POTENZIALITÀ E CRITICITÀ NEL RICICLO DELLE SABBIE DI FONDERIA

Evento finale del progetto
"Nuovi processi di riciclo per le sabbie di fonderia:
innovazione finalizzata all'ottenimento di materiali ad alto valore aggiunto"

IUSS
UNIVERSITÀ DEGLI STUDI DI BRESCIA
Fondazione CARIPLO
ASSOFOND
ASSOCIAZIONE ITALIANA FONDERIE

Upcycling di scarti industriali tramite manifattura additiva di grandi dimensioni

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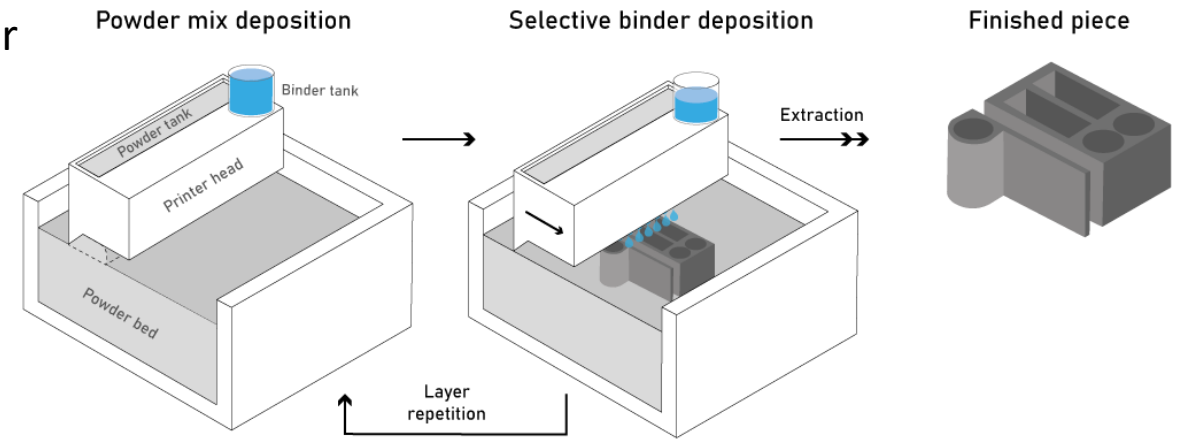
- Foundry sand as part of the powder bed in Binder Jetting
- Inorganic binder based on a geopolymer (metakaolin + alkaline solution)
- Additive manufacturing of large scale fully inorganic components
- Potential applications: ranging from building components to coastal protection

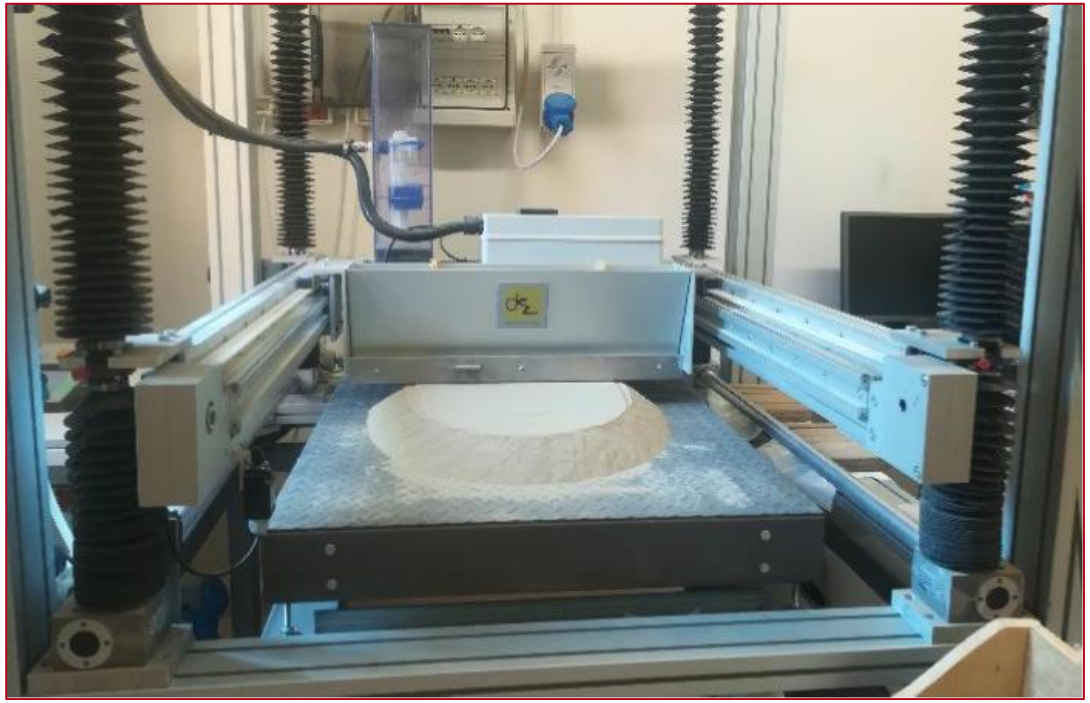
Powder-based 3D Printing (Binder Jetting)

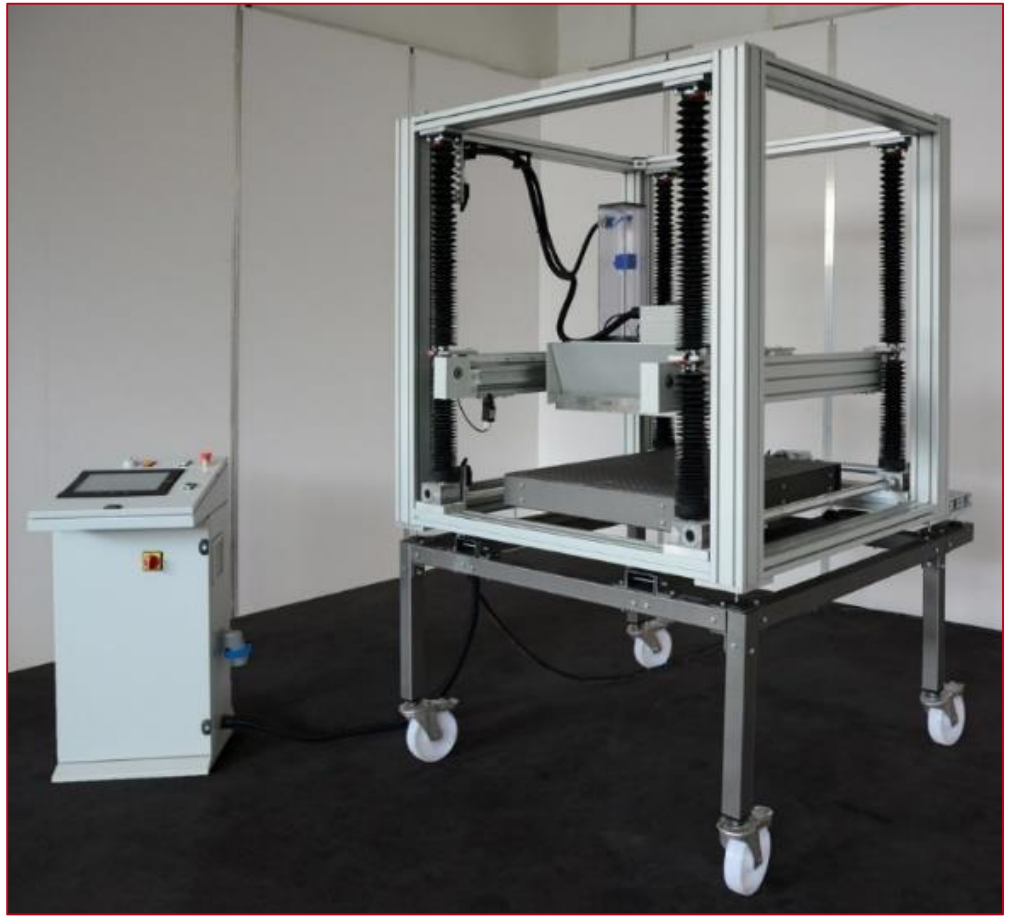
The process steps are:

1. Creation of the powder bed/creation of the first layer
2. Selective deposition of the activating liquid
   + immediate recoating of the printed layer
3. Re-deposition of the new layer of powder
4. Repetition of the cycle till the end of the part
5. Extraction and cleaning of the part



Powder-based 3D Printing (Binder Jetting)





- Large scale AM: 600 x 600 x 600 mm
- Voxel resolution: 3 mm^3
- 192 nozzles
- Printing speed: 10 - 50 mm/sec

Note: the binder is provided in part in the powder bed and in part through the liquid activating solution

*F. Gobbin et al, Large scale additive manufacturing of artificial stone components using binder jetting and their X-ray microtomography investigations, Open. Ceram. **7** (2021) 100162*

Binder Jetting of recycled sand

Caratteristiche richieste	Campione
Sabbia a maggior contenuto di fase amorfa e ad alto contenuto di silice e allumina. Granulometrica maggiore di 300 micron.	1A (alto contenuto Si e Al, granulometria maggiore)
Sabbie cristalline e/o amorfe con contenuto di metalli, carbonio, ecc. Granulometrica maggiore di 300 micron.	11A (elevato contenuto di metalli, granulometria non fine)

(Reactive) Powder bed

- Foundry Sand, inert aggregate (70 to 80 wt%). Two types (1A and 11A)
- Metakaolin, reactive powder (20 to 30 wt%; 55 wt% SiO_2, 39 wt%Al_2O_3)

Liquid

- Alkaline solution, (sodium/potassium silicate + sodium/potassium hydroxide + water), 19 wt% SiO_2, 16 wt% Na_2O/K_2O, 65 wt% H_2O

Printing condition

- One day on the printing bed, extraction and cleaning. Two curing temperature (T_room e T_60°C). Test after 10 days

- Amount of Metakaolin and liquid binder computed on the basis of the desired geopolymer formulation
- Jetting of liquid binder controlled by **pressure drop** and **nozzle opening time**

H. Elsayed et al, Additive manufacturing of inorganic components using a geopolymer and binder jetting, Additive Manufacturing **56** (2022) 102909

Binder Jetting of recycled sand

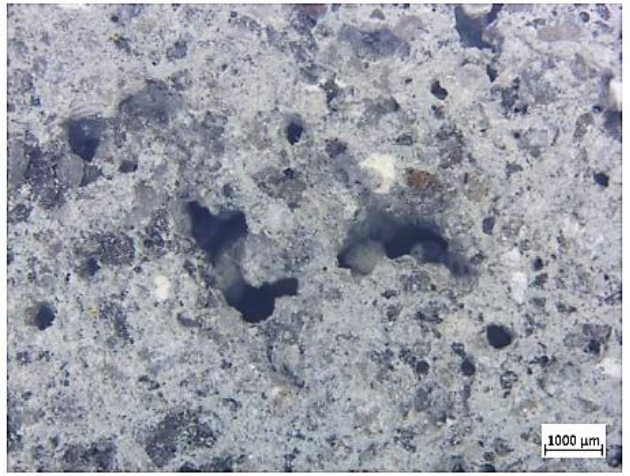
Printed part
Sand 1A
20 wt%
metakaolin

Printed part
Sand 11A
20 wt%
metakaolin

10 giorni	Geometric density [g/cm^3]	Pa [%]	P [%]	Compressive strength [MPa]	Dev. Std.	Flexural strength [MPa]	Dev. Std
1A	1,5865	33,82	35,78	5,2	1,301	2,3	1,041
1A_C40	1,5732	35,42	36,48	5,0	0,628	2,3	0,557
11A	1,8928	29,46	32,95	4,5	0,733	1,7	0,058
11A_C40	1,7885	34,63	39,63	4,1	1,147	1,6	0,153

Binder Jetting of recycled sand

Printed part
*Sand 1A_*
30 wt% metakaolin



7 giorni	Geometric density [g/cm^3]	Pa [%]	P [%]	Compressive strength [MPa]	Dev. Std.	Flexural strength [MPa]	Dev. Std
1A	1,4890	39,61	40,78	6,3	0,786	2,9	0,058
1A_C60	1,5456	39,03	41,08	7,2	0,729	2,4	0,153

Binder Jetting Case Studies at DII
(all samples contain > 50wt% sand)

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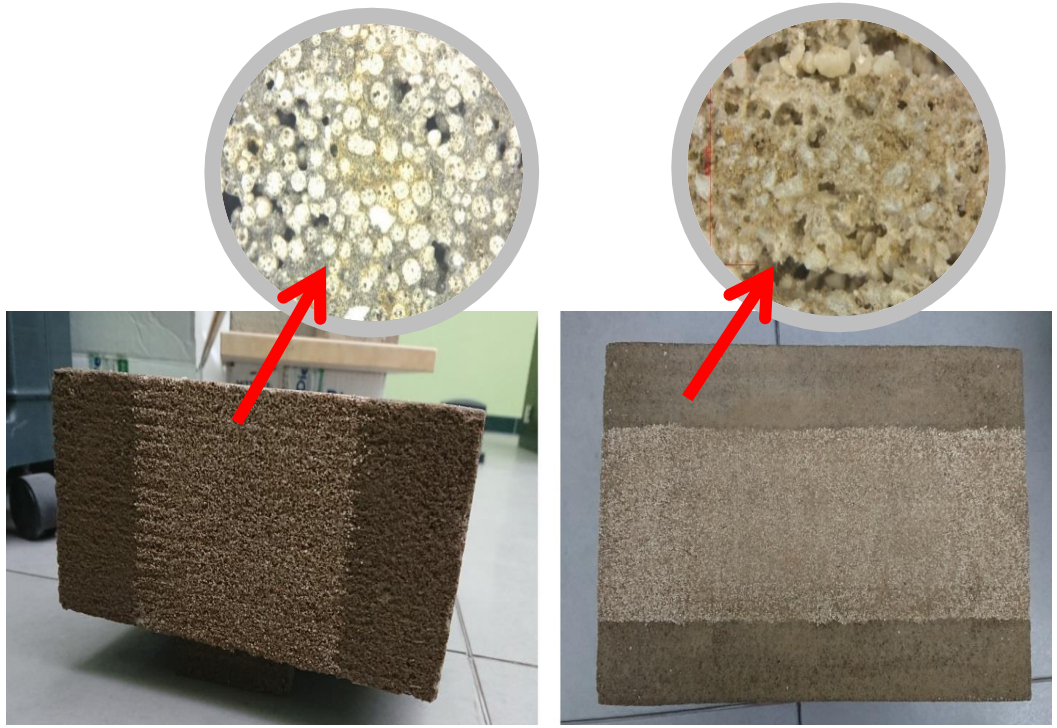
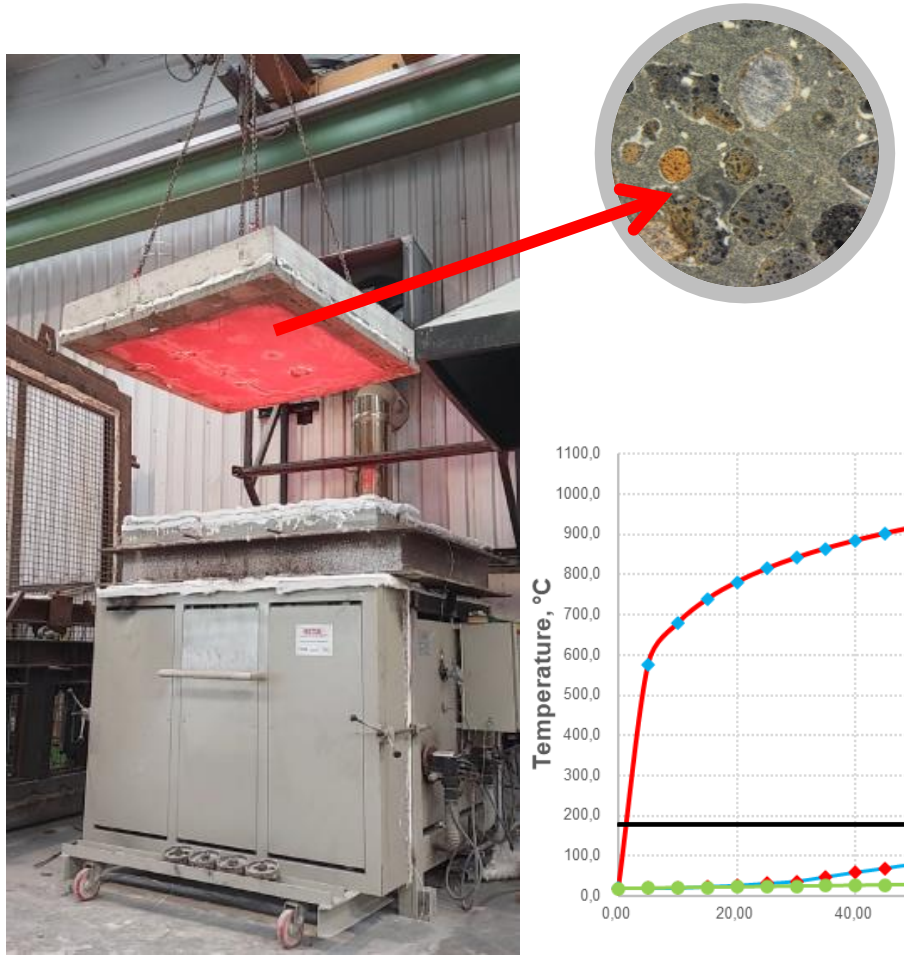
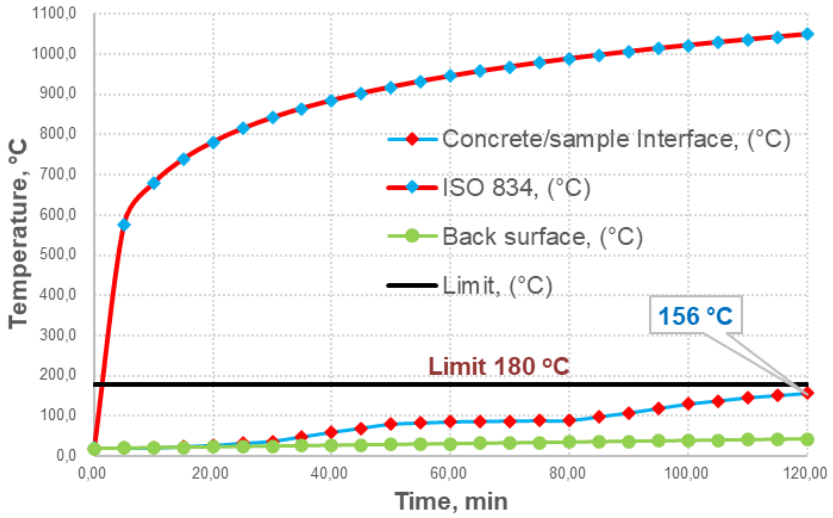
Construction sector elements
Thermal and sound insolation, sewage hub, thermal storage, fire protection element





IDEAL
Supported by eit RawMaterials Connecting matters



Binder Jetting Case Studies at DII

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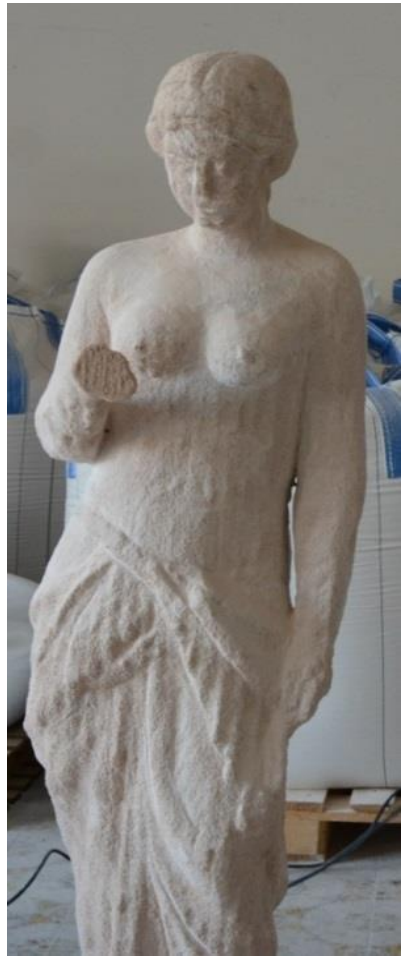
Coastal protection

Artificial reef
100 x 100 x h 73 cm^3

http://www.cursa.it/tag/progetto-bioreef/

Artwork copies

The Indian Girl
Erastus Dow Palmer
36 x 44 x h 120 cm



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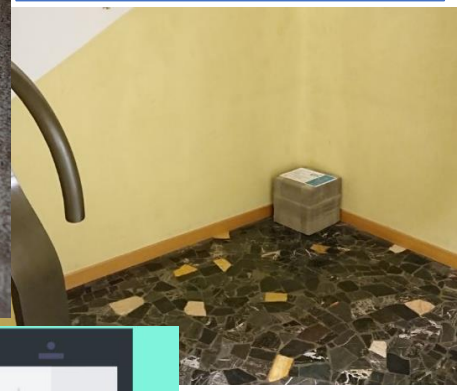
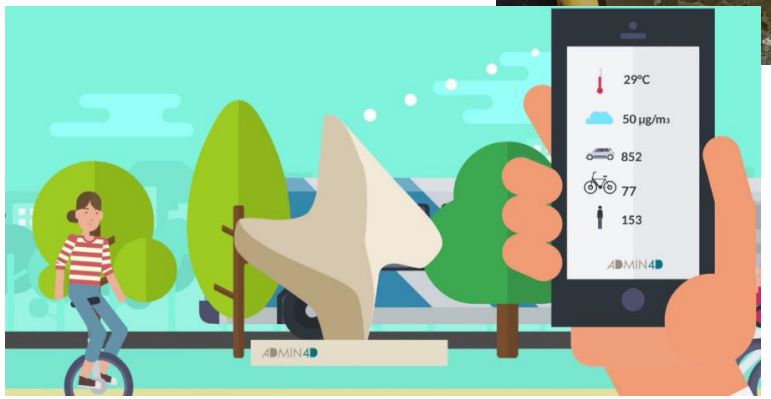
Smart urban furniture





https://www.desamanera.com/admin-4d-la-smart-manufacturing-del-futuro/

Design

Tavoli Palladio
Progetto: Arch. Tognon
70 x 70 x 54 cm^3 e 60 x 60 x 70 cm^3

https://www.palladioscale.com/

Binder Jetting Case Studies at DII

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Building sector

Sewer pipes and connectors

Fire protection of tunnel structures (pipes, cables)

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D3Vero

Molds for blown glass

Conclusion and future work

- It is possible to upcycle foundry sand to fabricate inorganic, large scale components by Additive Manufacturing (Binder Jetting)
- Optimal amount of metakaolin reactive powder is 30 wt%
- Sand 1A (clean) possessed a certain degree of reactivity towards an alkaline solution (→ it might be possible to reduce the content of reactive metakaolin in the powder bed formulation)
- Printed parts are stable in contact with boiling water (→ completed geopolymerization reaction)
- Strength and density of the parts suitable for some applications (urban furniture, non-load-bearing parts, coastal protection)