIGPLAN

MAX. BETON
GNSN. PRIS
MIN. CO_2

FORSØGSDESIGN – 25 SPØRGSMÅL



ARKITEKTUR

PRIS

BRUGER

DGNB

CO_2

BETONBYGGERI - UDFORDRINGER, MYTER OG FORDOMME

BRAND
UORGANISK

PRODUKTION
ELEMENTER
IN-SITU

STATIK
KK3
ROBUSTHEDSKRAV
BEREGNINGSMETODIK

RESSOURCER
KNAPHED
GENBRUG
BIODIVERSITET

AKUSTIK
BR DK
FREKVENSER

CO2
CEMENT
HÆRDETID
GENBRUG

ÆSTETIK
PERCEPTION
HISTORIE
PATINERING

TIDLIGERE ERFARING HOS REALDANIA BY&BYG - GLASALSTRUP, HASSELAGER (1967)

Realdania
Realdania By & Byg

TIDLIGERE ERFARING HOS REALDANIA BY&BYG
- KNUD FRIIS VILLA, BRABRAND (1958)

MINICO2 ETAGEHUS BETON/TRÆ/TEGL - KONGENSSTRÆDE 88-92, FREDERICIA

DOBBELT BUNDLINJE KONSTRUKTIONER ARKITEKTUR

DOBBELT BUNDLINJE

KONSTRUKTIONER

ARKITEKTUR

DOBBELT BUNDLINJE

0.25

03 | BYGNINGSDELE

05 | DÆK

5.1 | ETAGEDÆK
5.1.4 | INSITU DÆK
C16 UNIGREEN PLUS**
120MM

INSITU DÆK C16 UNIGREEN PLUS 120MM.**
Standard in-situ betondæk med lav betonstyrke og optimeret armeringsmængde.

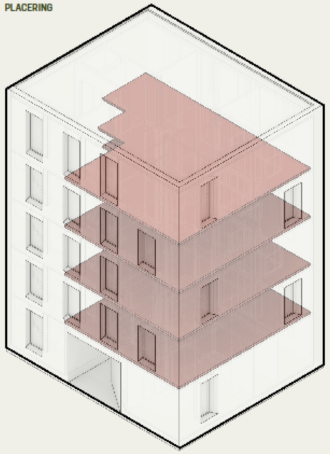
Fordele
Meget lav CO2 belastning
Høj robusthed og fleksibilitet
Tyndt etagedæk uden bjælker
Lidt lavere pris

Ulemper
Længere afformningstid

(**)Produktet er på markedet, men GWP tal oplyst af producent, som afhænger af projektspecifik EPD.

Insitu dæk C16 Unigreen plus**

PLACERING

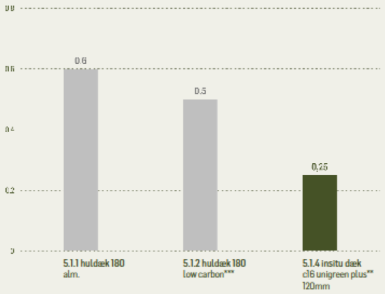


PRISKLASSE

400 - 600

Kr. / m²

LCA I GWP



0.24

03 | BYGNINGSDELE

05 |DÆK

5.2 | GULV
5.2.1 | BETONGULV
25MM GLITTET

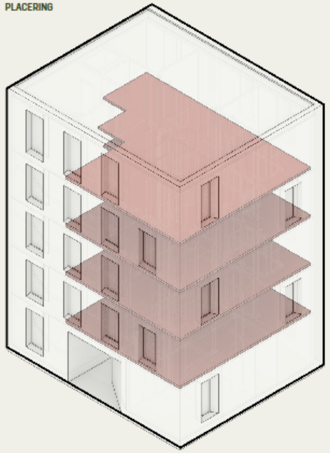
BETONGULV 25MM GLITTET
Udføres med 5 mm lyddug af genanvendt gummi fra bildæk og et meget tyndt afretningslag i beton med revnearmering. Glittet overflade.

Fordele
Optimeret betongulv

Ulemper
Risiko for revner
Opmærksomhed om lydtransmissioner.
Højt krav til udførelse

Betongulv

PLACERING

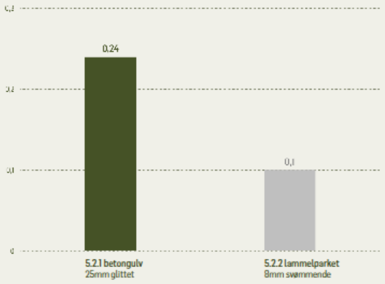


PRISKLASSE

700 - 1050

Kr. / m²

LCA I GWP



DOBBELT BUNDLINJE

Udvikler og bevarer

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0.60

03 | BYGNINGSDELE

03 | YDERVÆGGE

3.0.3 | MURET GENBRUGSFACADE OG C20 ELEMENT*** 80MM

PRISKLASSE

6500 - 13000

Kr. / m²

MURET GENBRUGSFACADE OG C20 ELEMENT* 80MM**
Optimeret betonelement facade med 80 mm bagvæg, 300 mm blød isolering og 80 mm forplade i genbrugsbeton.

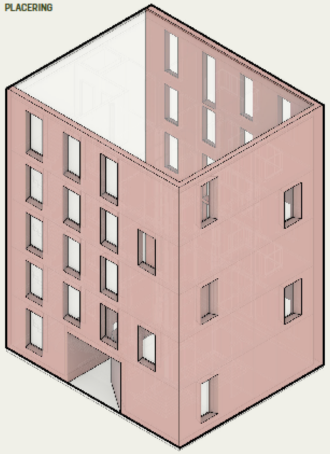
Fordele
Optimeret
Minimalt Ressourceforbrug
Genbrug af betonelementer
Mulighed for biogen isolering

Ulemper
Kort hærdetid på grund af løft af elementer
Tidskrævende opmuring af formur
Pris på genbrugte betonsten

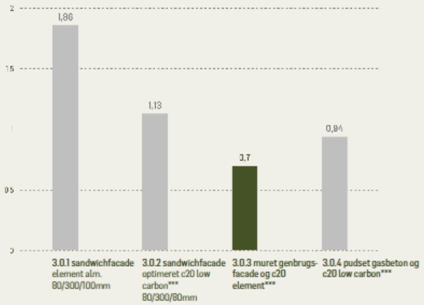
(***) Fremskrevet GWP af producent, som vurderes markedsparat indenfor 6 mdr.

Muret genbrugsfacade og C20 element***

PLACERING



LCA I GWP



0.80

03 | BYGNINGSDELE

03 | YDERVÆGGE

3.0.4 | PUDSET GASBETON OG C20 ELEMENT LOW CARBON*** 80MM

PRISKLASSE

1500 - 4000

Kr. / m²

PUDSET GASBETON OG C20 ELEMENT LOW CARBON * 80MM**
Optimeret betonelement facade med 80 mm bagvæg, 300 mm blød isolering og 80 mm forplade i porebetonblokke.

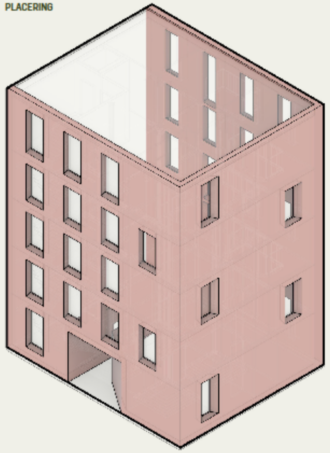
Fordele
Optimeret
Mulighed for biogen isolering
Lav pris

Ulemper
Kort hærdetid på grund af løft af elementer
Tidskrævende opmuring af formur

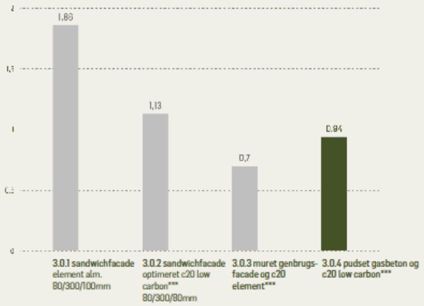
(***) Fremskrevet GWP af producent, som vurderes markedsparat indenfor 6 mdr.

Pudset gasbeton og C20 element low carbon***

PLACERING

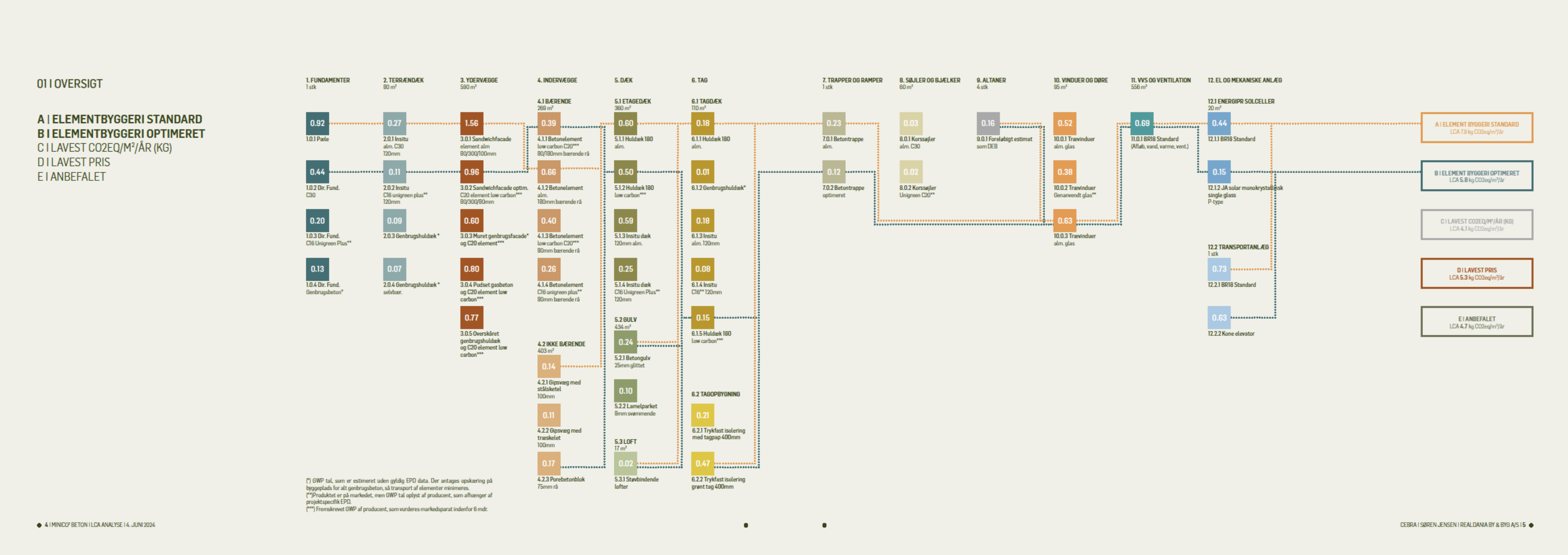


LCA I GWP



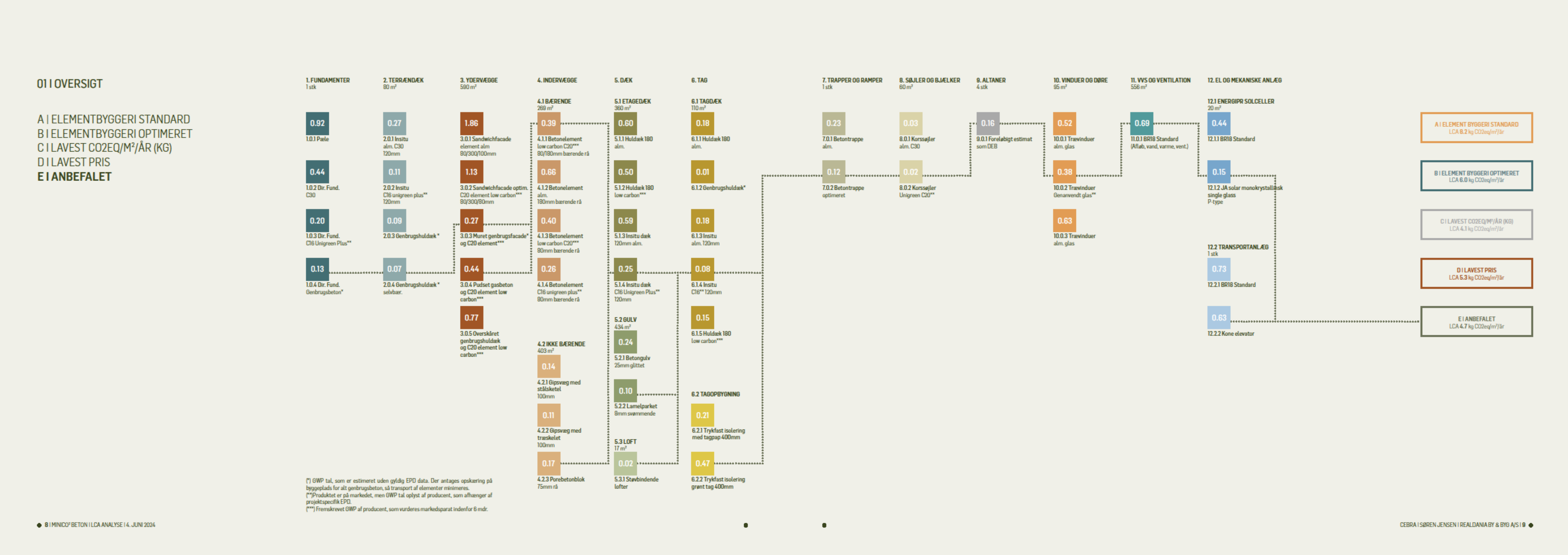
DOBBELT BUNDLINJE

Udvikler og bevarer

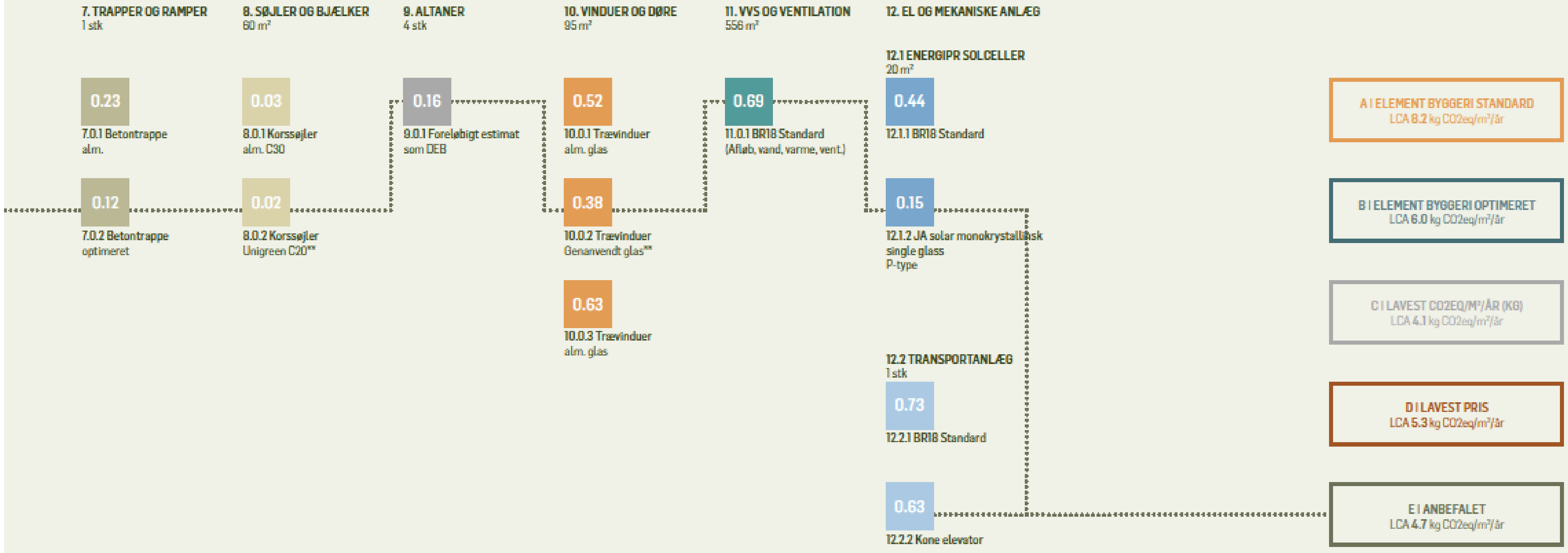


DOBBELT BUNDLINJE

Udvikler og bevarer



DOBBELT BUNDLINJE



02 | ANALYSE

E | ANBEFALET

ANBEFALET
Den anbefalede variant er den, der har det lavest CO2 med mest muligt beton og en pris på cirka 20.000 kr/m2. Udføres med pladsstøbte dæk i beton, betonsøjler og bærende betonelement ydervægge. Facader, fundamenter og terrændæk udføres delvist med genbrugte betonelementer.

Fordele
Lav CO2
Pris indenfor forventet ramme
Mest muligt anvendelse af beton
Høj anvendelse af kendte byggeprincipper
Høj fleksibilitet og robusthed
Anvendelse af genbrug

Ulemper
Lidt længere byggetid
Nye principper for genanvendelse af beton

(*) GWP tal, som er estimeret uden gyldig EPD data. Der antages opskæring på byggeplads for alt genbrugsbeton, så transport af elementer minimeres.
(**)Produktet er på markedet, men GWP tal oplyst af producent, som afhænger af projektspecifik EPD.
(***) Fremskrevet GWP af producent, som vurderes markedsparat indenfor 6 mdr.

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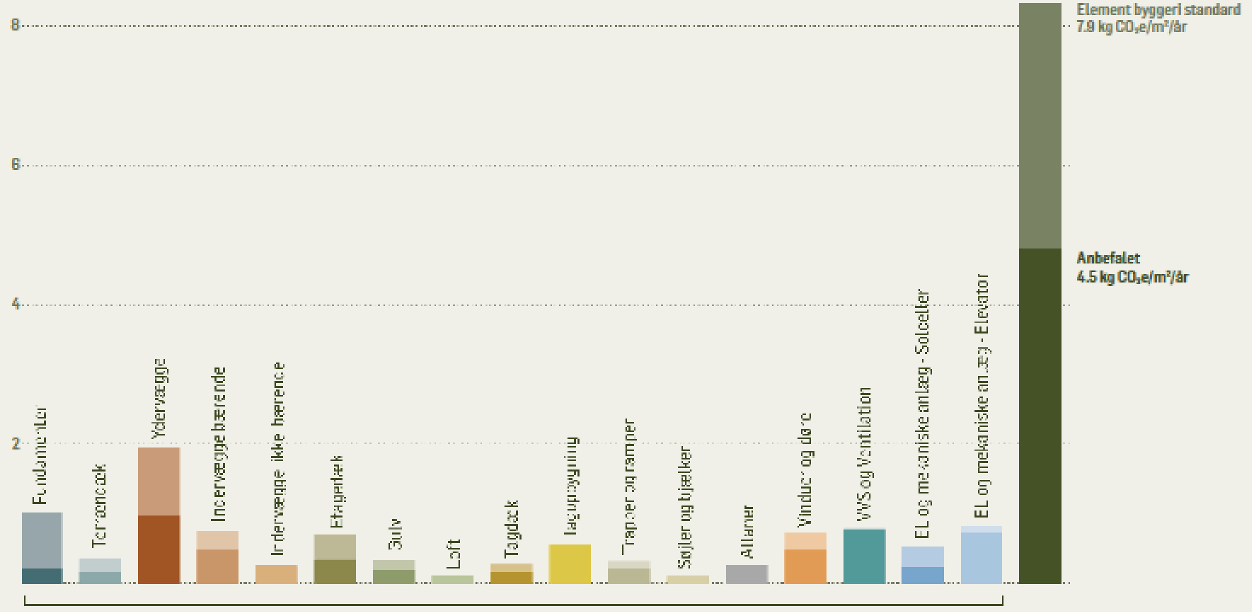
KONKLUSION

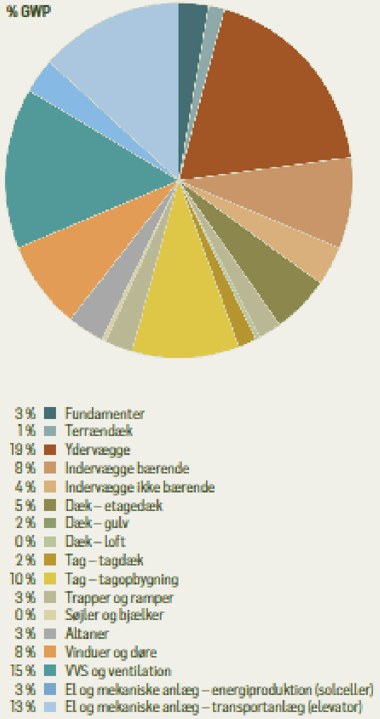
556 m²	19.000 - 21.000 /kr. m²
Bruttoareal	Pris

LCA I GWP

Den øjeblikkelige opnåede baseline beregning baseret på forslagets udformning



% GWP



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DOBBELT BUNDLINJE
KONSTRUKTIONER
ARKITEKTUR

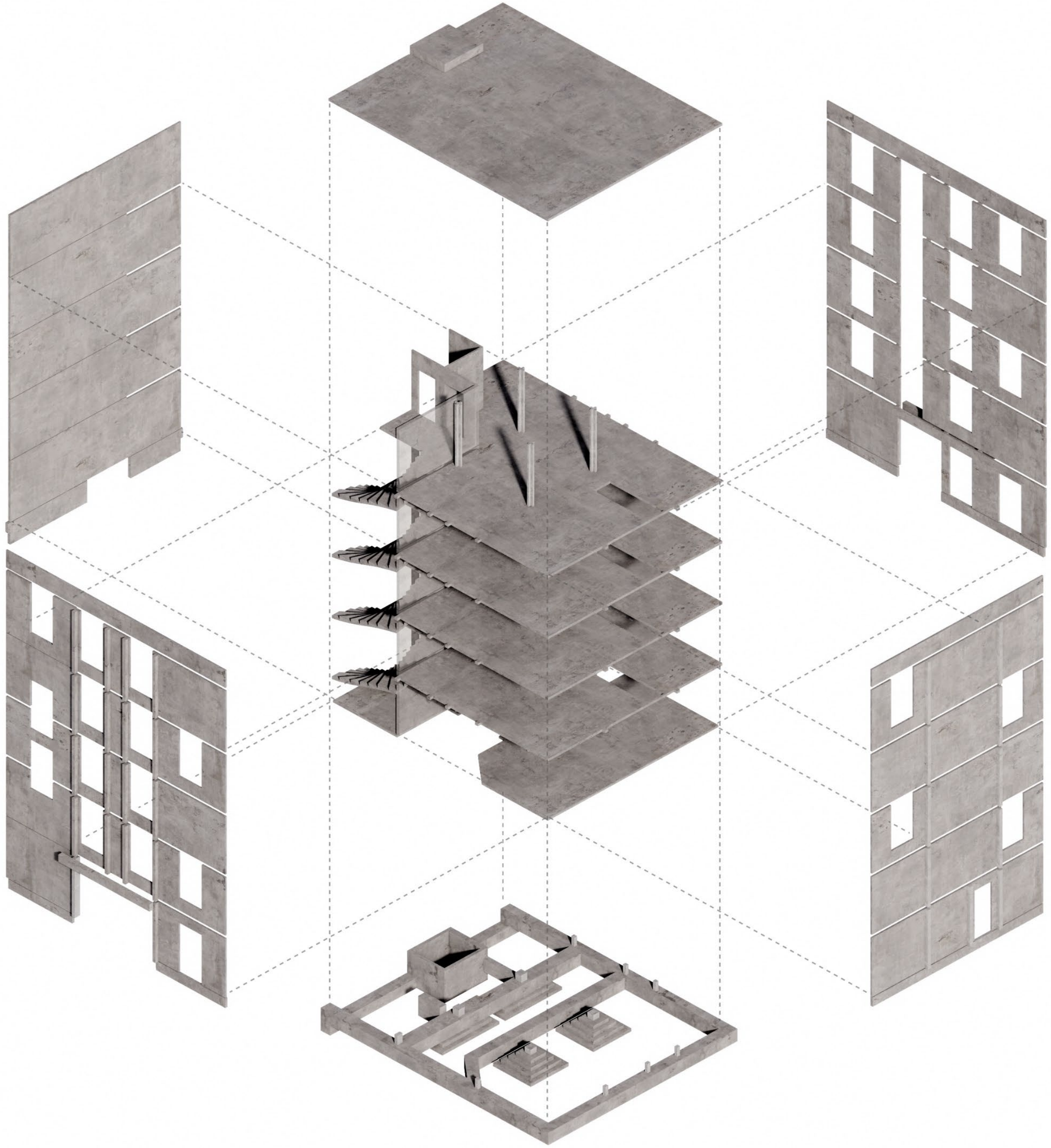
KONSTRUKTIONER

In-situstøbte betondæk og trappe

Betonelement søjler og bærende vægge

Fundamenter i in-situ og genbrugselementer

CO2 reduceret Beton C16

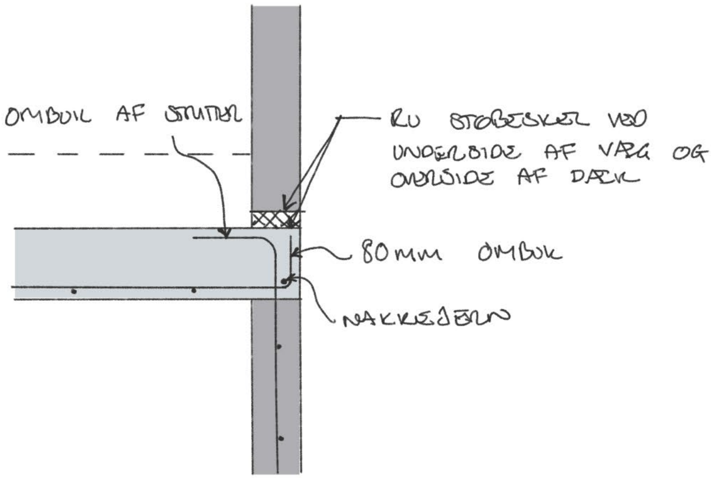


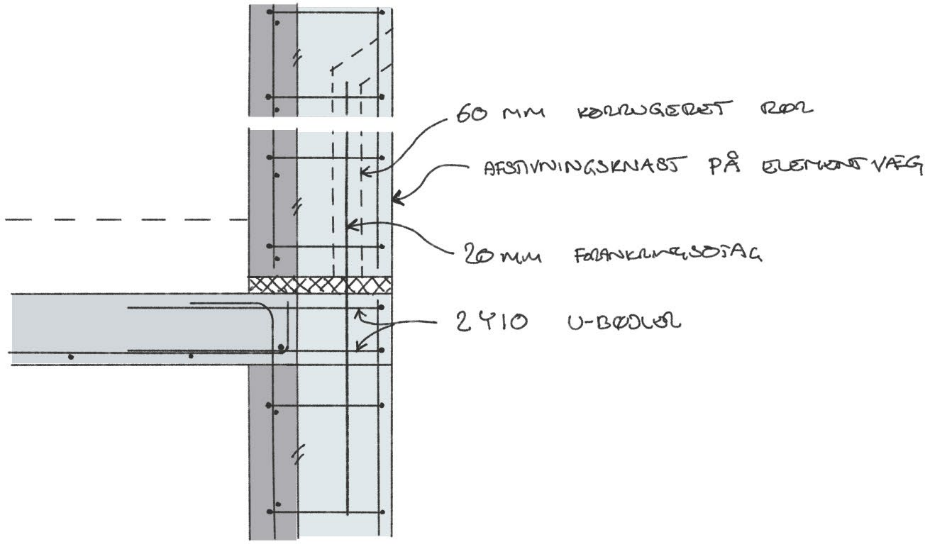
KONSTRUKTIONER

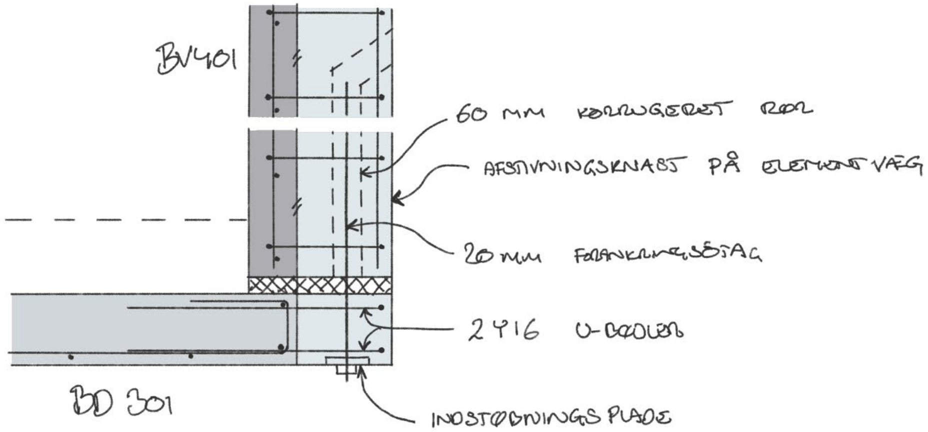
Ydervægge
Lodret snit

12 cm dæk

8 cm bærende betonelement ydervægge



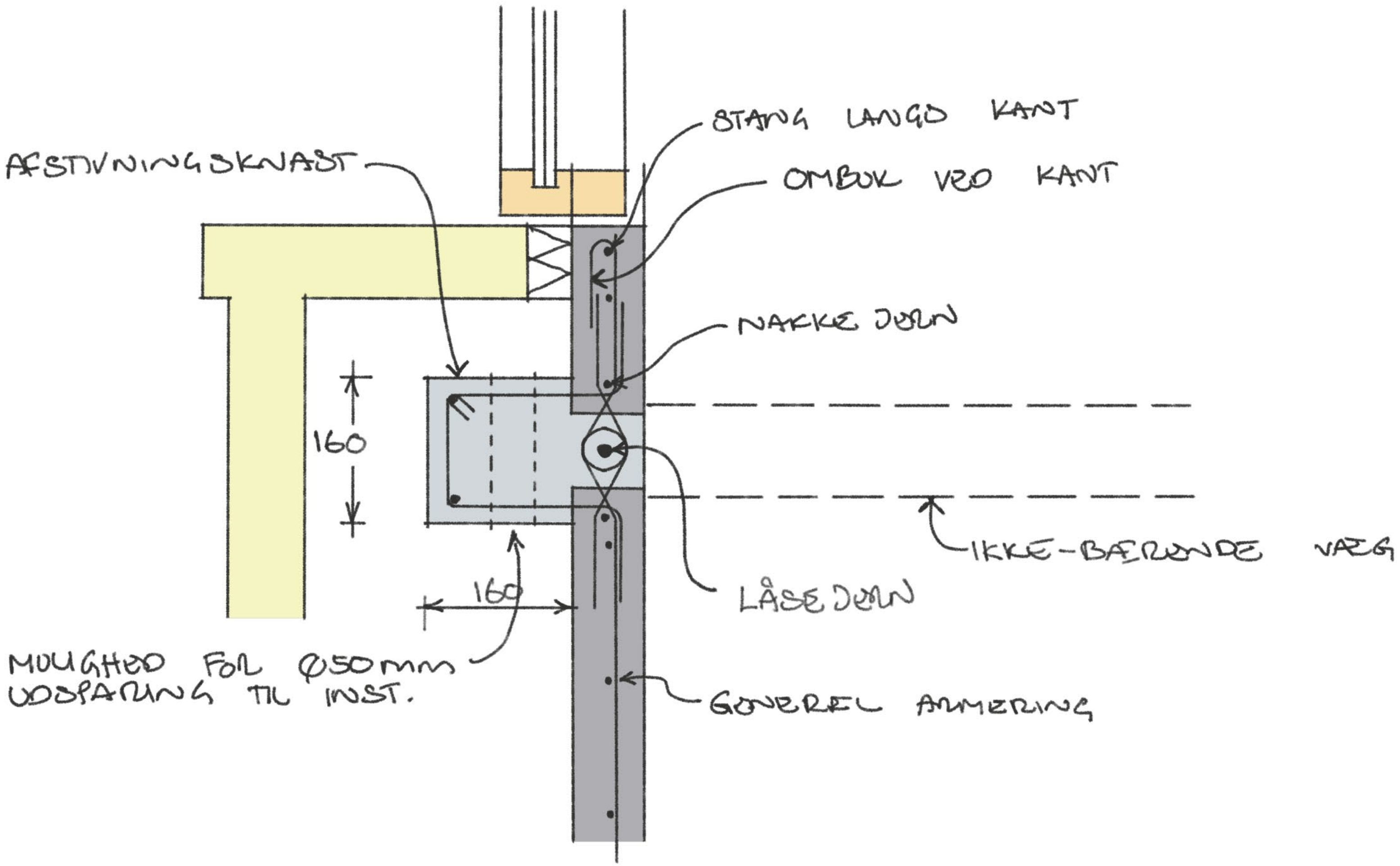




KONSTRUKTIONER

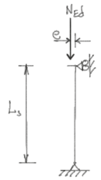
Ydervægge
Vandret snit

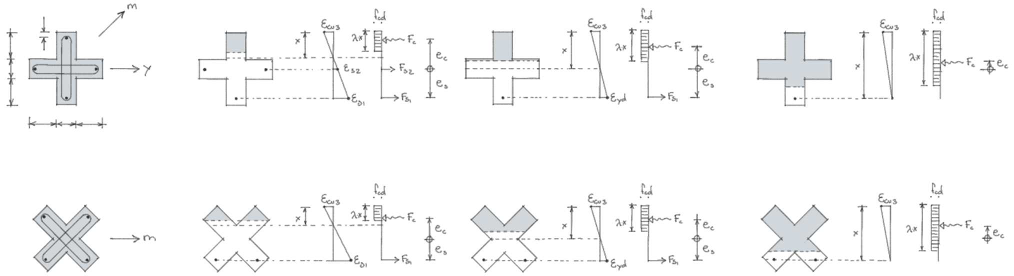
8cm betonvæg
med knast

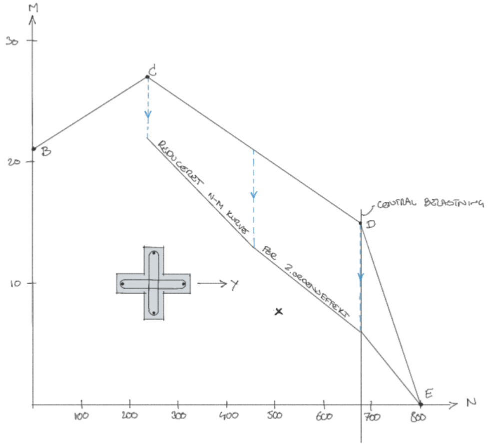


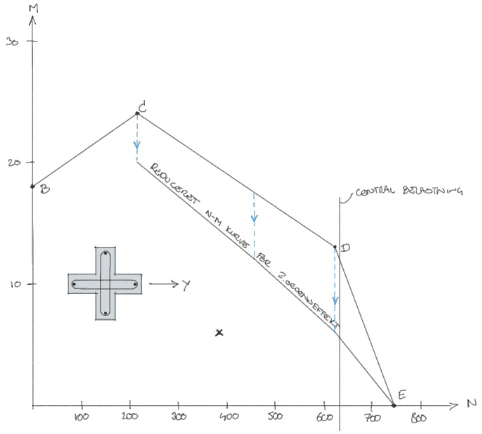
KONSTRUKTIONER

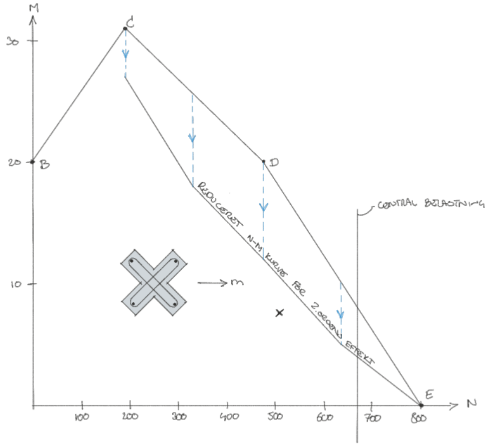
Korssøjler

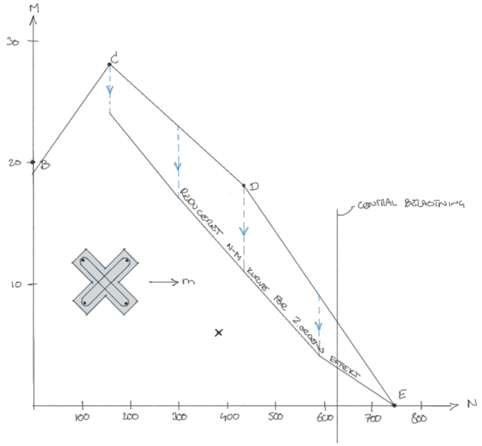












KONSTRUKTIONER

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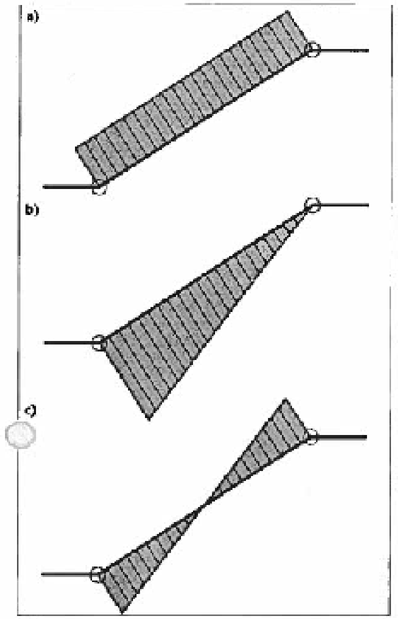
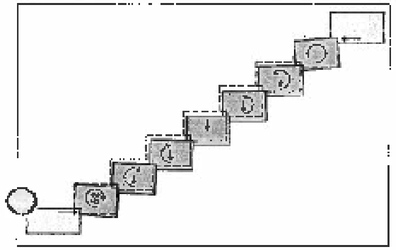
KONSTRUKTIONER

Inspiration fra klassiske trapper

In-situstøbt trappe
Indstøbt i de stabilisende vægge

Realdania
Realdania By & Byg





very considerably the stresses in the treads.

A flight with rebated treads has even more unknowns than a flight with plain treads. To simplify the analysis the conservative assumption can be made that the horizontal restraint is only applied at the landings and that the horizontal force is therefore constant throughout the flight, producing a constant couple in all the treads (Fig 15a). In the case of a straight flight with stone landings at the top and bottom, the landings can restrain the flight, and so develop the horizontal force that reduces the torsion in the treads. The couple due to the vertical loads still increases down the flight, as for the plain tread (Fig 15b). The resultant net torsions in the treads are shown in Fig 15c. So, for the flight shown schematically in Fig 16 there is a net clockwise torsion on the lower treads, where the moment from the vertical loads is greater than the moment from the horizontal force, and there is a net anti-clockwise torsion in the upper treads, where the moment from the horizontal force is greater than the moment from the vertical loads. The middle tread is in balance. The rotations are symmetrical, giving the deflected shape shown in Fig 16. The mid-flight deflection will be a quarter of the deflection at the top of a similar flight of unrebated treads.

Fig 15c shows the effect of the rebates. The maximum

Fig 15. (Left) Diagram showing the torsion in a staircase made with rebated treads under a uniform applied load. (a) Torsion due to restraint forces (b) Torsion due to load (c) Resultant torsion *(courtesy Ian Fussell)*
Fig 16. (Below left) Diagram showing the deflected shape of a rebated flight *(courtesy Ian Fussell)*
Fig 17. (Below) Landing within a flight of the Beauty Stair at Hampton Court *(photo courtesy Sam Price)*

torsion on a tread is halved. The stresses in the supporting wall are reduced even more significantly, because the torsion at the wall will be largely provided by the stone-to-stone connection. The wall only has to supply the additional torsion to carry the load from that tread, rather than the whole torsion that would be required by unrebated treads.

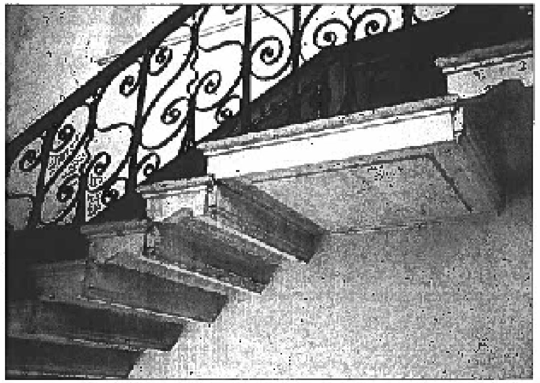
It is acknowledged that there are a lot of unknowns in this simplified analysis of a flight made with rebated treads. The value of the horizontal force between the treads is difficult to assess, as it depends not only on the stiffness of the stone and of the supporting wall but also on the end restraints to the flight i.e. how the flight is supported, both vertically and horizontally, at the landings. The detailing of the stones in the flights and landings could affect the way the staircase works, as would the way in which it was built.

One way of testing the accuracy of this analysis is by measuring the deflection in a real flight under a load test. We have had the opportunity to do this on a few occasions, and the actual deflections have always been less than predicted, and usually so small as to be difficult to measure. This indicates that the assumptions made in this simple analysis are conservative.

Modern scientific analysis may not be able to predict accurately the stresses in the treads, but the builders of the late 19th century knew what was going on. They put their faith in the rebates and cut the treads down to the elegant triangular section that became the standard for the 19th century. This reduced the torsional strength of the tread to about a third of its rectangular counterpart and reduced the stiffness to about a sixth. Such dramatic reductions could only be possible with rebated treads.

Landings within the flights and at the top of the flight

The Fountain Court at Hampton Court contains a wonderful collection of stone staircases designed by Wren, or more probably Talman. The 'Beauty Staircase' has a landing within the flight (Fig 17). Here the landing slabs are rebated onto each other, and the load is transmitted in the same way as it



is between the treads in the flight.

Similar detailing is normally used at landings at the top of staircases, which can be made up of many separate pieces rebated to each other. An alternative to the rebated joint is the joggled joint, normally lead-filled.

Landings at changes of direction

Again, at Hampton Court, it is possible to see how the flights and landings are interacting by looking at the detailing of the rebates. The general arrangement, for quarter or half landings, is to build the corner pieces of the landings into the two walls of the stairwell. As these pieces of stone are supported

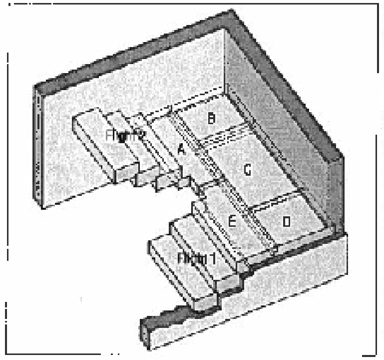


Fig 18. (Left) Diagram showing the rebates between stones in a typical half landing *(courtesy Ian Fussell)*

on two walls at right angles they can provide a rigid support for the flight or landing.

This means that in effect the whole staircase is made up of structurally independent flights, with pieces of the landing fitting between. In Fig 18 the stones making up the half landing are lettered A to E. The lower Flight 1 is propped horizontally by stones C, D and E, with stone E spanning between the top of the flight and stone D, which is built into both walls. The load of the upper Flight 2 is carried by landing slab A on to the corner slab B, which is built into both walls. In some of the stairs a crack has opened along the line of the rebate between the top tread and the landing, i.e. below stone E, which shows that the horizontal force from the landing has not held the top of the flight (probably due to the rebate being too shallow). It also shows that the lower flight 1 is not supporting the landing.

Spiral staircases

Spiral stairs with unrebated treads behave in principle in the same way as straight flights of unrebated treads. The

torsional stresses in the treads are less than the stresses in a straight flight because the width of the tread at the outer edge is less than the width at the wall. The eccentricity of the vertical forces that cause the torsion is therefore less, while the section of the tread resisting the torsion is greater. In spirals with rebated treads the horizontal forces developed by the rebates can be restrained throughout the staircase by the enclosing wall, and it is likely that very little, if any, torsion is developed in the treads.

Failures and repairs

With such a large number of these stairs in use it is not surprising that there have been some failures. Like any piece of structure they can be overloaded, and unlike structures made out of

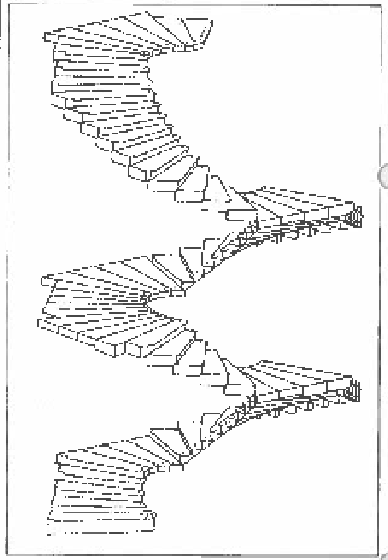
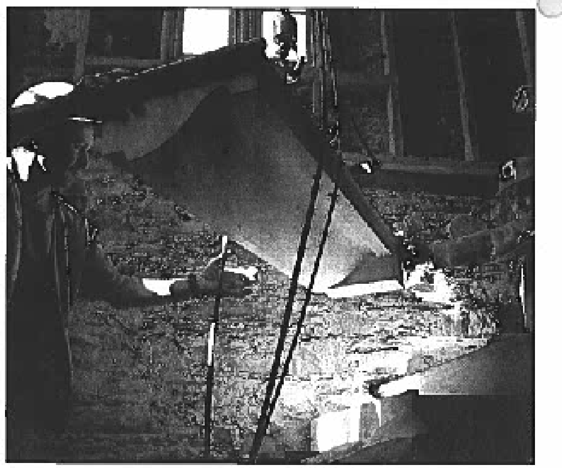
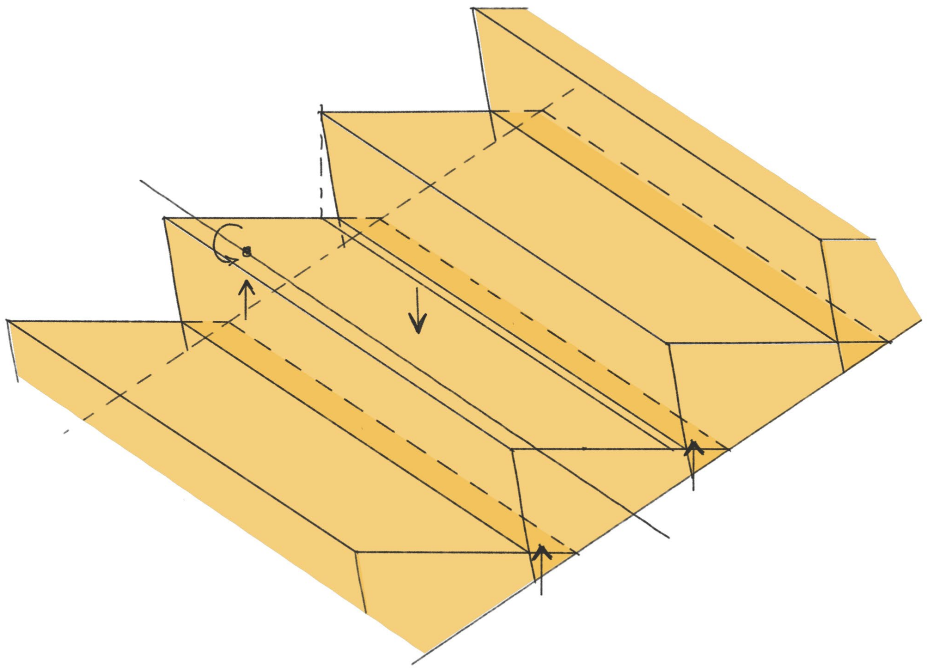
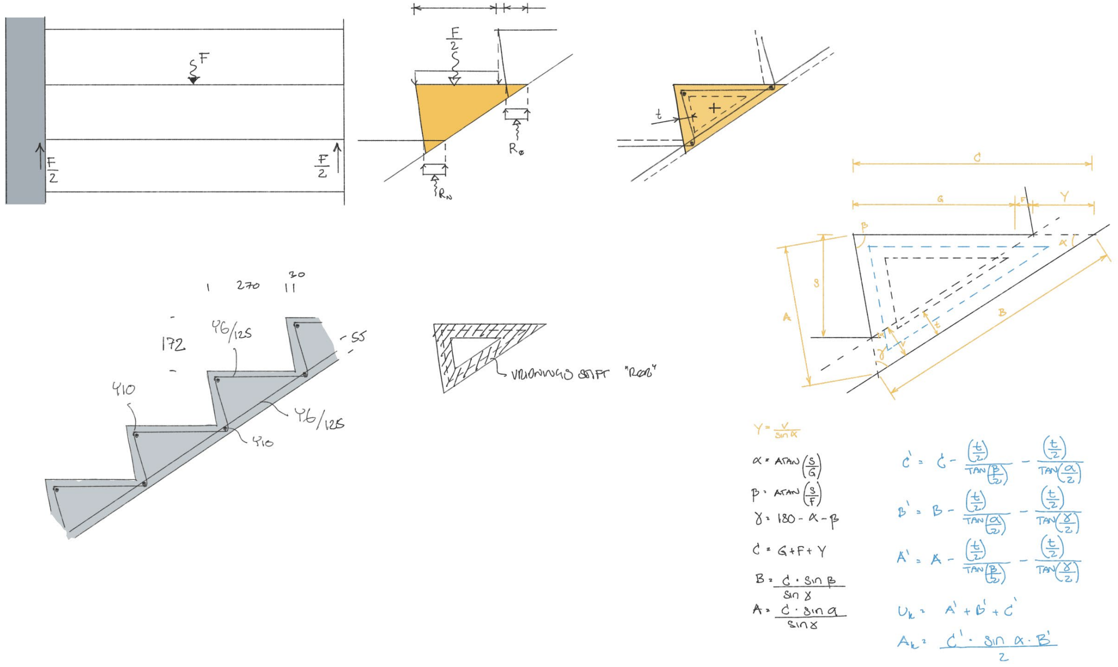


Fig 19. (Below left) Broken tread *(photo courtesy Russell Taylor)*
Fig 20. (Right) 3D model of new staircase at Corbalton Hall *(courtesy Helen Rogers)*
Fig 21. (Below) Construction of a new staircase



Trappeskitser

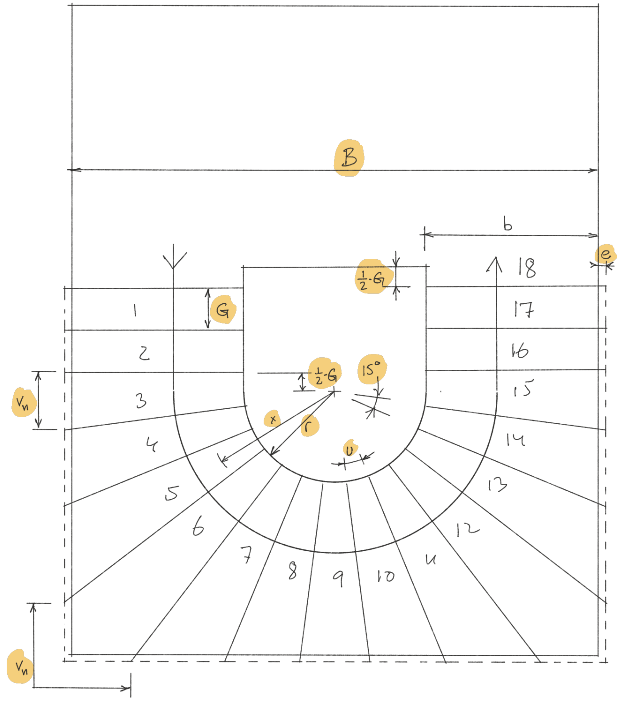




Udvikler og bevarer

Realdania Realdania By & Byg

Trappeskitser



$$S = \frac{2924}{18} = 162{,}4444$$

$B = 3335$ mm

$G = 270$ mm

$b = 1100$ mm

$e = 30$ mm

$$r = \frac{B}{2} - b$$

$$V_3 = V_{15} = \tan\left(\frac{15}{2}\right)\cdot(r+b+e) + \frac{G}{2}$$

$$V_4 = V_8 = V_{10} = V_{14} = \left(\tan\left(15+\frac{15}{2}\right) - \tan\left(\frac{15}{2}\right)\right)\cdot(r+b+e)$$

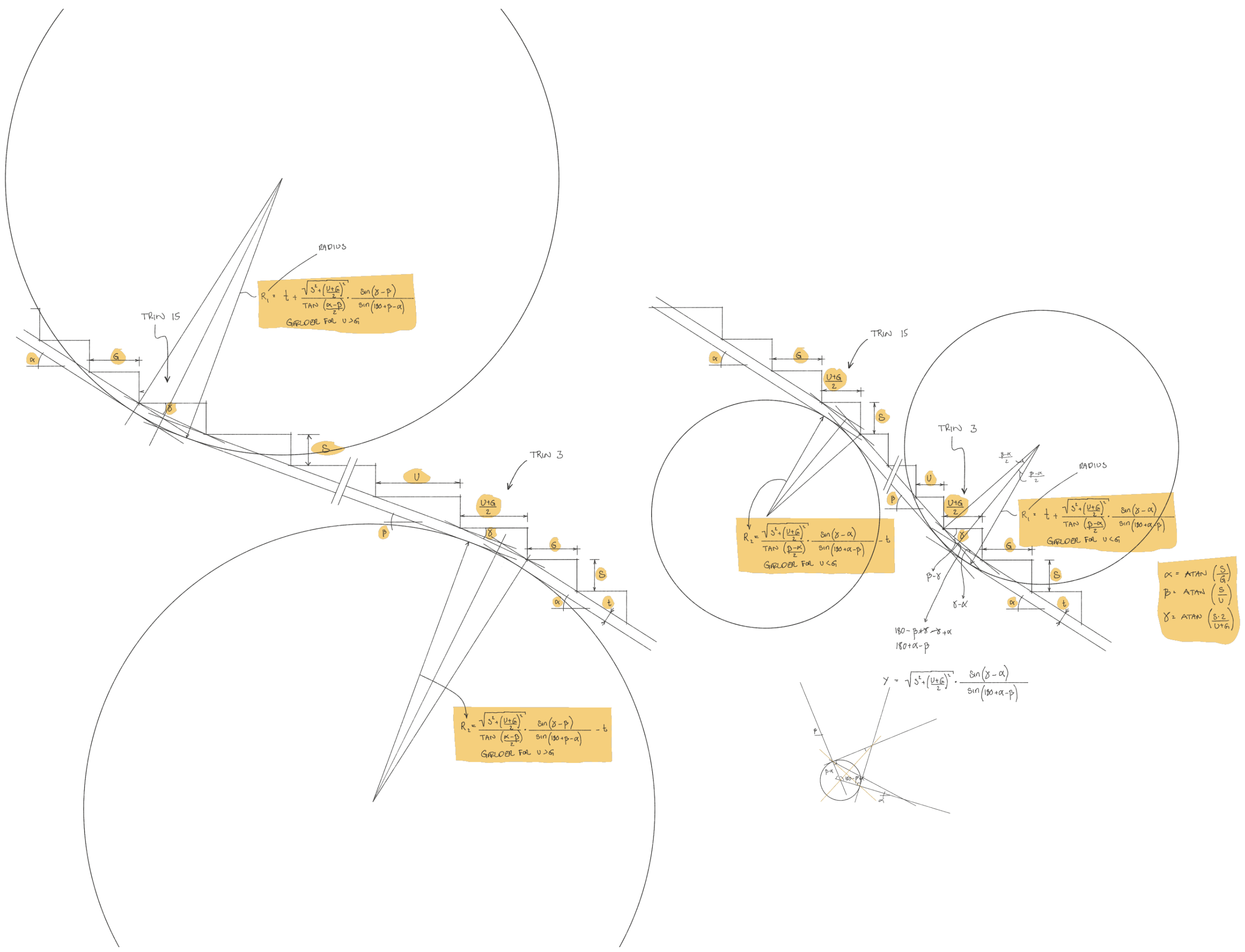
$$V_5 = V_7 = V_{11} = V_{13} = \left(\tan\left(30+\frac{15}{2}\right) - \tan\left(15+\frac{15}{2}\right)\right)\cdot(r+b+e)$$

$$V_6 = V_{12} = \left(\tan(45) - \tan\left(30+\frac{15}{2}\right)\right)\cdot(r+b+e)\cdot 2$$

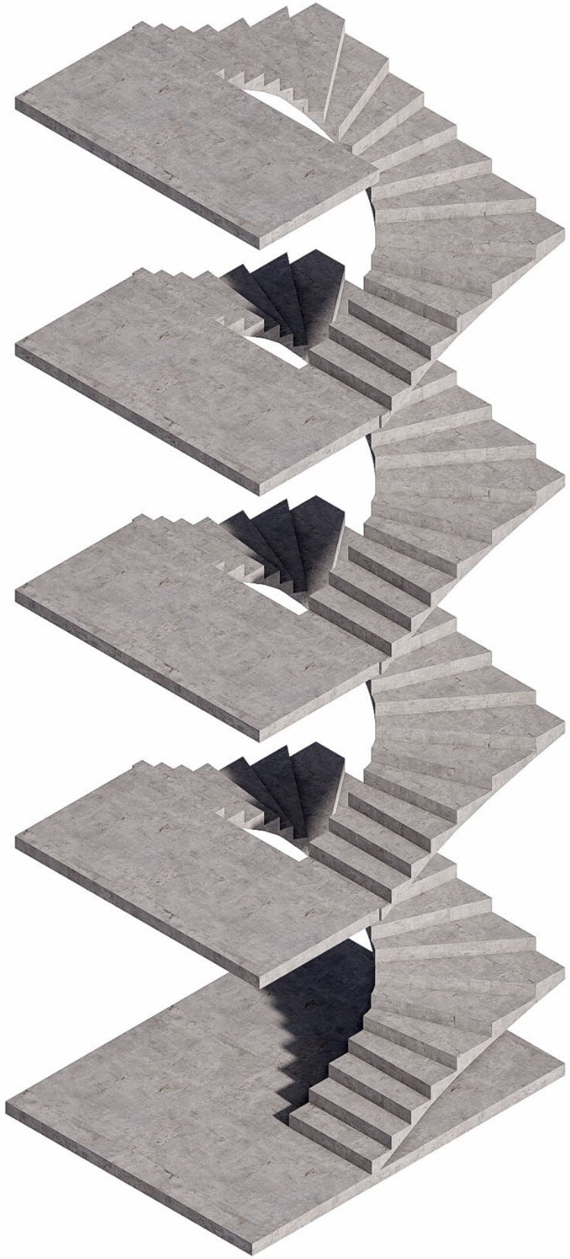
$$V_9 = \tan\left(\frac{15}{2}\right)\cdot(r+b+e)\cdot 2$$

$$U = \frac{\pi\cdot r}{180°}\cdot 15°$$

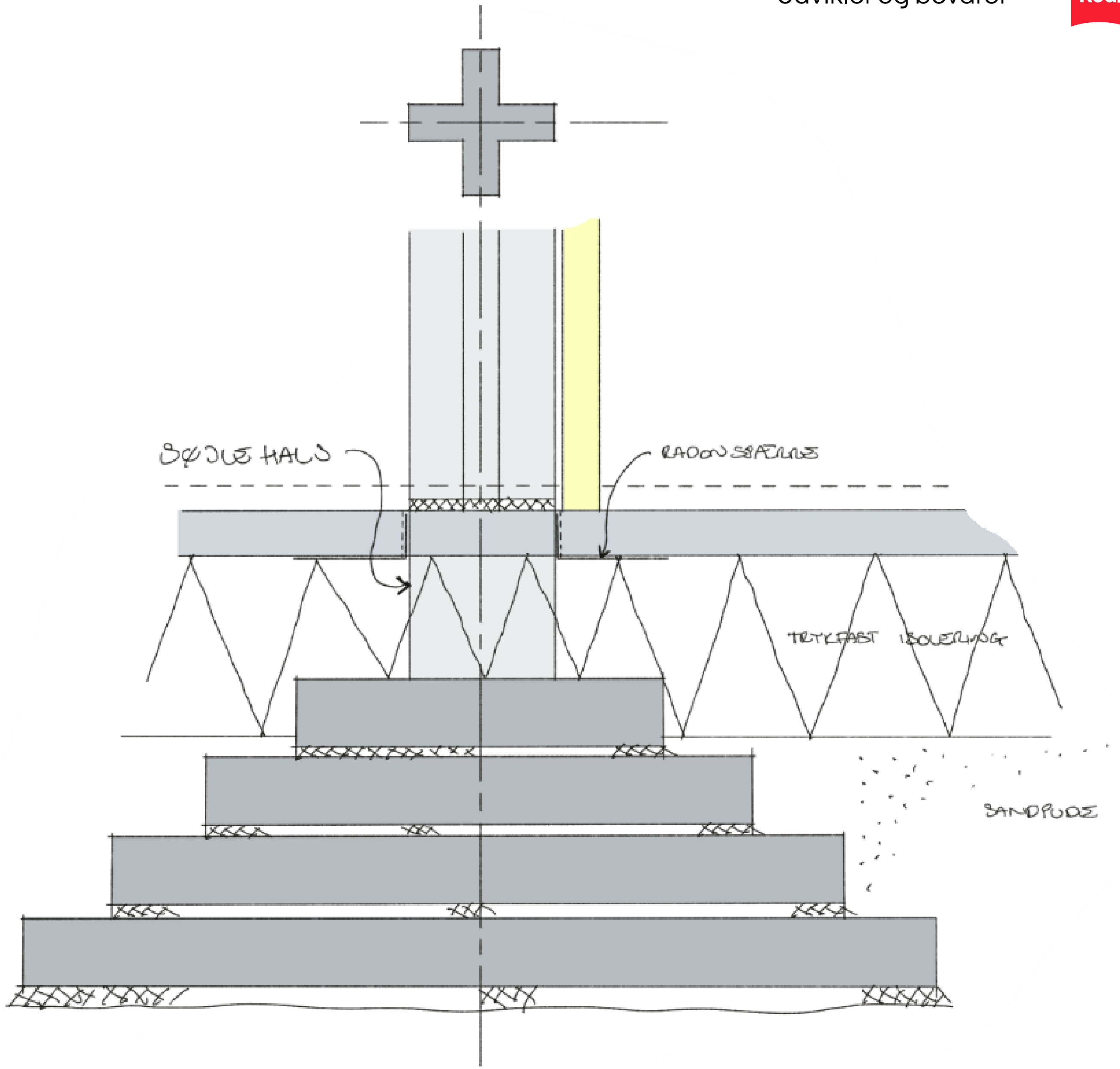
$$U(x) = \frac{\pi\cdot x}{180°}\cdot 15°$$



70% CO_2 reduktion sammenlignet med standart elementtrappe

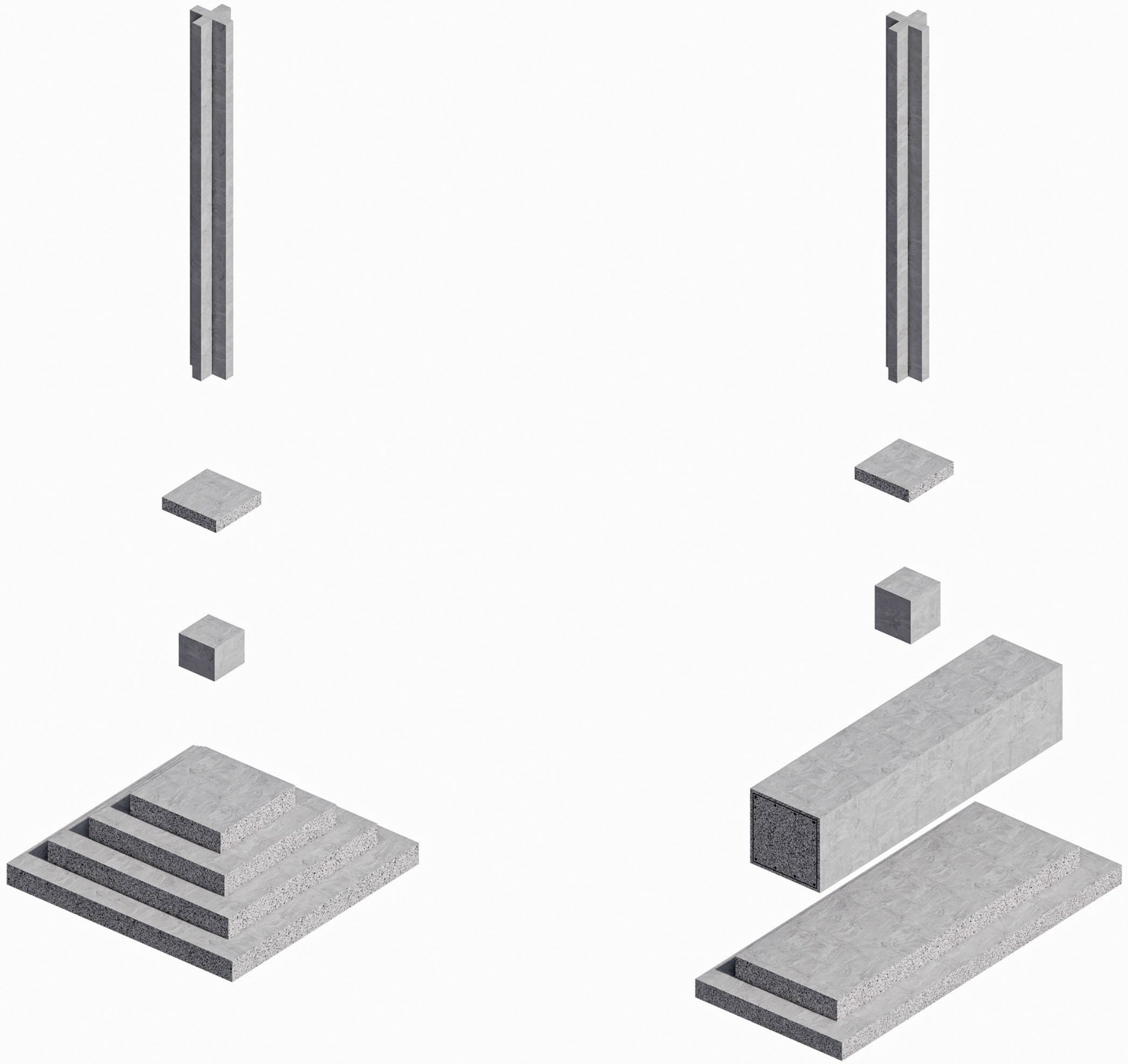


Fundamenter af genbrugte vægelementer



KONSTRUKTIONER

Fundamenter af genbrugte vægelementer



Realdania

Realdania By & Byg

DOBBELT BUNDLINJE KONSTRUKTIONER ARKITEKTUR

ARKITEKTUR

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ARKITEKTUR

Selvbærende, opmurede facader

Enkle bærelinjer

Biogen isolering

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ARKITEKTUR

Spolia

ARKITEKTUR

Betonsten af genbrugselementer i samarbejde med

KINGO

SLAATTO MORSBØL

BYGGESELSKABET CF HANSEN

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ARKITEKTUR

Vægelementer
Gellerupparken

Udvikler og bevarer

Realdania | Realdania By & Byg

Høst af elementer
November 2024

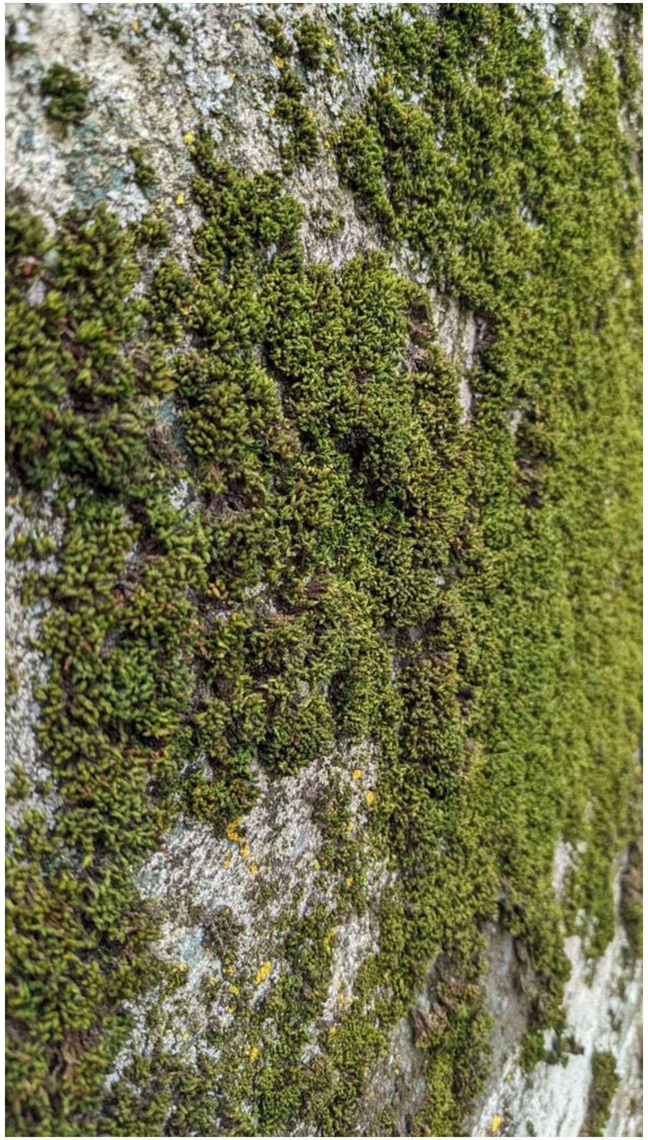
ARKITEKTUR

Spolia

ARKITEKTUR

Spolia

MOS



ARKITEKTUR

Begrønning

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ARKITEKTUR

Porebeton med diffusionsåben puds

Optimerede vinduesstørrelser

Passiv solaafskærmning

Passiv ventilation

Udnyttelse af termisk masse

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Indvendige vægge i pudset porebeton

Gulve i genbrugt bøgeparket fra Gellerup Parken

Døre og inventar i træ

Realdania

Realdania By & Byg

KOMMENDE PROCES

Ansøgning om byggetilladelse i december

Dialogfase under Udførelsesprojekt

Bo Michelsen valgt som hovedentreprenør

Realdania

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