

## **Calculations**

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### **Case 1 Use 3D printer to only construct walls**

#### **Building assumptions**

Total area of exterior wall (length of wall\*height)  
 $20*5=100\text{m}^2$

Total area of interior wall (length of wall\*height)  
 $100\text{m}^2$  (this can vary but its a good estimation)

#### **Printing**

Wall thickness (cm) i.e width of each print layer  
5 (5 cm is a good estimate as per research)

Layer height(cm)  
2 (2cm is a good estimate as per research)

Print speed(cm/s)  
30 cm/s (research shows print speeds can vary from 10-100cm/s. The variation is due to nature of construction material being printed)

Material printed per hour ( $\text{m}^3/\text{h}$ )  
Length to be printed per second \* wall thickness \* height of wall to be printed by printer per second =  $30\text{ cm} * 5\text{ cm} * 2\text{ cm} = 300\text{cm}^3$  is extruded per second  
In 1 hour we have  $300\text{ cm}^3 * 3600\text{s} = 108000\text{ cm}^3/\text{h} = 1.08\text{ m}^3/\text{h}$

Specifications taken from [COBOD](#)

#### **Economics**

Price of 3D concrete per  $\text{m}^3$   
268

Number of operators  
2

Hourly rate of operators (EUR/h)  
40

## Setup Time and Safety

Risk factor

50% (this means increase in print hours, it depends on printer and staff expertise)

Onsite printer setup (hours)

8 (as per literature)

Take down of printer on site (hours)

4 (as per literature)

Number of workers involved in setup and dismantlement

2 (as per literature)

## Total Cost

Total area of wall:

(outer wall+inner wall)=100+100=200 m<sup>2</sup>

Total area of wall to be printed

Area of exterior face of outer wall + Area of interior insulation facing wall + Area of interior facing

wall=100 + 100 + 100 =

300 m<sup>2</sup>

Total material use (m<sup>3</sup>)

Area of wall(m<sup>2</sup>)\*Thickness of wall(m)=300m<sup>2</sup> \* 15cm= 300m<sup>2</sup> \* 0.15m= 15m<sup>3</sup>

Theoretical hours of print time

Total amount of material / Material printed per hour= 15m<sup>3</sup>/1.08 m<sup>3</sup>/h=13.89 hours

Hours of print time needed including safety considerations (we took 50%)

13.89\*1.5=20.84 hours

Total operator print hours needed including safety

Print hours(2 workers) + preparation hours of workers =(2\*20.84) + 3=44.6 hours

Total operation hours for project (hours)

Total operator print hours + (hours for 2 operators to setup and takedown printer)= 44.6+

2\*(8+4)=68.6 hours

Total cost of operator hours

Cost per hours \* total hours =  $40 * 68.6 = 2744$  Euro

Total cost of concrete

Cost of concrete per m<sup>3</sup> (100 EUR) \* total volume of concrete required =  $120 * 15 = 1800$  Euro

**Total cost of project**

**Total cost of labour + Total cost of concrete =  $2744 + 1800 = 4544$  Euro**

### **Case 2 when construction is done purely manually and comparison**

As per literature 3D printing saves 80-90% time of construction. For our case we can write that as:

If 3D printing project time is 68.6h then using only manual labour it would be  $68.6 * 5 = 343$  hours

In terms of cost that would be =  $343 * 40 = 13,720$  Euro

Fyi: 15 m<sup>3</sup> concrete is extruded out. For human run project there would be waste due to mistakes. But in this we assume human workers do not produce waste concrete.

Total project cost =  $13,720 + 2744 = 16,464$  EUR

So total cost saving = Cost of manual labour + Cost of concrete (80 EUR/m<sup>3</sup>) - Cost of 3D printed project labour - Cost of 3D concrete  
=  $13720 + (100 * 15) - (2744) - (120 * 15) = 13720 + 1500 - 2744 - 1800 = 10676$  Euro

% in savings cost =  $(10676 / 15220) * 100 = 70.14\%$  (mostly in labour costs)

% in savings time = 80% (literature, 3D printing company websites)

### **Case 3 when the foundation of the house is 3D printed**

Volume of foundation concrete = Area of foundation \* Thickness of foundation =  $100\text{m}^2 * 400\text{mm} = 100 * 0.4 = 40$  m<sup>3</sup>

Volume of foundation insulation (styrene) = Area of foundation \* Thickness of foundation =  $100\text{m}^2 * 150\text{mm} = 100 * 0.15 = 15$  m<sup>3</sup>

Cost of 1m<sup>3</sup> special styrene = 60 EUR

<http://www.finnfoam.com/products/finnfoam/>

Cost of concrete =  $120 \text{ EUR} * \text{m}^3$

Print speed of printer = 30cm/s

Layer height= 5cm  
Layer thickness= 2cm

Concrete material use cost: Volume of concrete foundation in m<sup>3</sup> \* cost of 3D concrete =  
 $40 \times 120 = 4800$  EUR

Insulation material use cost: Volume of insulation in foundation m<sup>3</sup> \* cost of insulation =  
 $15 \times 60 = 900$  EUR

1.08m<sup>3</sup>/h concrete is extruded. So time taken to extrude 40 m<sup>3</sup> concrete= 37.03h

1.08m<sup>3</sup>/h foamed insulation is extruded. So time taken to extrude 15 m<sup>3</sup> concrete= 13.88h

Printer setup and removal time by 2 people=  $12 \times 2 = 24$ h

Total time taken=  $37.03 + 13.88 + 24 = 74.91$ h

Operator time= 2 operators required =  $2 \times 40 \times 74.91 = 5992.8$  Euro

Total project cost= Operator time + concrete cost + insulation cost=  $5992.8 + 4800 + 900 +$   
 $= 11692.8$  Euro

#### **Case 4 when the foundation of the house is done manually**

Volume of foundation= Area of foundation \* Thickness of foundation =  $100 \times 0.4 = 40$ m<sup>3</sup>

Volume of foundation insulation(styrene)= Area of foundation \* Thickness of foundation =  $100 \times 0.15 = 15$ m<sup>3</sup>

Cost of concrete=100 Euro/m<sup>3</sup> \* Volume of foundation=  $100 \times 40 = 4000$  Euro

Cost of styrene=60 Euro/m<sup>3</sup> \* Volume of foundation=  $60 \times 15 = 900$  Euro

Time required is more than 3D printing= Time required for 3D printing \*  
 $5 = (37.03 + 13.88) \times 5 = 254.55$ hours

Cost of operator hours= $254.55 \times 40 = 10,182$  Euro

Total project cost= Operator time cost+ concrete cost + insulation cost=  
 $10182 + 4000 + 900 = 15082$  Euro

Savings in project cost= cost of manual project - cost of 3D printed= 15082 - 11692.8=3389.2 EUR

**% savings when using 3D printing=  $(3389.2/15082)*100=22.47\%$**

### **Case 5 when the insulation of the house is 3D printed**

The 3D printed insulation is a foam material. The printing speed is the same and it is extruded at the same time as when the walls are made. So no extra cost for labour or time. Just cost of foamed insulation.

Thickness can be 30 cm i.e 0.3m.

Volume of Foam= 100m<sup>2</sup> ext wall\* 0.3 m= 30 m<sup>3</sup>

Cost of foamed insulation per m<sup>3</sup>= 100 EUR when polyurathane is used

Cost for insulating= volume of foam\*cost per m<sup>3</sup>= 30\*100=3000 Euro

We do not need separate labour cost for insulation extrusion as it happens during wall printing. So we save labour cost.

**Total cost of project= insulation material = 3000 EUR**

### **Case 6 when the insulation of the house is done manually**

When insulation is done manually. There is extra cost of labour and time. The insulation materials is the same foamed materials but done manually.

Spraying 100m<sup>2</sup> by 3 staff takes 2h. So for 200m<sup>2</sup> by 3 staff takes 4h. We need 3 staff simultaneously.

Cost for staff= 4\*3\*40=12\*40=480 EUR

Thickness can be 30 cm i.e 0.3m.

Volume of Foam= 100m<sup>2</sup> ext wall\* 0.3 m= 30 m<sup>3</sup>

Cost of foamed insulation per m<sup>3</sup>= 100 EUR when polyurathane is used

Cost for insulating= volume of foam\*cost per m<sup>3</sup>= 30\*100=3000 Euro

Total cost of project= cost of insulation + cost of staff= 3000+ 480=3480 EUR

Savings using 3D printing=  $(480/3480)*100=13.78\%$

**3D printed roofs are not mature yet so we will use regular method.**

**Cost for plumbing**

**Cost of Electrical installations**

**Cost of minor finishings**

**Other**

The electricity cost for running the printer is low [50 watt per hour](#). This will vary from equipment producer, environmental strain etc. So there is no precise answer as manufacturers often guard it for competition reasons. However it is clear that it would be very less. Because we have such large savings due to other factors we can ignore this.

**They combine to form approx 45% of the housing cost.**

**Total cost of 3D printed house**

Cost for wall=	4544
Cost for foundation=	11,692.8
Cost for insulation=	3000
<b>Total=</b>	<b>19,236.8</b>

**Total cost of manually built house**

Cost for wall=	16,464
Cost for foundation=	15,082
Cost for insulation=	3480
<b>Total=</b>	<b>35,026</b>

Cost savings=  $35026 - 19236.8 = 15789.2$

**%savings in terms of category construction=  $(15789.2/35026)*100=45.07\%$**

Total cost of manually built house+Other=  $35026+28657.63=63683.63$  Euros

Total cost of 3D built house+Other=  $19236.8+28657.63=47893.63$  Euros

Overall savings=  $63683.63 - 47893.63 = 15790$  Euros

**% overall savings=  $(15,790/63,683.63)*100=24.79\%$**