



Design Examples

October 2021

Introduction

the following design examples show case the out comes of using 3dcp., all of these buildings are easily “printable” with the machines provided by COBOD International A/S.

Thereby, these examples acts as a reference for architects, designers, engineers or anyone who is interested in knowing the possibilities of the technology.

These designs can be used as a reference for cost comparison, an over all estimation can not be accurate, for some extended the first couple of projects would cost more, with time and experience the process of 3d printing will be optimized locally in your country and will drop the cost.



2 story building by Kamp c - Belgium

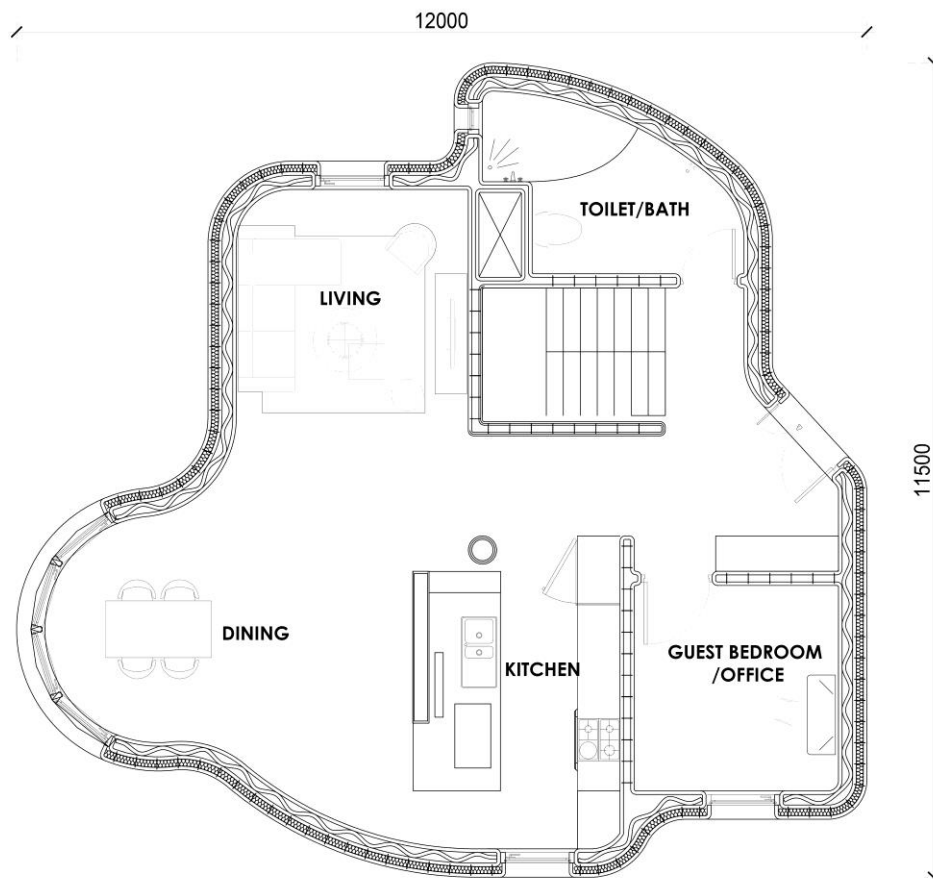
Design 1 – Organic design house

Exterior Perspectives

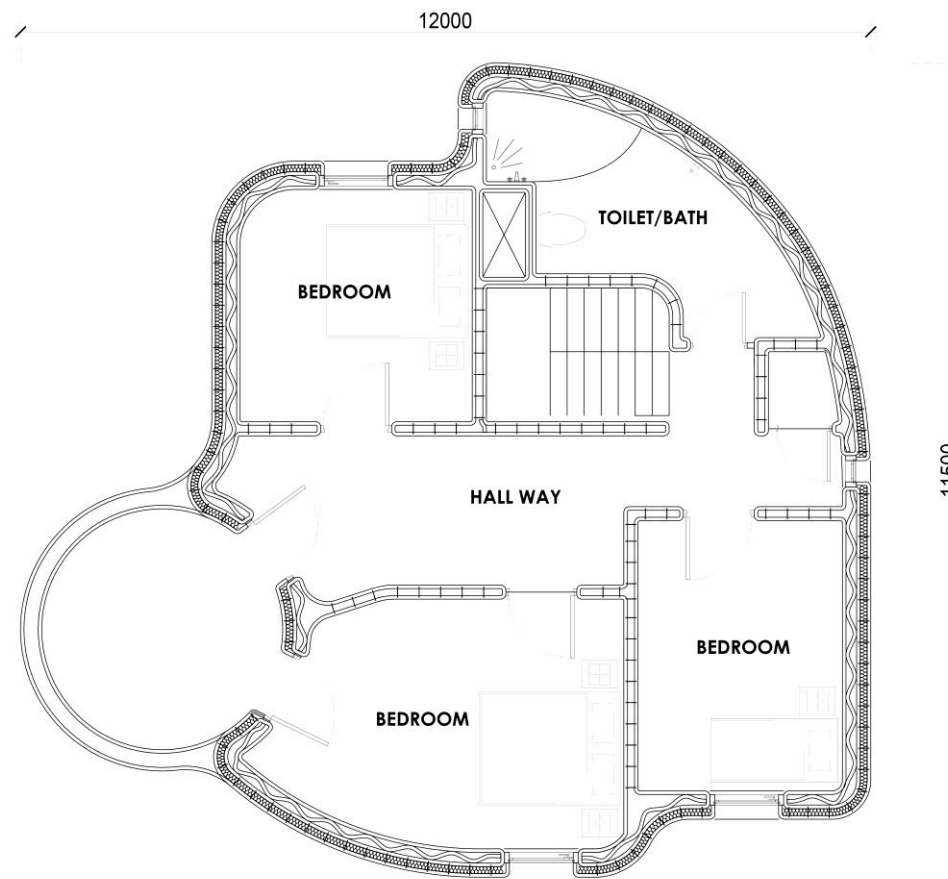


Design 1 – Organic design house

Plan layout



GROUND FLOOR PLAN
AREA 97.3 SQM



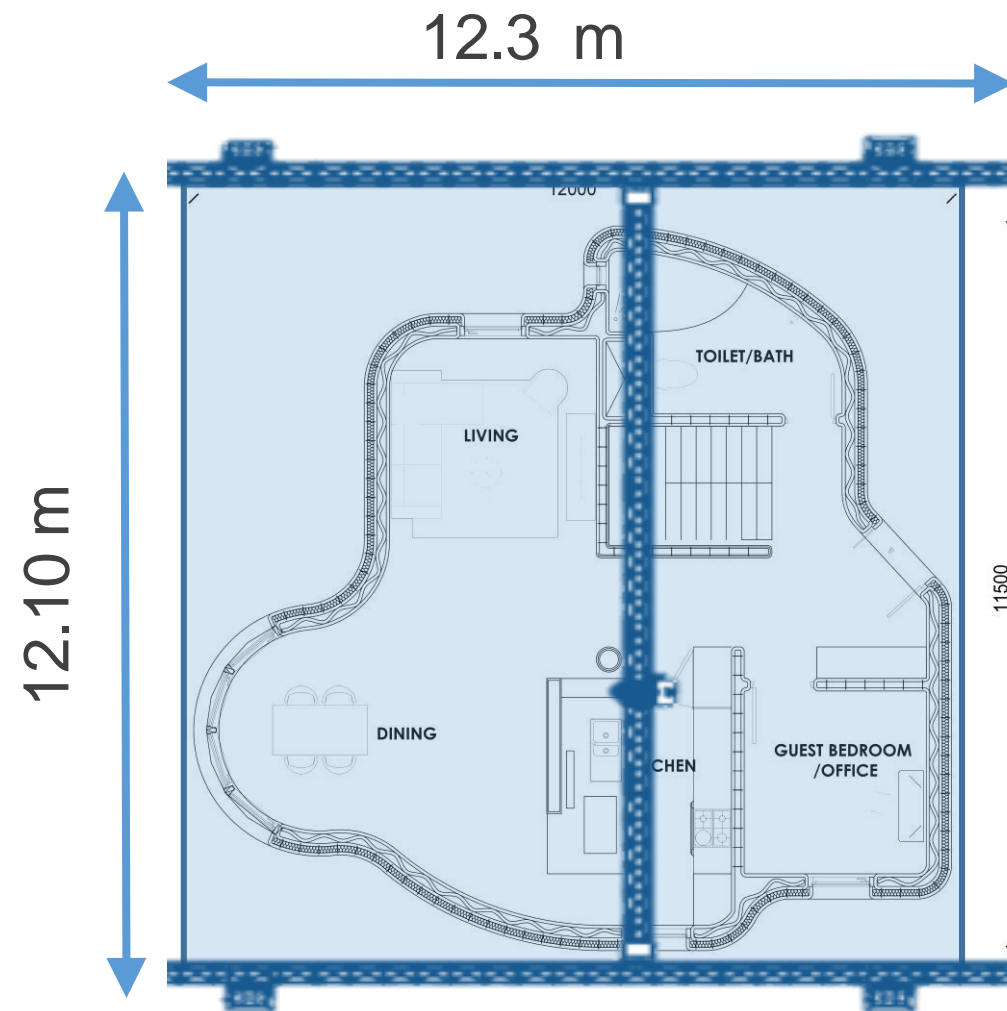
FIRST FLOOR PLAN
AREA 89 SQM

Design 1 – Organic design house

General info

Building dimensions	width: 12 m length: 11.5 m
Ground floor area	≈ 97.3 m ²
First floor area	≈ 89 m ²
Total area	≈ 189.3 m ²

BOD 2 model	5-5-4
Printable area	12.10 x 12.4 x 8.14 m
	146.77 m ² up to 3 floors

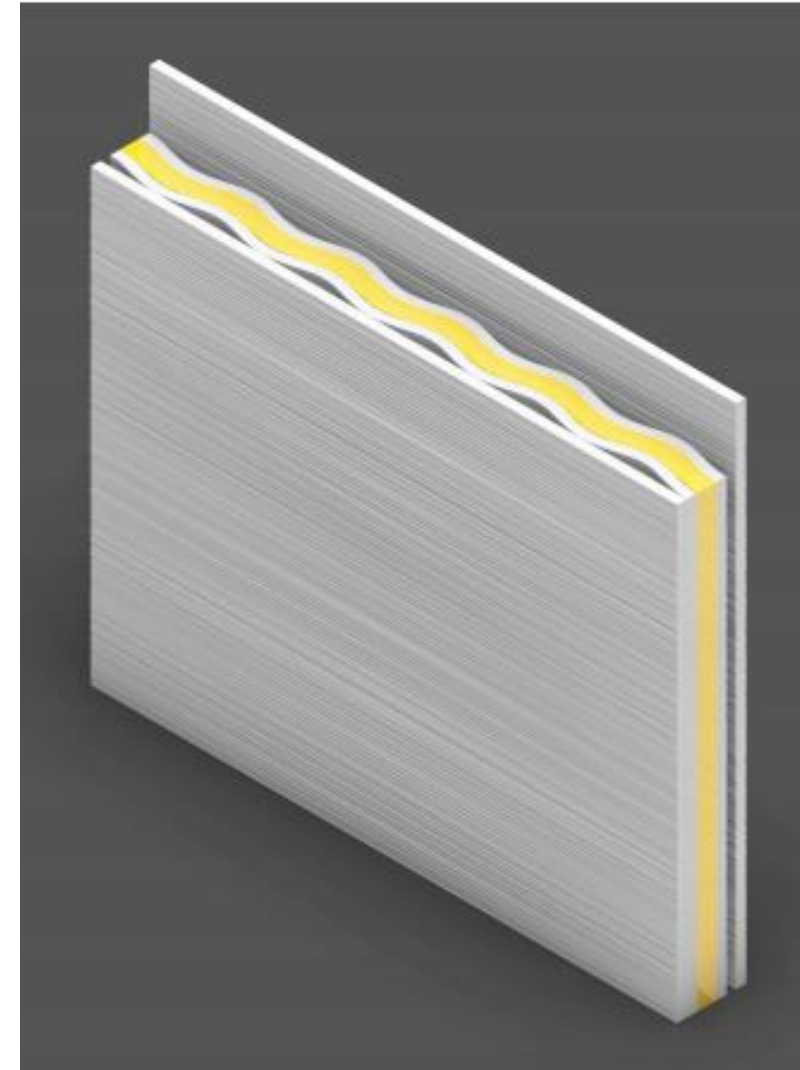
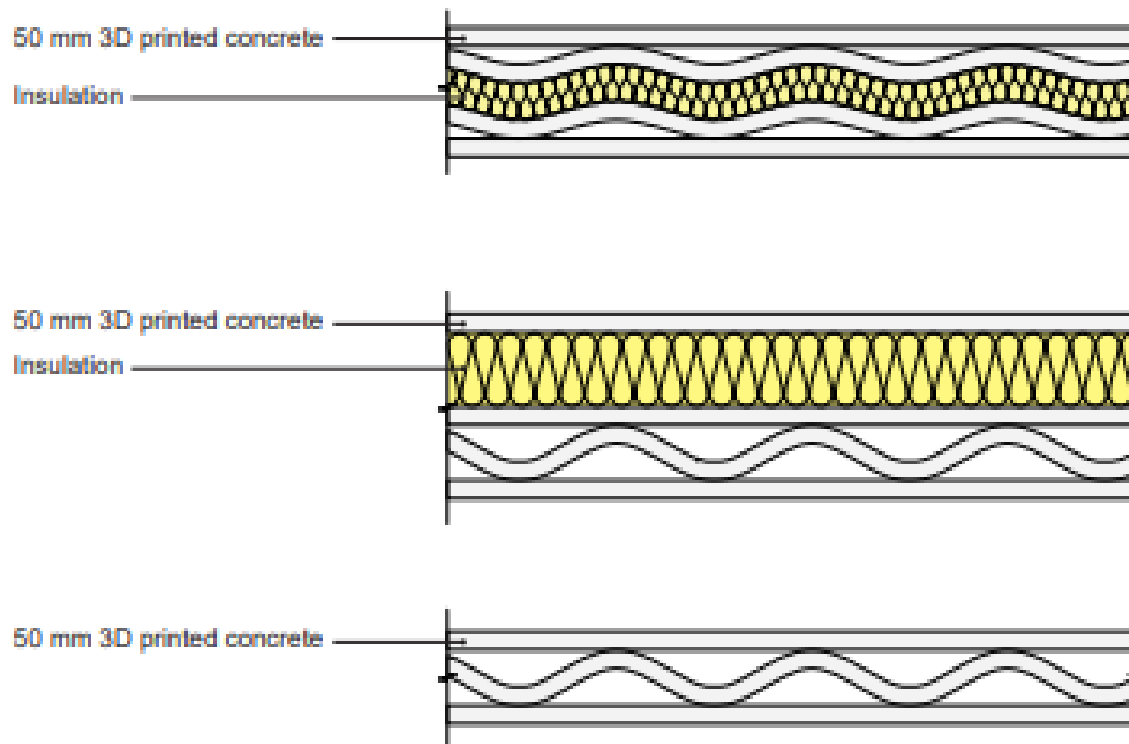


BOD-2 5-5-4

Design 1 – Organic design house

Wall detail and structural system

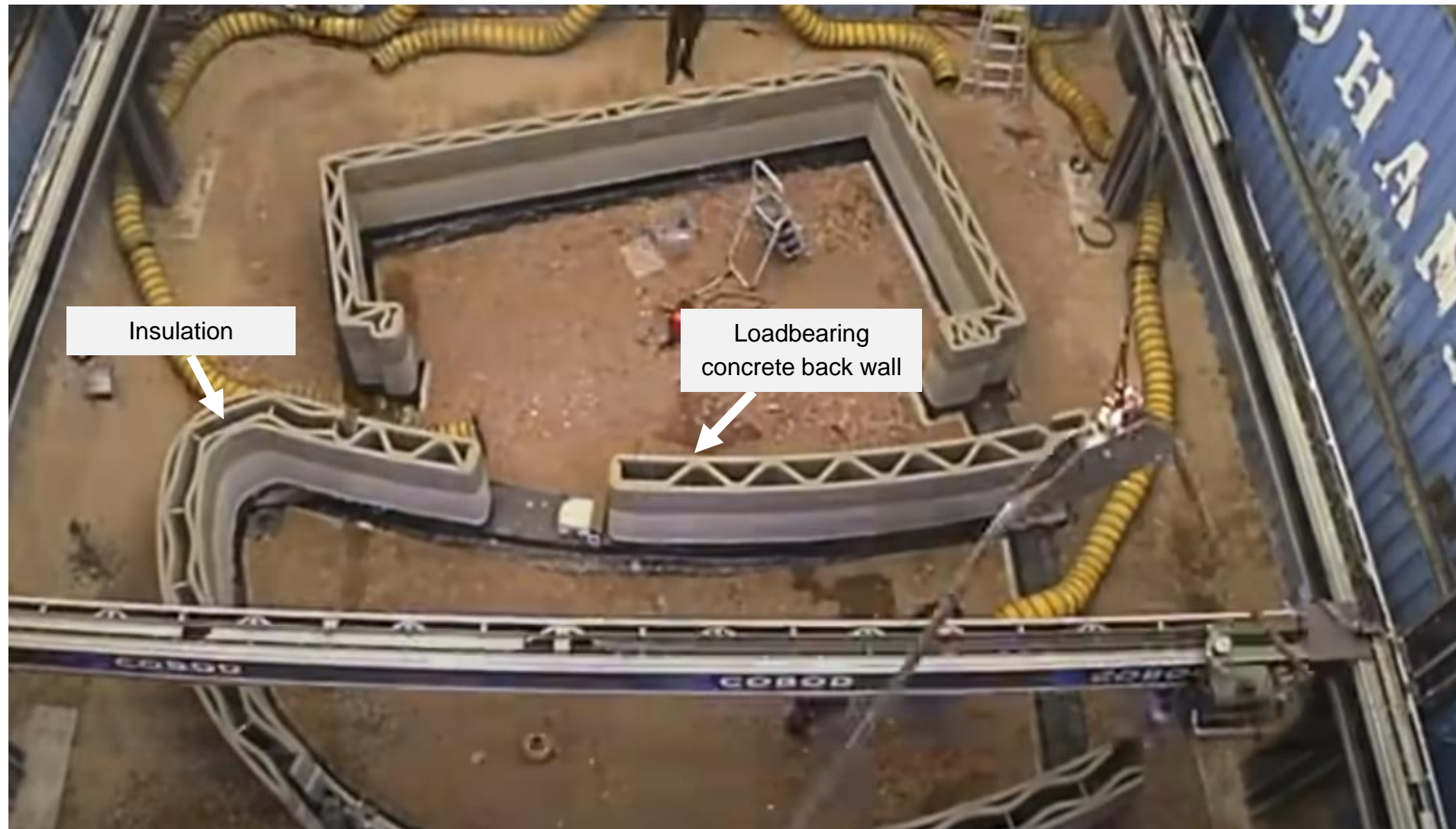
“Snake wall” Creating internal curvy wall sections acting as structural elements. Three variations are illustrated, showcasing different ways of creating this type of wall.



Design 1 – Organic design house

Wall detail and structural system

In the following, picture showcase the use of “Snake wall” Creating internal curvy wall sections acting as structural elements. Two story building by Kamp C – Belgium



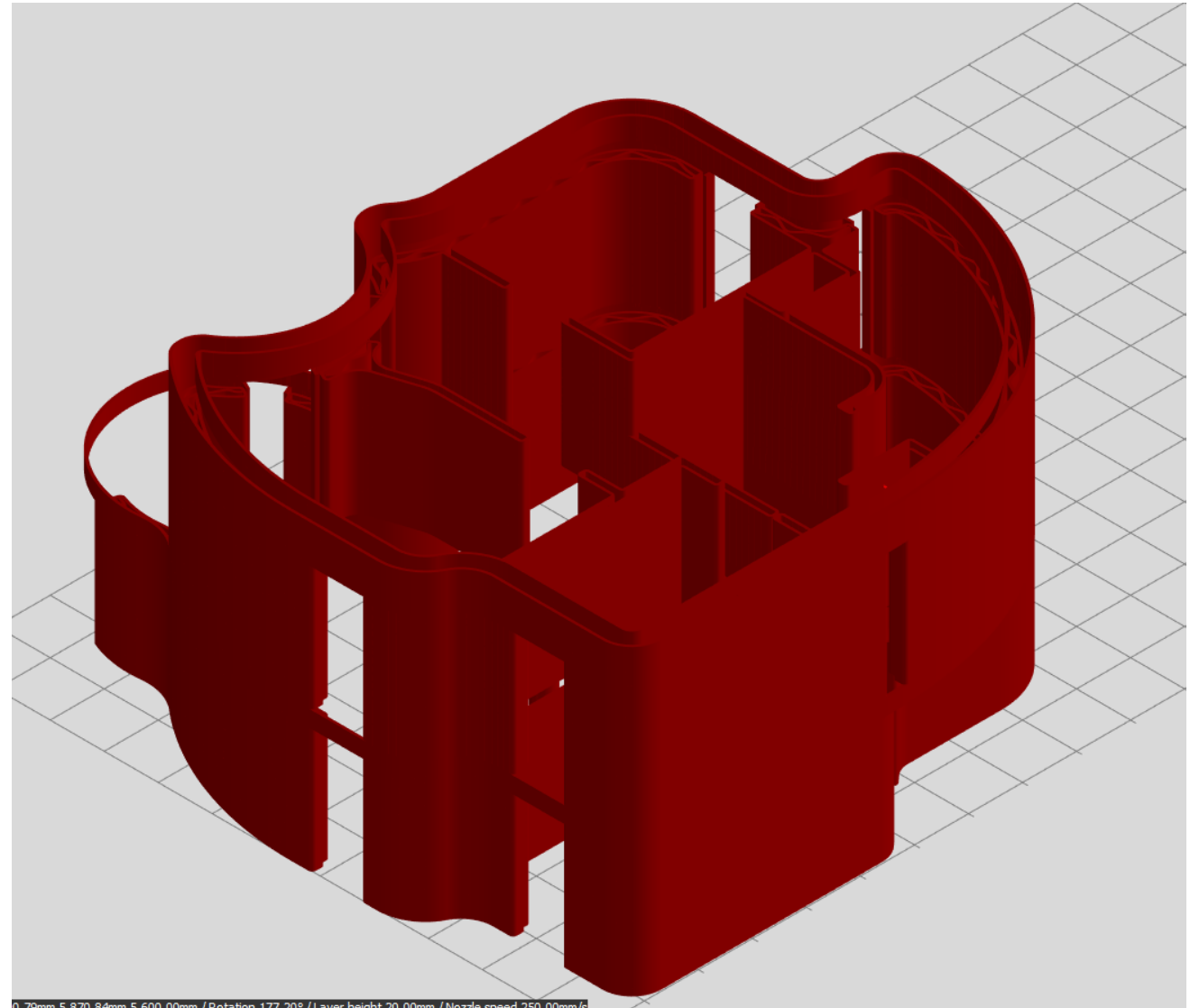
Printing time and materials consumption

Printing time		
Estimated printing time at 25 cm/sek	30 % safety factor added	In total
63 hours	≈ 18.9 hours	81.9 hours

The calculated printing times do not include installation time for the 3D printer, just as they do not include the time needed to start the print and cleaning time after each day. Usually it is 30 minutes in the beginning of the day and 30 minutes after finishing printing.

Material consumption		
Estimated volume	10 % waste factor added	In total
40.5 m ³	≈ 4.05 m ³	44.55 m³

These calculations were based on using a Snake print wall with 50 mm thickness for each, allowing for installation of electrical features, insulation etc. between the walls.



Screenshot from COBOD Slice

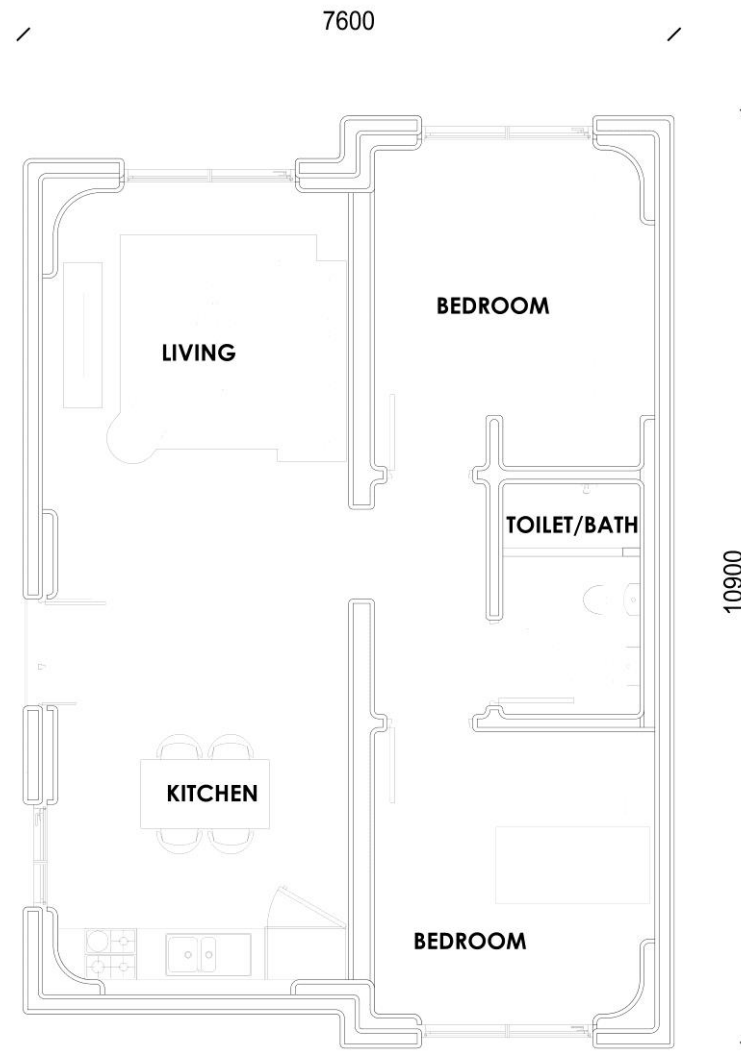
Design 2 – Single story house

Exterior Perspectives



Design 2 – Single story house

Plan layout



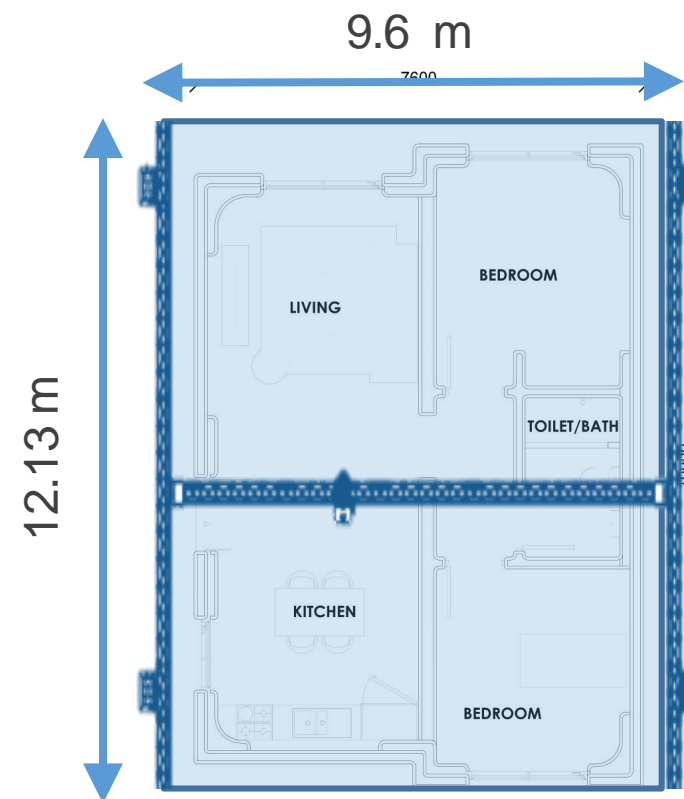
AREA 76 SQM

Design 2 – Single story house

General info

Building dimensions	width: 7.6 m length: 10.9 m
Total area	≈ 76 m ²

BOD 2 model	4-5-3
Printable area	9.6 x 12.13 x 5.6 m
	116 m ² up to 2 floors



AREA 76 SQM

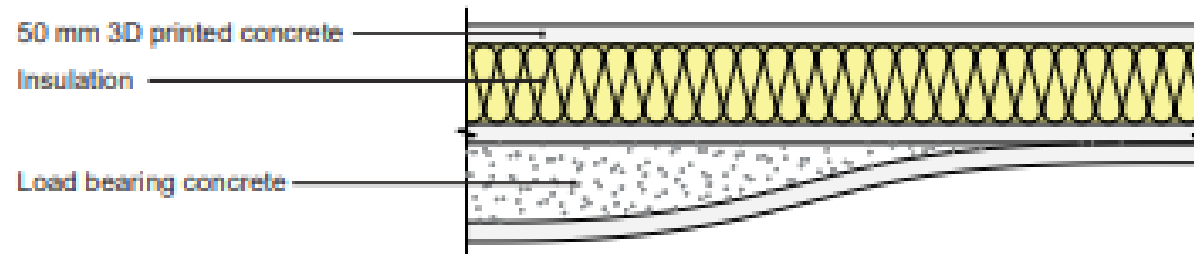
BOD-2 4-5-3

Design 2 – Single story house

Wall detail and structural system

“bespoke” Loadbearing concrete back wall with parallel insulation layer.

Insulation layer
with loadbearing wall sections in selected areas.



Design 2 – Single story house

Wall detail and structural system

In the following, picture showcase the use of “bespoke” Loadbearing concrete back wall with parallel insulation layer. Beckum Building by Peri – Germany



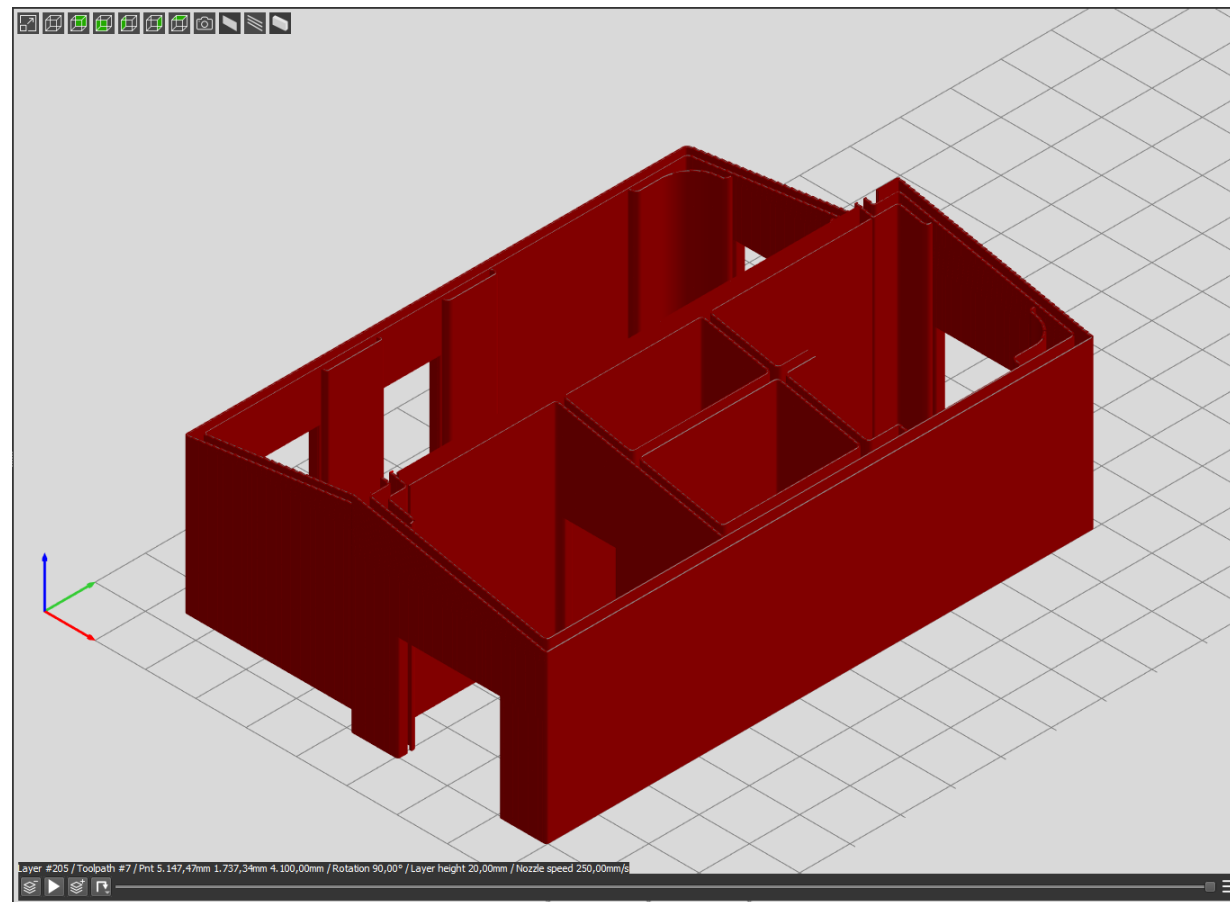
Printing time and materials consumption

Printing time		
Estimated printing time at 25 cm/sek	30 % safety factor added	In total
36 hours	≈ 10.8 hours	46.8 hours

The calculated printing times do not include installation time for the 3D printer, just as they do not include the time needed to start the print and cleaning time after each day. Usually it is 30 minutes in the beginning of the day and 30 minutes after finishing printing.

Material consumption		
Estimated volume	10 % waste factor added	In total
19 m ³	≈ 1.9 m ³	20.9 m³

These calculations were based on bespoke print wall with 50 mm thickness for each, allowing for installation of electrical features, insulation etc. between the walls.



Screenshot from COBOD Slice

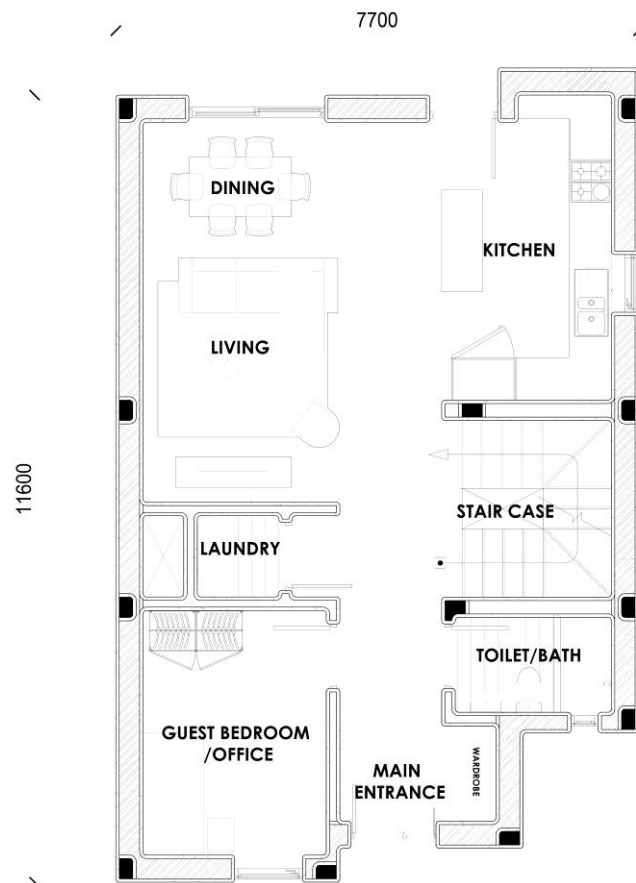
Design 3 – Row houses

Exterior Perspectives

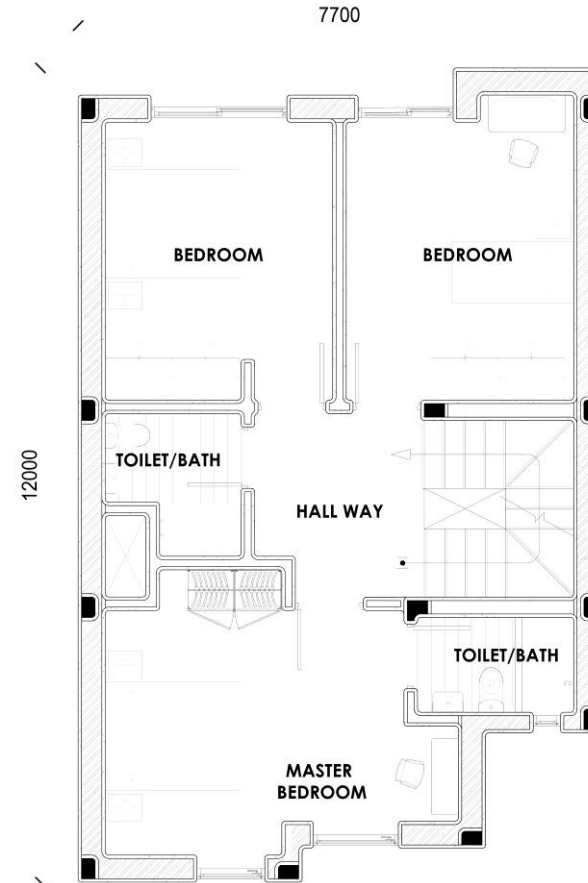


Design 3 – Row houses

Plan Layout



GROUND FLOOR PLAN
AREA 82 SQM



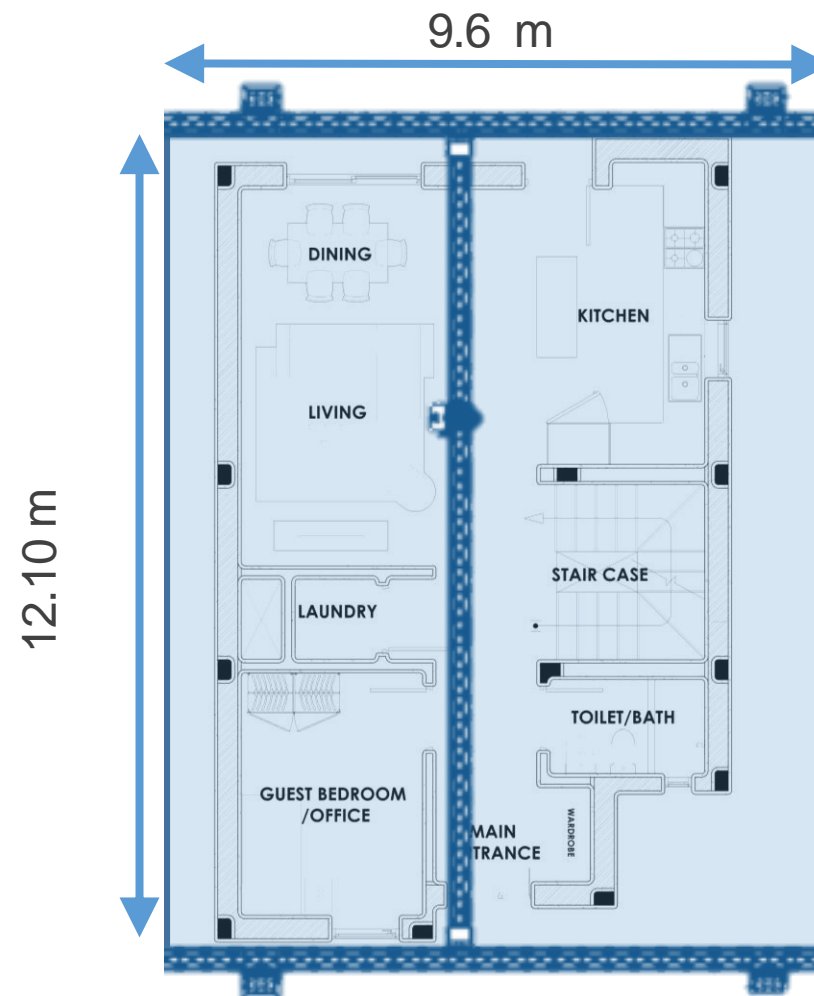
FIRST FLOOR PLAN
AREA 82 SQM

Design 3 – row house (1 unit)

General info

Building dimensions	width: 7.6 m length: 11.6 m
Ground floor	≈ 82 m ²
First floor	≈ 82 m ²
Total	≈ 164 m ²

BOD 2 model	5-4-4
Printable area	12.10 x 9.6 x 8.2 m
	116 m ² up to 3 floors Total 348



BOD-2 5-4-4

Design 3 – row house (2 unit)

General info

Building dimensions	width: 15 m length: 11.6 m
Ground floor	≈ 164 m ²
First floor	≈ 164 m ²
Total	≈ 328 m ²

BOD 2 model	5-7-4
Printable area	12.10 x 17.6 x 8.2 m
	207.88 m ² up to 3 floors Total of 623.4



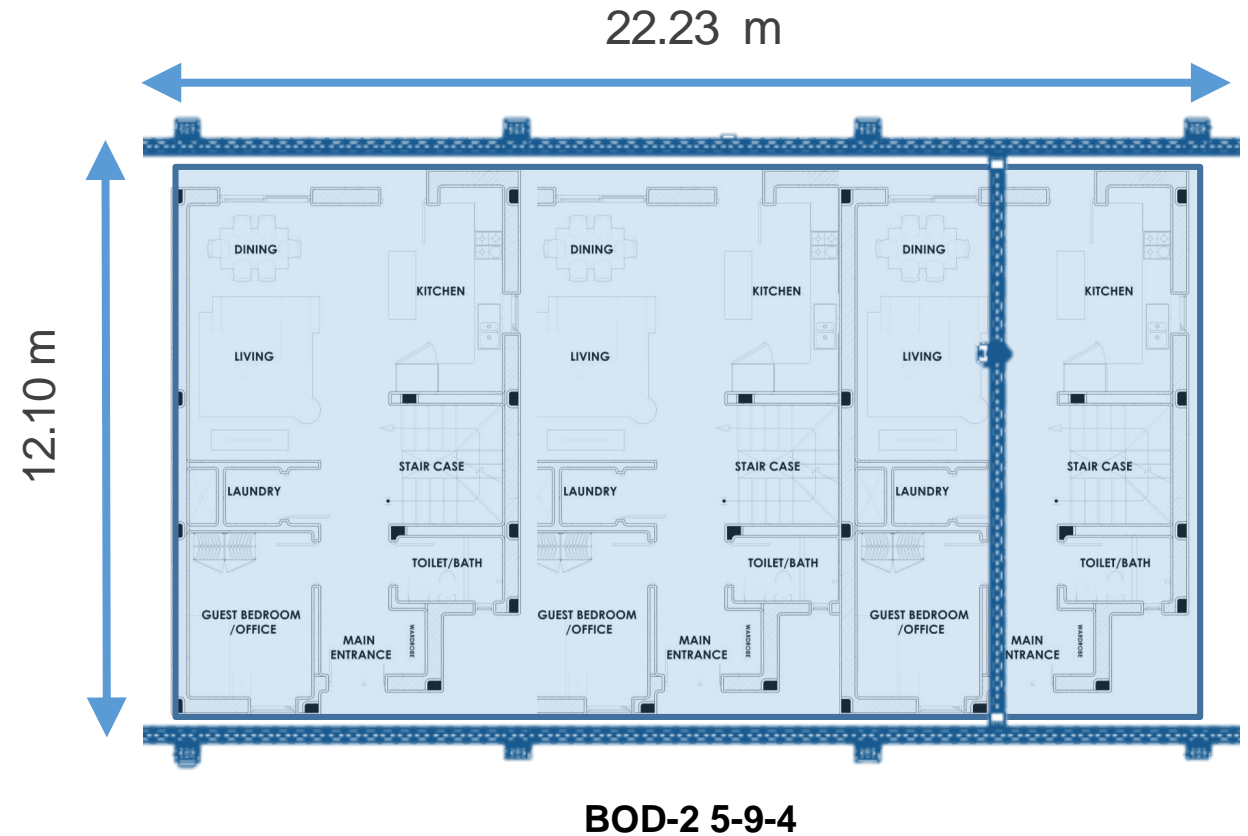
BOD-2 5-7-4

Design 3 – row house (3 unit)

General info

Building dimensions	width: 14.6 m length: 22.2 m
Ground floor	≈ 264 m ²
First floor	≈ 264 m ²
Total	≈ 492 m ²

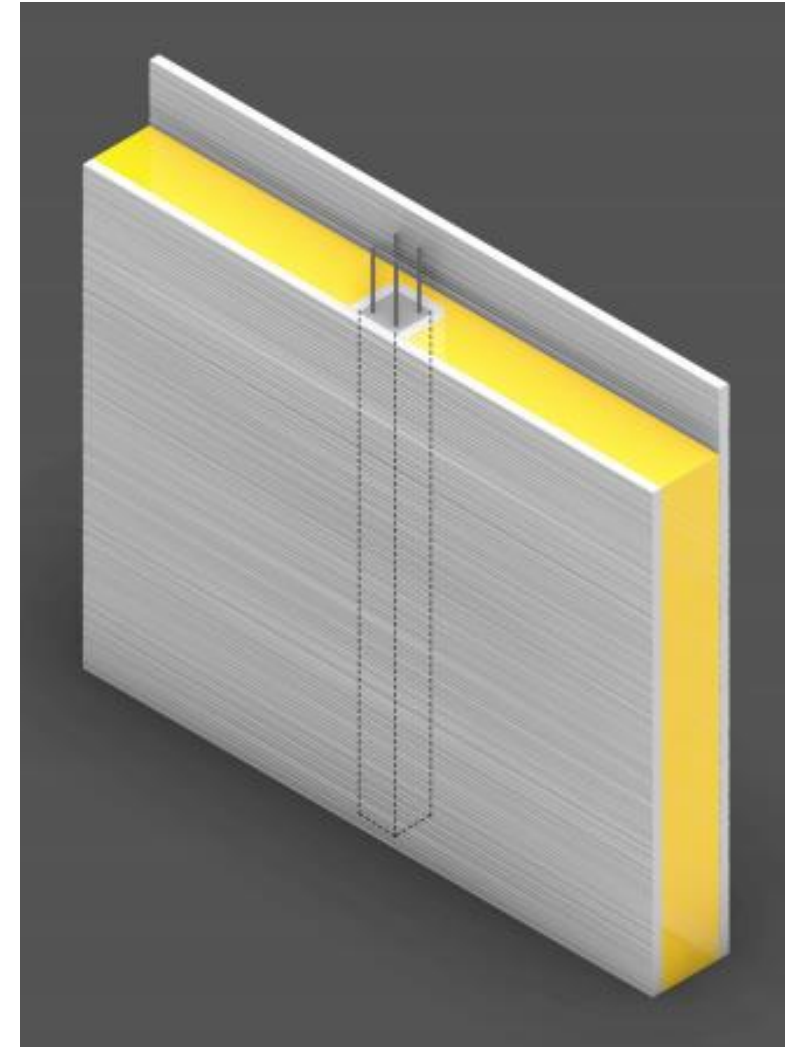
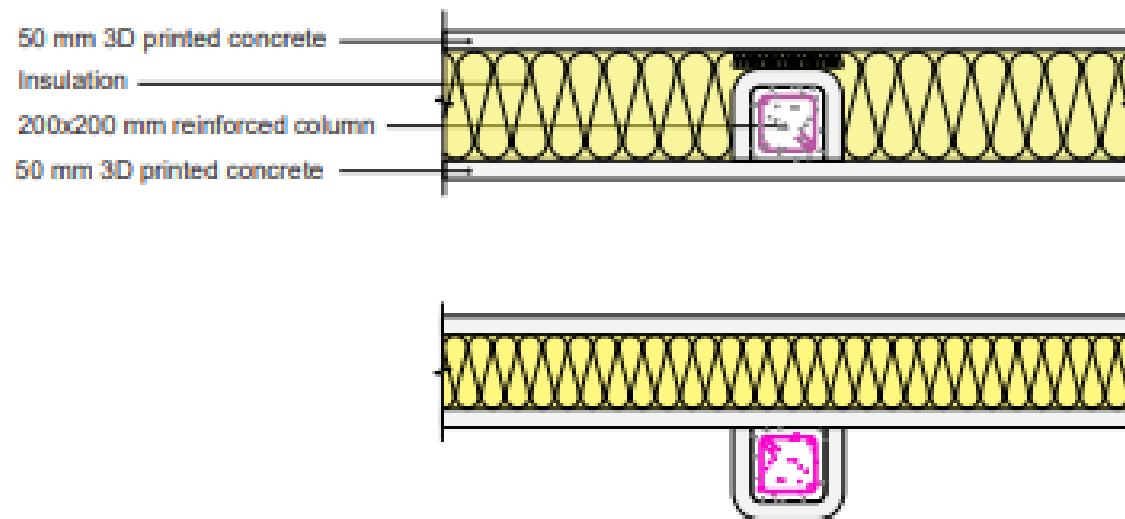
BOD 2 model	5-9-4
Printable area	12.10 x 22.23 x 8.2 m
	269 m ² up to 3 floors Total of 806



Design 3 – Row houses

Wall detail and structural system

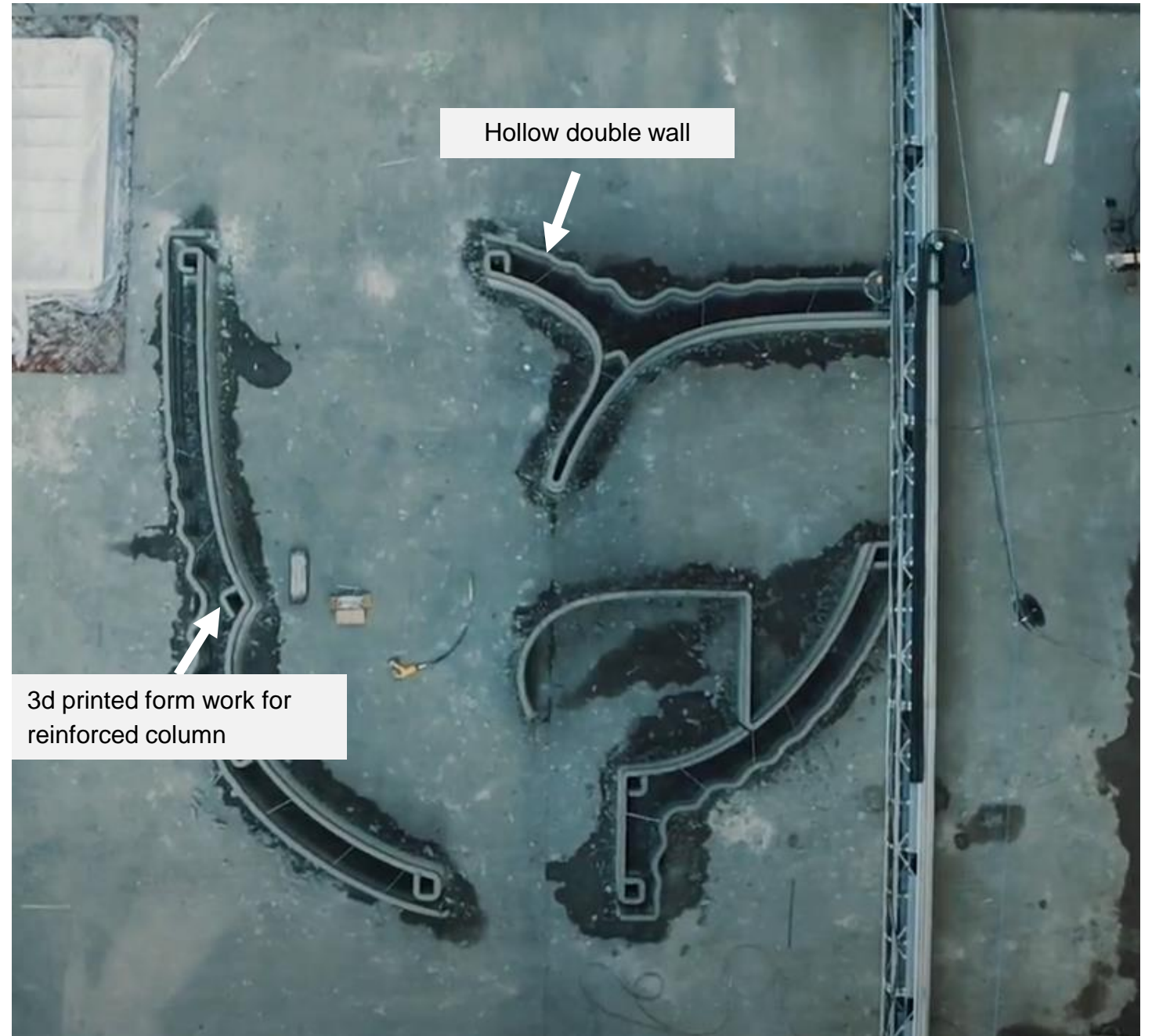
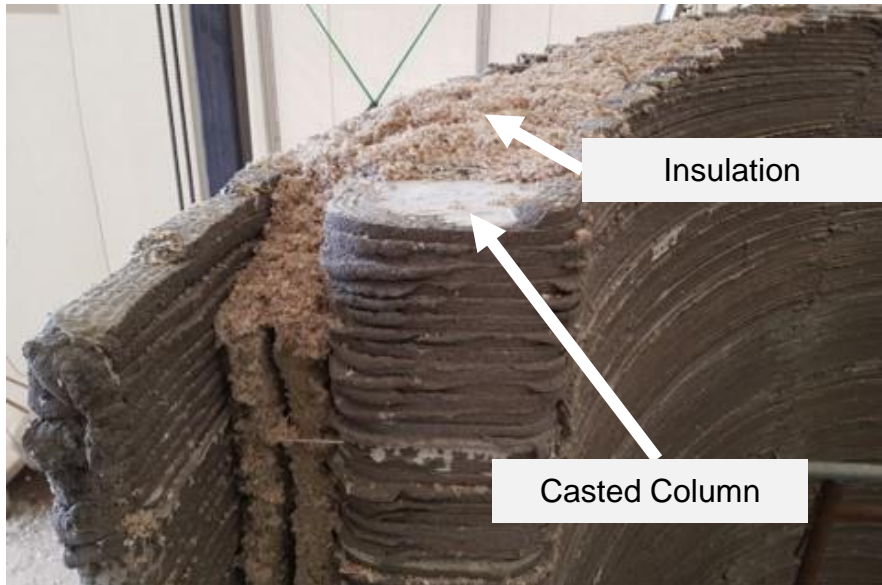
Hollow wall with integrated columns The integration of columns makes it possible to apply load calculations based on column placement (easy to get approved by local authorities, since the columns acts as load bearing traditional elements)



Design 3 – Row houses

Wall detail and structural system

In the following, picture showcase the use of the hollow wall with integrated wall detail and structural system in the BOD building – Denmark Copenhagen



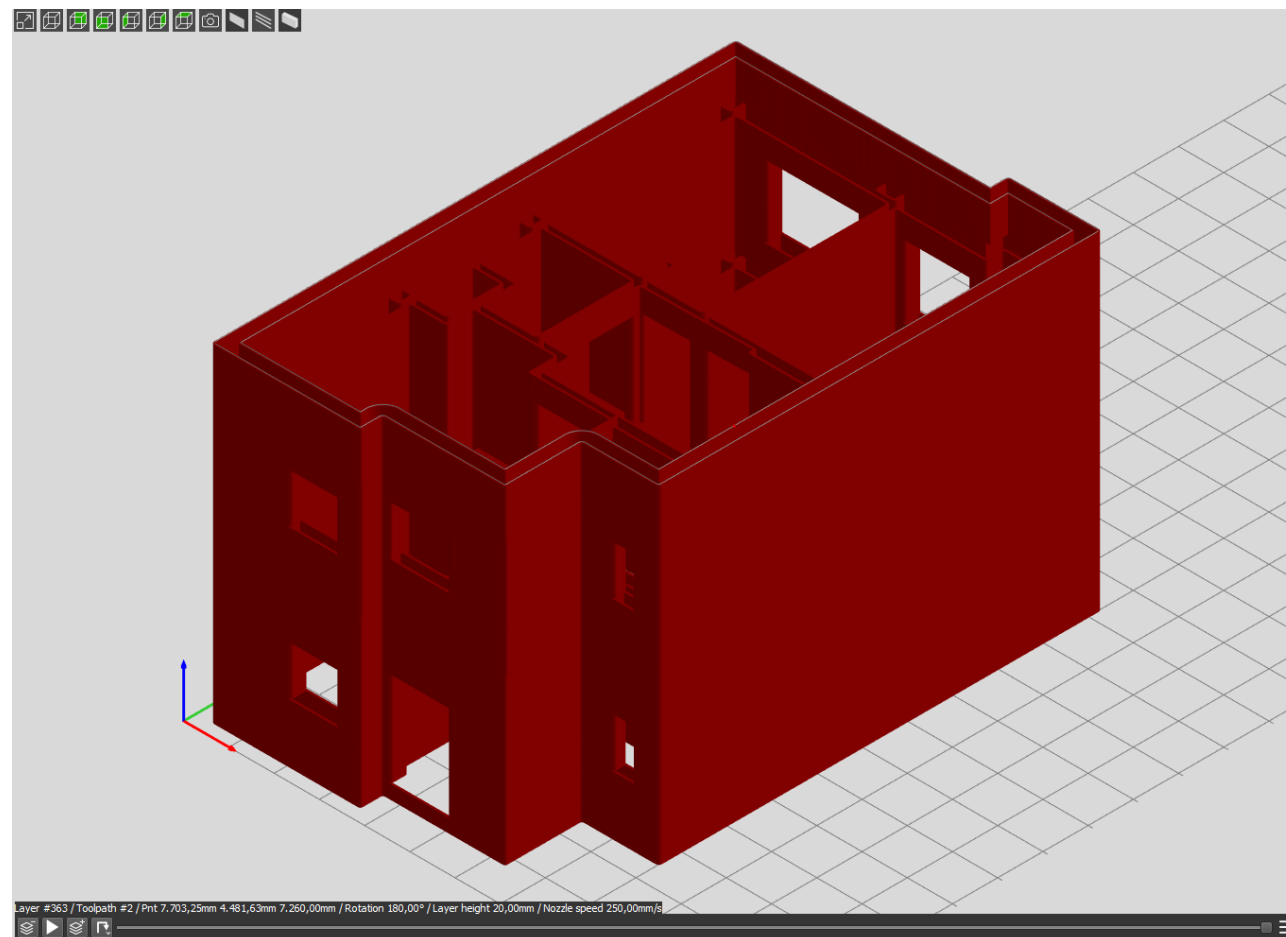
Printing time and materials consumption

Printing time		
Estimated printing time at 25 cm/sek	30 % safety factor added	In total
66 hours	≈ 6.6 hours	72.6 hours

The calculated printing times do not include installation time for the 3D printer, just as they do not include the time needed to start the print and cleaning time after each day. Usually it is 30 minutes in the beginning of the day and 30 minutes after finishing printing.

Material consumption		
Estimated volume	10 % waste factor added	In total
36.3 m ³	≈ 3.62 m ³	39.92 m³

These calculations were based on double wall print with 50 mm thickness for each, allowing for installation of electrical features, insulation etc. between the walls. And housing loading bearing columns.



Screenshot from COBOD Slice

Guide to cost calculation

The following is a basic guide to help grasp the costing process for 3d printed structure.

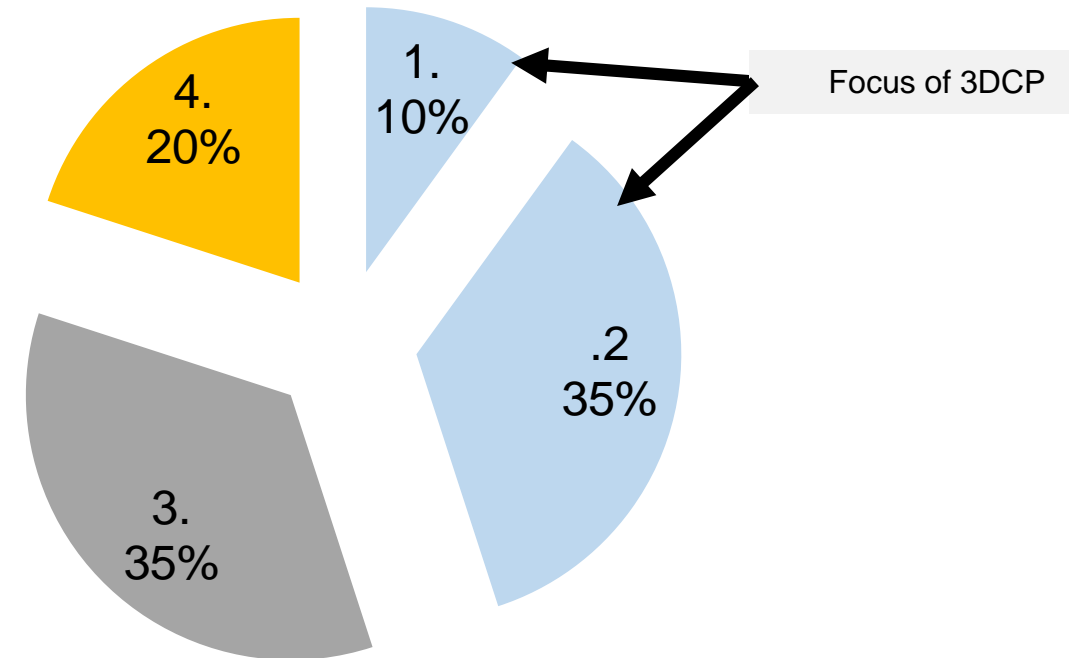
The cost estimates depends on these main points:

- 1- Type of 3d printed walls, as explained previously in the examples. As it will affect the materials consumption.
- 2- Design decisions. Keeping the 3d printed walls as is, or plastering and smoothing the walls.
- 3- The level of finishing.
- 4- structural systems (reinforcement in columns, foundations and slabs)

General acknowledgment for cost calculation.

- 3DCP do not print the whole building, it contributes to 30 - 40% of a building components.
- Cost savings in not exclusive in materials, saving take place in less man hours spend on non-3d printed elements (like plumbing, electrical wiring and foundations) as the use of the printer can facilitate and save time for these jobs.
- Cobod international A/S provides 3d printing materials solutions, by using locally sourced materials, in addition to 1-3 % special additives to make 3d printed concrete. (d-fab solution).
- Cost calculation is affected by design decision, for example the architects decision of keeping the 3d printed walls textured as is, or plastering and smoothing the 3d printed walls.

Allocation of total building cost



- 1: Foundation/slab etc.
 - 2: Raw house structure (walls, roof, floor) Focus of 3DCP
 - 3: Finishings/surfaces (doors, windows, insulation, painting, tiles, ceiling)
 - 4: Other like electricity, heating, plumbing etc.
- Note: these percentages differ according to local standards and construction methods.

Materials choice

1. Ready mix dry mix 3DCP mortars

- ▶ Recommendable for small prints/quantities
- ▶ Comes in 25 kg bags, you just need to mix water in
- ▶ Very easy and convenient; easy mixing, storage, stock maintenance etc.
- ▶ Very expensive (due to requirement for drying aggregates)
- ▶ Mixer and pump in one solution (M-tec), lower investment cost



Ready mix dry mix mixer & pump

2. 3D printable concrete

- ▶ Recommendable for large prints/industrial application
- ▶ Mix whole recipe on site based on cement, sand, gravel and additives.
- ▶ Concrete with the strenght that you would like to have
- ▶ More complex, but much, much cheaper – comparable to ordinary concrete.
- ▶ Requires real concrete mixing plant (mini batch plant) and concrete pump; higher investment cost



Concrete mini batch plant (mixer)

Concrete pump

Calculations for Dfab solution: Make 3D printable concrete based on locally sourced materials

**Cement and aggregates are sourced locally.
 Special Dfab additives (make up 1% of the recipe).
 These can be sourced from COBOD
 Recipe mixed with Cobod batch plant.**

Base recipe:

- 450 kg of CEM2 cement
- 780 kg of sand (0-2mm) - Sourced locally according to what is available
- 880 kg of gravel (2-8 mm) – Sourced locally according to what is available. Maximum gravel size is 10 mm with the use of 100 mm hose)
- 200 liters of water
- Density: 2,31 tons/m3 . Compression strength: 30-35 Mpa . Water/cement ratio. 0.44

In addition, the Dfab additives.

Depending on the specific local temperature and humidity, more or less of these additives will be needed,
 The recipe will be adjusted once on site.

Estimated Cost of 1 m3 of 3d printed concrete =
 Cost of Component + Cost of addtives
 (sum of total table A + Sum of total table B

Table A: Estimated cost of componantes1 m3 of 3d pritned concrete.

Component name	Quantity needed	Euro/KG	Total Euro ex. Works
CEM2 cement	450 kg	-	-
Sand (0-2mm)	780 kg	-	-
Gravel/ Aggregate	880 kg	-	-
Water	200 kg	-	-
Total	2310 kg		-

Table B: Estimated cost price of Dfab additives for making 1 m3 of concrete, excluding shipping and works

Additive name	Additive type	Quantity needed	Euro/KG	Total Euro ex. Works
β 1.00	Stiffener	1.5 kg	1.03	1.55 €
α 1.00	Superplasticiser	5.0 kg	1.43	7.15 €
Isoxel 545	Accelerator	2.3 kg	1.63	3.64 €
Isoxel 899	Accelerator	2.3 kg	2.03	4.57 €
Total		11 kg		16.93 €