IV CONVEGNO INTERNAZIONALE

PRE-FREE UP-DOWN RE-CYCLE

PRATICHE TRADIZIONALI E TECNOLOGIE INNOVATIVE PER L'END OF WASTE

a cura di
Adolfo F. L. Baratta

anteferma

PRE-FREE UP-DOWN RE-CYCLE

PRATICHE TRADIZIONALI E TECNOLOGIE INNOVATIVE PER L'END OF WASTE

a cura di
Adolfo F. L. Baratta

anteferma

ROMA TRE
UNIVERSITÀ DEGLI STUDI
DIPARTIMENTO DI ARCHITETTURA

Atti del IV Convegno Internazionale
PRE|FREE - UP|DOWN - RE|CYCLE
Pratiche tradizionali e tecnologie innovative per l'End of Waste

Proceedings of the 4th International Conference
PRE|FREE - UP|DOWN - RE|CYCLE
Traditional solution and innovative technologies for the End of Waste

Acta de el IV Congreso Internacional
PRE|FREE - UP|DOWN - RE|CYCLE
Prácticas tradicionales y tecnologías innovadoras para la disposición de los desechos

a cura di | edited by | editado por
Adolfo F. L. Baratta

ISBN: 979-12-5953-005-9

Editore
Anteferma Edizioni Srl
via Asolo 12, Conegliano, TV
edizioni@anteferma.it
Prima edizione: maggio 2021

Progetto grafico
Antonio Magarò
www.conferencerecycling.com

Tutti i contributi sono stati valutati dal Comitato Scientifico, seguendo il metodo del Double Blind Peer Review.
All papers were evaluated by the Scientific Committee, following Double Blind Peer Review Method.
Todas las contribuciones fueron evaluadas por el Comité Científico, siguiendo el método de Peer Review doble ciego.

PRE|FREE - UP|DOWN - RE|CYCLE

pratiche tradizionali e tecnologie innovative per l'End of Waste

traditional solutions and innovative technologies for the End of Waste

prácticas tradicionales y tecnologías innovadoras para la disposición de los desechos

Indice
Table of Contents

Premessa / *Foreword*

14 Premessa. Il riciclaggio come ambito di ricerca per la pratica virtuosa
Foreword. Recycling as a research field for virtuous practice
Adolfo F. L. Baratta

Saggi / *Essays*

28 Upcycling dei materiali del patrimonio architettonico nella progettazione circolare
Upcycling of heritage materials in circular design
Graziella Bernardo

40 La qualità delle architetture con tecnologia di riciclaggio
The quality of architecture with recycle technology
Agostino Catalano

52 Informazione materiale: strumenti per l'implementazione dello urban mining in edilizia
Material information: tools for the urban mining implementation in the building sector
Massimiliano Condotta, Elisa Zatta

64 Da rifiuto a risorsa: il contributo dell'Italia al programma LIFE
From waste to resource: Italian contribution to the LIFE programme
Gigliola D'Angelo, Monica Cannaviello

74 Uso e riuso delle plastiche viniliche in edilizia
Use and reuse of vinyl plastics in construction
Camilla Sansone

Ricerche / *Researches*

88 *The environmental impact evaluation of building elements in architecture: the design for disassembly*
Laura Calcagnini

100 Guardare al passato per migliorare il futuro
Upcycle approach per l'Isola di Vetro
A glimpse into the past to develop a better future
Upcycle approach for the Isle of Glass
Paola Careno, Stefano Centenaro, Filippo De Benedetti

112 DRINC Beer: Designing Recycle
IN Concrete with Beer
DRINC Beer: Designing Recycle
IN Concrete with Beer
Denis Faruku, Roberto Giordano, Stefania Riccio

124 Lane minerali di vecchia generazione: la pericolosità del rifiuto dismesso
Old generation mineral wools: the riskiness of discarded waste
Ornella Fiandaca, Alessandra Cernaro

140 Lane minerali di vecchia generazione: la circolarità del rifiuto dismesso
Old generation mineral wools: the circularity of discarded waste
Alessandra Cernaro, Ornella Fiandaca

156 Diseño de productos y espacios desde el reciclaje y la reutilización de desechos
Design of products and spaces from recycling and reuse of waste
Fabio Enrique Forero Suarez

172 *E-waste recycling for monitoring the microclimate in sub-Saharan Africa*
Antonio Magarò

186 Sistemi di logistica del materiale per la gestione dei rifiuti nelle strutture ospedaliere
Material logistic systems for waste management in hospital
Massimo Mariani

198 *Effect of moisture content and mixing procedure on the Properties of Recycled Aggregate Concrete with Silica fume*
Beatriz E. Mira Rada, Andres Salas Montoya

210 Uva, nocciola e frumento: nuovi ingredienti per l'architettura e il design?
Grape, hazelnut and wheat: new ingredients for architecture and design?
Elena Montacchini, Silvia Tedesco, Jacopo Andreotti

222 Verso il circular building quale prassi progettuale. Un esempio di Design for Disassembly
Towards the circular building as design practice. A Design for Disassembly case study
Elisabetta Palumbo, Massimo Rossetti, Francesco Incelli, Francesca Camerin, Chiara Panozzo

236 *Reuse of salt waste in 3D printing: Case study*
Vesna Pungercar, Martino Hutz, Florian Musso

248 Il recupero di materiali attraverso la demolizione selettiva: un'analisi costi-benefici
The recovery of materials through selective demolition: a cost-benefit analysis
Giulia Sarra, Paola Altamura, Francesca Ceruti, Vito Introna, Marco La Monica

262 Il riciclaggio come propulsore innovativo nel settore produttivo del vetro
Recycling as an innovative driver in the glass production sector
Luca Trulli

Architetture e Design / Architectures and Design

276 Dallo scarto al valore. Quando dalla forma dei residui litici emergono vocazioni nascoste
From waste to value. When hidden vocations emerge from the shape of the stone residues
Laura Badalucco, Luca Casarotto

290 Il riciclaggio come pratica per la sostenibilità sociale. I mattoni in plastica riciclata di Gjenge Makers in Kenya
Recycling as a practice for social sustainability. Gjenge Makers' recycled plastic bricks in Kenya
Laura Calcagnini, Luca Trulli

304 Rifiuti e ospitalità in spazi urbani comuni: un'esperienza didattica nel laboratorio CIRCO
Waste and hospitality in common urban spaces: a didactic experience in the CIRCO laboratory
Francesco Careri, Fabrizio Finucci, Enrica Giaccaglia, Marco Mauti

316 Promuovere la cultura del riciclo: i Centri di Riuso
Promoting the culture of recycling: the Reuse Centres
Francesca Castagneto

328 Criteri di smontaggio e riciclaggio di componenti edilizi nei progetti di recupero e di nuova progettazione modulare. Qualità architettonica ed edilizia per costruzioni sostenibili
Criteria for disassembly and recycling of building components in restoration and new modular Architectural design. Building quality for sustainable construction
Agostino Catalano, Camilla Sansone

342 Distanze di cartone: sperimentare un Living Lab per l’Upcycling degli imballaggi
Carboard Distances: An experiment on an Upcycling Living Lab for envelopes
Stefano Converso

354 Fallimenti e successi di una start-up dell’economia circolare: il caso di studio Sfridoo
Failures and successes of a circular economy start-up: Sfridoo case study
Mario Lazzaroni, Marco Battaglia, Andrea Cavagna

366 Il recupero del legno rigenerato: l’esperienza olandese di Superuse Studios
The remanufacturing of reclaimed wood: the Dutch experience of Superuse Studios
Rosa Romano

380 Profili degli Autori
Authors Profiles

Beatriz E. Mira Rada
Professor
Universidad Autónoma de Manizales, Facultad de Ingenieria
beatrize.mirar@autonoma.edu.co

Andres Salas Montoya
Associate Professor
Universidad Nacional de Colombia, Civil Engineering Department
asalasmo@unal.edu.co

Effect of moisture content and mixing procedure on the Properties of Recycled Aggregate Concrete with Silica fume

Silica Fume, Strength, Elastic Modulus, Aggregates, Recycling

Summary

This document summarizes the results of a laboratory study to determine the effect of the moisture state of aggregates and mixing method on some of the mechanical properties of concretes produced using natural (NA) and recycled concrete aggregates (RA) including silica fume (SF).

Concrete wastes were crushed and used as 100% replacement for natural coarse aggregate to produce concrete mixtures.

The study includes the evaluation of the compressive strength and static modulus of elasticity of the concrete mixes produced following the standard mixing procedure and the two-stage mixing approach, using aggregates in different moisture states: oven dry (OD), air dry (AD) and saturated surface dry (SSD).

Based on the results, it was feasible to produce high quality concretes using recycled aggregates in the concrete by manipulating the parameters of the mix, such as the mixing procedure, and the moisture content of the aggregates.

Introduction

There is a worldwide search on new sources of aggregates to produce concrete, due to the critical shortage of the natural resources [BBC, 2021; Tam e Tam, 2007]. The use of recycled materials could be an alternative for replacing natural aggregates in concrete in terms of fulfilling, at least, part of the aggregates demand, also for reducing environmental problems [Gonzales, 2018; Singh, 2018; Mohammed et al., 2018; Kumar et al., 2018]. Numerous researchers have deeply studied the use of RA to produce Portland cement concrete [Gonzales, 2018; Singh, 2018; Tam et al., 2018; Gonzales-Taboada, 2016; Yehia, 2015]. Several techniques have been developed to off-set some difficulties with RA so that the concrete can achieve the desired performance criteria at least on par or above the performance of natural aggregate concrete (NAC), and thus prevent the properties of RAC from being negatively affected [Yehia, 2015; Li et al., 2009; Katz, 2004], but few of those researches have emphasized on the combined effect of key factors such as the moisture content of the aggregate in conjunction with the mixing procedure and the use of supplementary cementitious materials [Tam e Tam, 2007; Gonzales, 2018; Tam et al., 2018; Yehia, 2015; Li et al., 2009; Ferreira et al., 2011]. One method proposed to enhance properties of RAC that has shown high effectiveness was the termed by Tam et al. [Tam, et al., 2008] as Two Stage Mixing Approach (TSMA), in which the sequence of different steps for mixing process was utilized, not following the ordinary mixing approach suggested by the ASTM called normal mixing procedure (NMP) [Tam e Tam, 2007; am et al., 2018; Faysal et al., 2020; Tam, et al., 2008; Ka-hung ng. et al., 2006; Kong, D. et al., 2010]. The main thrust of this research was to evaluate the effect of combining two strategies in different recycled aggregate concretes and their comparison with a control concrete using only NA to enhance the performance of RAC. The first method is a change on the moisture content, and the second is the use of two different mixing procedures: the TSMA and the NMP.

Materials

Commercial silica fume (SF) suitable with ASTM C 1240 and Portland cement type V, compatible with ASTM type I Portland cement, were used as cementitious materials. A liquid Polycarboxylate Polymer

Agg.	Type	Maximum size [mm]	Density [g/cm³]	Abs. Capacity [%]	Degree of saturation [%]
Fine agg.	Natural coarse river sand	4.75 (No. 4)	2.75	1.64	-
	Natural fine river sand		2.71	2.6	-
NA AD	Natural coarse aggregate, crushed basalt, humid, pre-wetted state				75
NA SSD	Natural coarse aggregate, crushed basalt, saturated-surface-dry (SSD)		2.98	1.61	100
NA OD	Natural coarse aggregate, crushed basalt, oven dry (OD)	19			0
RA AD	Recycled coarse aggregate, humid, pre-wetted state				55
RA SSD	Recycled coarse aggregate, saturated-surface-dry (SSD)		2.47	4.7	100
RA OD	Recycled coarse aggregate, oven dry (OD)				0

Table1. Notation and Physical Properties of Aggregates. [Original from authors].

superplasticizer (SP), conforming to ASTM C494 was used as liquid chemical admixture.

Natural Aggregates

Three different NA were blended: a crushed basalt as coarse aggregate and two river silicious sands, a coarse sand with fineness modulus of 3.63 and a fine sand with fineness modulus of 1.78, as fine aggregate. The defined properties of aggregates are in table 1. The notation given in table 1 includes three parts. The first part indicates the origin of aggregates: RA for recycled coarse aggregate and NA for natural aggregates. The second part is used to identify the moisture content of aggregates: AD for air dried state, SSD for saturated surface dry and OD for oven dry state. Finally, third part indicates the mixing procedure followed: NMP for the ASTM C192 standard procedure and the TSMA for Two Stage Mixing Approach.

Recycled Aggregates

Recycled coarse aggregate (RA) were used as 100% replacement of coarse NA in the concrete mixtures. Recycled aggregates were obtained from crushed beams and cylinders that were selected, crushed, cleaned, and sieved from a concrete laboratory. After production of RCA, aggregates were separated using individual sieves and then recombined to have the same sieve distribution of the natural coarse and fine aggregates, and thus have a basis for comparison.

Aggregate moisture conditions

To analyze how the moisture states of the recycled aggregates affects concrete behavior, authors analyzed three different humidity conditions in aggregates: Oven dry state (OD), Air dried state, AD and Saturated Surface Dry (SSD) state.

Mixture Proportions

Twelve concrete mixtures were formulated and prepared using NA and RA, with 440 kg of cementitious materials per cubic meter of concrete and with water/cementitious material ratio (w/cm) of 0.45. The dosage of superplasticizer was between 1.0 and 1.3 L/m^3 of binder mass to provide a workability between 125-150 mm. Potable water was used for casting and curing specimens. All mixes contained 10% silica fume (SF) as supplementary cementitious material replacing Portland cement by weight.

Mixing Concrete

As mentioned previously, authors used two different mixing procedures: the ASTM C192 [ASTM C192] standard mixing procedure, and the Two-Stage Mixing Approach (TSMA) suggested by Tam et al. [Tam e Tam, 2007; Bentur, 1988]. To prepare concrete specimens, all concretes were mixed in a tilting drum mixer. Six mixtures were prepared in accordance with ASTM C 192 and six concretes were mixed following the TSMA. The procedures are explained in a previous publication [19].

Hardened Concrete Testing

The hardened tests were conducted in accordance with ASTM standards. Measured properties of concrete mixtures included compressive

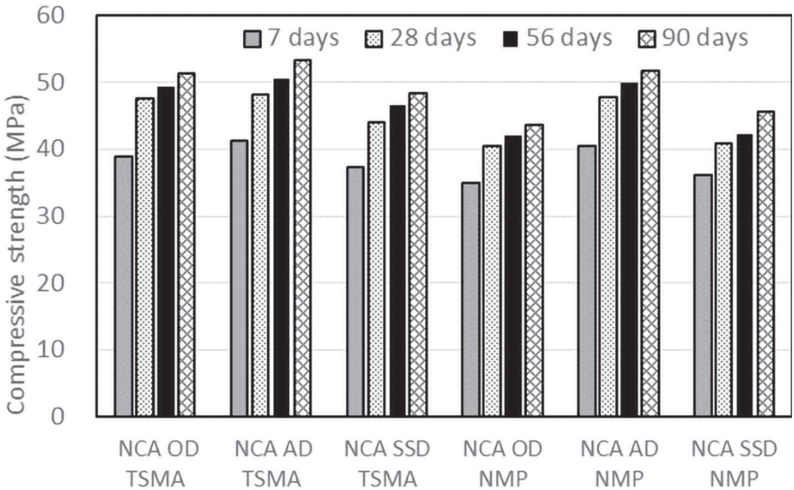

Figure 1. Compressive Strength of the concrete mixes. [Original from authors].

strengths, according to ASTM C 39 using three 100×200 mm cylindrical specimens at 7, 28, 56, and 90 days and elastic modulus on two 100×200 mm cylindrical specimens by using ASTM C 469.

Tests results

Compressive Strength

According to Figure 1, the moisture content of the aggregates has an opposite effect on the strength properties for both, NA and RCA concretes. For NA concretes, the mixes with aggregates in OD condition presented the lowest results on compressive strength when compared with those in AD and SSD states.

The reduction on the compressive strength of concretes with NA in OD condition is mainly related to the adherence between aggregate and cement paste due to the extra water added to compensate the absorption of the OD aggregate [Ferreira, 2011; Brand, 2015]. Meanwhile, the

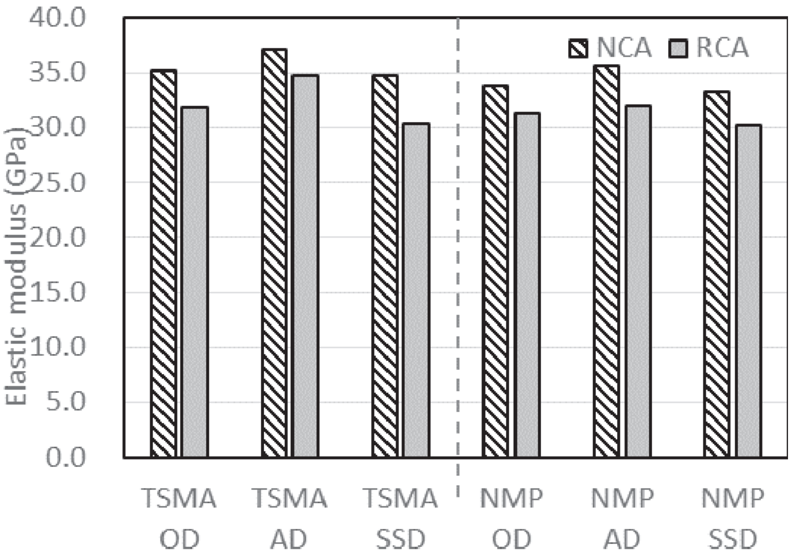

Figure 2. Elastic Modulus of the concrete mixes. [Original from authors].

results for the RAC are quite different, the best results on the compressive strength are for the concretes with aggregates in the AD and OD states at all tested ages, and the lowest results were for concretes with SSD aggregates. This is mainly caused by characteristics of the old mortar in RA, such as the absorption and its texture [Poon et al., 2004; Akir et al., 2015].

By the other side, when the RA are used in SSD state, the strength is lower because it is not possible to fill the cracks with the slurry of the cement pastes and thus fails to increase the density of the cement matrix near the ITZ of RA and the bond between the new cement paste and RA. With respect to the mixing procedure, the experimental results showed a slight difference on the compressive strength that the Two-Stage Mixing Approach was an effective method for enhancing the behavior of RAC. There is a triple benefit on the properties of concretes combining the incorporation of SF and the TSMA at the same time, compared to normal mixing.

Due to the very fine particle size of silica fume, it acts as a microfiller, fills pores and strengthening the microstructure of the mortar that is adhered to the original aggregate, enhancing adherence of aggregate-new cement matrix followed by a pozzolanic reaction at the same place [23] producing a substantial improvement in the strength when the results are contrasted to the NMP.

Modulus of elasticity

The results show that Ec decreases depending on the level of moisture content and the type of aggregates as shown in figure 2. All the concretes with natural aggregates show a higher elastic modulus, and the RA concretes, especially for those in SSD states, showed lower modulus of elasticity.

This trend may be explained by examining concrete as a three-phase composite material as proposed by Mindess et al. [Monteiro, 1993], composed of aggregate particles dispersed in a cement paste matrix and the transition zone between coarse aggregate and cement paste that has a strong influence over the elastic modulus. The bonding and interlocking between aggregates and paste is lower for the RCA concretes, especially for those prepared with the NMP.

Conclusions

According to the experimental results obtained from this work, following conclusions can be drawn:

1. According to the results of the analysis of the three mechanical properties of concrete, it can be concluded that the type of aggregate is a relevant factor in concrete manufacturing, it influences the properties and recycled aggregate can increase the average compressive strength, and modulus of elasticity.
2. When the recycled concrete was used in the SSD states, the compressive strength of the concrete was affected due to the lack of absorption of the cement slurry inside the recycled aggregate.
3. The results revealed that there was a strong difference in compressive strength between NA and RA concrete.
4. The TSMA approach achieved higher compressive strength and elastic modulus compared with the NMP for both natural aggregate and RCA concrete.
5. The strength properties for RCA concrete were greatest when the RCA was at least in the partially saturated moisture state with TSMA.

Acknowledgement

This work was supported by Brain Pool Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT.

The authors wish to thank Universidad Nacional de Colombia and Universidad Autonoma de Manizales, Manizales Colombia for the support of this study.

Bibliography and bibliographic references

Akır O., et al., [2015], "Influence of silica fume on mechanical and physical properties of recycled aggregate concrete", *Housing and Building National Research Center HBRC Journal*, Volume 11, Issue 2, pp.157-166.

ASTM C192. "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory," *ASTM International*, *West Conshohocken*, 8.

BBC [2021]. Disponibile da: https://www.bbc.com/future/article/20191108-why-the-world-is-running-out-of-sand, (consultato il 19.01.2021).

Bentur A., et al., [1988], "The contribution of the transition zone to the strength of high quality silica fume concrete", *Proceedings of an Materials Research Society Symposium*, *Materials Research Society*, 114, pp.97–103.

Brand et al., [2015], "Initial moisture and mixing effects on higher quality recycled coarse aggregate concrete", *Construction and Building Materials*, 79, pp. 83–89.

Faysal R., et al., [2020], "Md. Effect of mineral additives and two-stage mixing on the performance of recycled aggregate concrete", *Journal of Material Cycles and Waste Management*.

Ferreira L., et al., [2011], "Influence of the pre-saturation of recycled coarse concrete aggregates on concrete properties", *Magazine of Concrete Research*.

González B. et al., [2018], "Recycled concrete with coarse recycled aggregate. An overview and analysis, *Materiales de Construcción*, 68, 330.

González-Taboada I., et al., [2016], "Study of recycled concrete aggregate quality and its relationship with recycled concrete compressive strength using database analysis", *Materiales de Construcción*, 66, 323.

Ka-hung Ng. et al., [2006], "Deformation and Sorptivity of Recycled

Aggregate Concrete Produced by Two Stage Mixing Approach", *Surveying and Built Environment*, 17,1, pp.7-14.
Katz A., [2004]. "Treatments for the Improvement of Recycled Aggregate", *Journal of Materials in Civil Engineering*, 16, 6.
Kong D., et al., [2010], "Effect and Mechanism of Surface-Coating pozzolanics materials around aggregate on properties and ITZ microstructure of recycled aggregate concrete", *Construction and Building Materials*, 24, 5, pp. 701-708.
Kumar V. et al., [2018], "Experimental studies on utilization of recycled coarse and fine aggregates in high performance concrete mixes" *Alexandria Engineering Journal*, 57, pp. 1749–1759.
Li J., et al., [2009]. "Influence of coating recycled aggregate surface with pozzolanic powder on properties of recycled aggregate concrete", *Construction and Building Materials*, 23, pp.1287–1291.
Mefteh H. et al. [2013]. "Influence of moisture conditioning of recycled aggregates on the properties of fresh and hardened concrete", *Journal of Cleaner Production*, 54, pp.282-288.
Mohammed N. et al. [2018]. "The influence of recycled concrete aggregate on the properties of concrete", *MATEC Web of Conferences* 162.
Monteiro J., [1993], "Concrete: A three phase material Cement and Concrete Research", 23, 1, pp.147-151.
Poon, et al., [2004], *Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates*, *Construction and Building Materials*, 18, pp.461-468.
Singh A.,et al, [2020], "Incorporating recycled aggregates in selfcompacting concrete: a review", *Journal of Sustainable Cement-Based Materials*, 9, 3, pp.165–189.
Tam et al., [2007], Optimization on proportion for recycled aggregate in concrete using two-stage mixing approach, Construction and Building Materials, 21, pp. 1928–1939.
Tam V., et al., [2008], "Diversifying two-stage mixing approach (TSMA)

for recycled aggregate concrete: TSMAs and TSMAsc", *Construction and Building Materials*, 22, pp. 2068–2207.
Tam V., et al., [2018], "A review of recycled aggregate in concrete applications (2000–2017)", *Construction and Building Materials*, 172, pp.272–292.
Tam V., Tam C., [2007], "Assessment of durability of recycled aggregate concrete produced by two-stage mixing approach", *Journal Materials Science*, 42, pp. 3592–3602.
Yehia S., et al., [2015], "Strength and Durability Evaluation of Recycled Aggregate Concrete", *International Journal of Concrete Structures and Materials*, 9, 2, pp.219–239.
Pavan, V. [2007]. *Creativi frammenti. Gli scarti della pietra da problema a risorsa*, Associazione culturale e parco regionale dell'Appia Antica, Roma.
Pellizzari, A.; Genovesi, E. [2017]. *Neomateriali nell'economia circolare*, Edizioni Ambiente, Milano.
Rampino, L. [2012]. *Dare forma e senso ai prodotti: Il contributo del design ai processi d'innovazione*, FrancoAngeli, Milano.
Thackara, J. [2017]. *Progettare oggi il mondo di domani: Ambiente, economia e sostenibilità*, Postmedia Books, Milano.
Viale, G. [2008]. *Azzerare i rifiuti*, Bollati Boringhieri, Torino.
United Nations [2015]. "Transforming our world: The 2030 agenda for sustainable development", Disponibile da: sustainabledevelopment.un.org (consultato il 10.10.2018).
Wong, W. [1976]. *Principles of Three-Dimensional Design*, Van Nostrand Reinhold Company, New York.

Finito di stampare nel mese di
Maggio 2021

Il IV Convegno Internazionale PRE|FREE - UP|DOWN - RE|CYCLE, dedicato alle "Pratiche tradizionali e tecnologie innovative per l'End of Waste", si è tenuto sulla piattaforma Microsoft Teams il 28 maggio 2021. I contributi sono stati distribuiti, a seguito della procedura double blind peer review, all'interno delle tre sezioni che caratterizzano il Convegno Internazionale: Saggi, Ricerche, Architetture e Design. La partecipazione ha visto il coinvolgimento di numerosi atenei, centri di ricerca e start-up oltre al nutrito numero di membri del Comitato Scientifico. La raccolta degli Atti fornisce lo stimolo alla riflessione sulle pratiche tradizionali e la loro intersezione con le azioni più innovative, attraverso un ripensamento dell'End of Waste. L'elemento più interessante degli Atti è la varietà di prospettiva: sebbene non vi sia la possibilità di leggere i contributi in continuità, essi restituiscono un panorama che promuove la conoscenza e stimola ulteriori indagini e ricerche.

Adolfo F. L. Baratta è Architetto e Dottore di Ricerca. Dal 2014 è Professore Associato in Tecnologia dell'Architettura presso l'Università degli Studi Roma Tre e, dal 2018, è abilitato come Professore Ordinario. È stato docente presso l'Università degli Studi di Firenze e Sapienza Università di Roma, nonché Visiting Professor presso la Universidad de Boyacá di Sogamoso (COL) e la HTWG di Konstanz (DE). Dal 2020 è esperto della Struttura Tecnica di Missione del Ministero delle Infrastrutture e delle Mobilità Sostenibili. È autore di oltre 200 pubblicazioni.

ISBN 979-12-5953-005-9

9 791259 530059

€ 22,00