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Forgotten dust: following plasterboard for non-destructive circular economies

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The exploitative and unsustainable life of the construction material plasterboard requires more sustainable economies. In this article I examine the disposal of plasterboard as an experimental case for discussing a type of non-destructive circularity. A non-destructive circular model is one way to open imaginaries for more sustainable activities of construction. My focus is on end-of-life plasterboard, including its demolition, removal from construction sites, recycling and landfilling. Three months of fieldwork in the south of Finland clarified the current state of the material. I followed plasterboard across two building sites, two recycling facilities and a landfill site, and visually exposed disposal practices and material states to show the entanglement of workers, materials and circular economy discourses. The results highlight that plasterboard reproduces a problematic circularity that merely focuses on waste management through limited recycling, doing little to decrease the need for raw gypsum extraction. I outline how plasterboard in disposal conceptually disappears from the current economic model, which fails to address a variety of opportunities for more sustainable construction. By exposing a material reality that is concerned with small amounts of plasterboard in disposal, I show gypsum crumbs and dust which are unable to play a role in the current circular economy. However, I argue that attending to end-of-life plasterboard opens possibilities to imagine more ethical engagements with the material, towards non-destructive circularities. The disposal of plasterboard makes the inadequacy of the material for current circulation visible and can contribute to a debate on more sustainable economies of construction.

KEYWORDS
diverse economies, circular economy, buildings, construction materials, materiality, plasterboard

1. Introduction

1.1. Plasterboard

The human activities of constructing and building are entwined with visions of growth-focused economic thinking, which falls short in ethical considerations for human societies and natural environments (White et al., 2015). Construction consumes 40% of all the raw materials extracted from the lithosphere, exploiting and polluting a large range of ecosystems (Ruuska and Häkkinen, 2014; Leising et al., 2018; UN Environment, 2019). In the European Union, construction and demolition are part of one of the heaviest and most voluminous waste streams (European Environment Agency, 2020). Building activities increasingly contribute to the extraordinary burdens of toxic chemistry, threatening life support systems and their sustainability (Egeghy et al., 2012; Plant et al., 2013; Varner, 2020). Additionally, construction-related CO_2 emissions continue to rise despite the building industry's focus on reducing its energy consumption and carbon emissions (Pomponi and Moncaster, 2017). The production and construction of buildings are commonly recognised as major contributors to global environmental impacts.

Considering the depth of the exigencies that mark contemporary constructions, there is little consideration for mundane construction materials and their consequences for the development of more sustainable economies (Lima et al., 2021). Current research on sustainable building and construction mainly discusses economic solutions that tend to focus on structural materials, such as concrete or metal (Al-Atesh et al., 2021; Bonoli et al., 2021). Little research pays attention to less permanent structures and the materials constructing our everyday environments, regarding their origin, the quality of their matter and their potential for circularity. Less permanent structures include building elements with shorter lifespans, for instance, the interior layers of buildings such as floors, ceilings and non-bearing walls (Brand, 1994). Such elements are often the most inexpensive and easiest to change in a building, on average, modified every 3–10 years (Brand, 1994; Thelen et al., 2019). This article contributes to addressing this research lacuna by focusing on the construction material plasterboard, which is widely used for building non-load bearing interior walls.

This article is based on a study of the plasterboard produced by the company Plaster Master,[1] which manufactures and distributes the material in Finland. Plasterboard, also called drywall or gypsum board, is a composite gypsum-based material, increasingly used since the 1940s in European countries for the construction of interior walls (Jiménez Rivero et al., 2016). The material is commonly used in buildings due to its ease of installation, familiarity, sound attenuation and fire-resistance properties (Kubba, 2017). It is one of the most inexpensive interior wall materials, making it contractors' likeliest choice for building interior structures. In fact, in the Nordics, ~95% of all interior walls are built out of plasterboard. Current investments in industrial wood constructions, a lower carbon-emission alternative to steel or concrete, and the use of wood in structural parts of buildings, mean that fire-resistant materials, such as plasterboard, have become increasingly in demand (Mölsä, 2021). In other words, the production and distribution of plasterboard are likely to increase as Finland moves towards less carbon-intensive buildings. This landscape provides an interesting empirical context in which to study the gypsum-based material and its consequences for the development of more sustainable economies of construction.

In order to better understand end-of-life plasterboard, I follow the material in disposal, through demolition, removal from construction sites, recycling and landfilling. I define a set of non-destructive economic principles to shed light on specific material realities of plasterboard and to discuss more sustainable construction. In Section 1.3, I further explore these principles of non-destructivity and propose a new model with which to understand construction materials. In line with a material semiotic approach, I consider plasterboard as a phenomenon entangled with activities of construction, people, ethics, politics and ecological entities (Fox and Alldred, 2016). Although my focus is on the material reality of circular economies, I move past the separation of material and discursive realms and, instead, examine what happens with the disposal of plasterboard, how discourses on circularity are made and how they make a difference (Daya, 2019). My concern for the material dimensions of plasterboard in disposal matters in both ethical and political terms. It exposes how construction materials which are deemed *ready for circulation* or able to be *put back into loops* are, in fact, challenging the development of more sustainable economies. The disposal of plasterboard informs the complex reality of building activities, including undesirable practices wherein environmental destruction is played out.

Paying attention to the material dimensions of end-of-life plasterboard also enables an examination of the neglected material states of buildings, the small amounts of construction materials that are made invisible in the processes of disposal. I expose how the disposal of plasterboard (and the resulting broken, crumbling and dusty gypsum pieces) renders its inadequacy for circulation visible. I also highlight how these processes of destruction can play a role in discussing opportunities for a less destructive circular model. In line with my conceptualisation of a non-destructive circularity, I show how certain processes of destruction can be addressed through *ethical considerations* for construction materials. I understand ethical considerations as affective concerns for the physical reality of buildings that emphasise the need for accountable and just handling of construction materials. As I follow plasterboard in disposal, I show how the workers closely handling plasterboard construct a sense of moral obligation that directs attention towards injustice and carelessness. By attending to gypsum crumbs and dust, I analyse current economies of construction and open a space for discussing and imagining how different economic thinking could generate more sustainable construction.

1.2. Circularity

The strategic vision of a circular economy has created an optimistic wave of responses from governments and industries. Circular strategies are viewed as operationalisation tools for the implementation of more efficient and more sustainable material and energy flows (Kirchherr et al., 2017). In the construction industry, such strategies are understood to play a substantial role in reducing the environmental impact of buildings (Arup, 2018; Leising et al., 2018; Hart et al., 2019). A circular economy is also seen as a way to increase entrepreneurial opportunities and reduce costs (Bocken et al., 2016; de Jesus and Mendonça, 2018; Velenturf et al., 2019). As such, the industry is keen to develop new practices in order to implement it (Ellen MacArthur Foundation, 2015; Sitra, 2015; Welch et al., 2016). Circular programmes for construction materials, for example, aim to reduce the building industry's reliance on raw material extraction by implementing markets for secondary materials, thereby keeping construction materials in circulation and avoiding discarding patterns (Jiménez Rivero et al., 2016; European Commission, 2022; GtoG, n.d.).

In Europe, the concept of a circular economy is being strongly advocated at a policy level (European Commission, 2015). Finland, in particular, has captured global attention with its road maps

[1] For research ethics reasons, the name of the company is anonymised.

and strategies for implementing a circular economy (Abend, 2022; Sitra, n.d.). In terms of the construction sector, the Nordic country is committed to increasing the amounts of recycled materials in new buildings and reducing construction and demolition waste (Ministry of Environment, n.d.). Construction industry leaders, such as Plaster Master, are increasingly interested in developing and implementing circular strategies. The multinational corporation Plaster Master is a world-leading supplier of gypsum products systems which produces ∼28 million square metres of plasterboard in Finland per year for use in the construction of interior walls and ceilings. Considering that plasterboard represents the largest proportion of recyclable gypsum waste in Europe (Rodríguez-Quijano et al., 2015), the company is interested in increasing the recycling of gypsum waste and in developing more circular solutions.

In 2019, when this research had just started, a representative from Plaster Master remarked that "plasterboard is close to being circular", emphasising the low environmental impact of the material and its 20–25% recycling capacity. This statement came as a response to increasing pressure from European governments and industry leaders to reduce the amounts of construction materials that end up in landfills and in response to construction material producers' interest in developing more sustainable strategies and business models (Leising et al., 2018; European Environment Agency, 2020). With its 90% gypsum content, plasterboard was understood to have recyclable value (Bermejo, 2014; Jiménez Rivero et al., 2016). When recycled, the material could increase the recycling targets of construction projects. In line with the European Commission directives from 2008 on demolition and construction waste management, this could help to achieve a higher percentage of material recovery from end-of-life buildings (European Commission, 2022).[2]

Although the current model of circularity either implicitly or explicitly promises to protect natural environments without restricting economic growth (Reike et al., 2018; D'Alisa, 2019), current global patterns of material and energy flows suggest caution about such a circular economy vision (Jackson, 2016; D'Alisa, 2019; Hickel and Kallis, 2020). As Kothari et al. (2019, p. 29) remarked, "the current pattern of global economy is far from current circular objectives". Arguably, decoupling economic growth and environmental impact has not been achieved at a significant ecological scale thus far (BIOS, 2020). In principle, natural resources and materials need to circulate within localised short loops in order to minimise material losses and energy consumption. However, since this principle "may imply curbing consumption and economic growth", industries that are in the position to reduce and refuse material throughput instead mainly focus on enhancing post-consumer waste management (Kirchherr et al., 2017, p. 226). As the flawed reality of the development of a circular economy operates within an economic model primarily concerned with profit maximisation, the idea of circularity is subsumed to the processes of recycling, dismissing strategies that could support more sustainable economies (Mahpour, 2018; Vermeulen et al., 2018).

In this study I consider processes of recycling as part of a cascading economic model that reproduces the destruction of construction materials and the exploitation of natural environments. As materials lose their structural integrity, degrading in quality and quantity over time, they can only enter loops of post-consumer waste management (Korhonen et al., 2018; Giampietro, 2019; Friant et al., 2020). To overcome these losses, new materials must be injected into the economy (Blankevoort, 2021). This supports a growing demand for raw material extraction that is embedded in global patterns of environmental inequity (Willow, 2018). In other words, the production of new materials generates, in return, demand for raw material extraction. As a result, current economies continue to exploit natural environments, extracting large amounts of raw materials and releasing unsustainable quantities of waste (Oksala, 2018; Kothari et al., 2019). As Hokkanen (2020) highlighted, physically extracting minerals in order to create financial value through international trade can be characterised as an exploitative practice, both in terms of its social and environmental impact. Profit-driven mechanisms feed on the ruins of construction materials through processes that demand, assure and remake the destruction of materials and their environments.

1.3. Non-destructive circularity

In this article, I reframe the idea of a circular economy within a lively debate on diverse economies, offering a new perspective to discuss a more sustainable and ethical circular model (Gibson-Graham et al., 2013, 2020; Demaria and Kothari, 2017; Kothari et al., 2019). In line with diverse economies thinking, I understand the economy as a site of ethical negotiations (Gibson-Graham and Miller, 2015; Gibson-Graham et al., 2020). As I reflect on the multiple dimensions of the economic activities of construction, I make destructive economic practices visible on the grounds of their exploitative character. To make destructive practices visible includes, for instance, critiques on the global organisation of raw material extraction and product manufacturing, and how these benefit transnational corporations (Acosta, 2013; Folke et al., 2019). As Gibson-Graham et al. (2020) suggest, diverse economies thinking provides an alternative reading of the economic status quo, with its dominant pathway of growing environmental degradation. The idea is to look for spaces of ethical negotiations that can challenge the current socio-material configurations (Gibson-Graham et al., 2020). To think in terms of diverse economies can generate ideas for economic models that could replace the unsustainable activities of building with more environmentally sustainable construction.

In order to offer a new perspective with which to discuss more sustainable activities of construction, I conceptualise a non-destructive model of circularity. My non-destructive economic principles derive from discussions on diverse economies, which sees economic activities as inherently social and ecological (Gibson-Graham and Miller, 2015; Gibson-Graham et al., 2020).

2 As part of a package of measures for the circular economy, the directives from 2008 were amended in 2018, strengthening rules on waste prevention and focusing on the responsibility of organisations to contribute to the reusability and recyclability of products. Plasterboard is understood to be recyclable, hence supportive of the new directives.

The principles of non-destructive circularity bring attention to the interconnectedness of social and ecological activities. By paying attention to dynamic contexts that incorporate both socioeconomic and biophysical constraints, a model of non-destructive circularity emphasises the interconnectedness of humans and natural environments. In other words, circularity involves the ways in which humans, non-humans and natural ecosystems organise themselves to sustain life and get on with living. This emphasises the necessity of interdependence with nature, rather than emphasising nature's exploitation, and places the needs and wellbeing of human and non-human beings as central concerns.

The ability to envision a non-destructive model of circularity can be hindered by the destructive premise of the current economy of construction. In the current model, it is near impossible to imagine activities of construction in ways that would not imply some sort of violence towards all the things that humans stand in relation to, including minerals, plants, animals and other humans (Shapiro and McNeish, 2021). The extraction of raw natural resources, fragmented landscapes, carbon-intensive transport, and the accumulation of synthetic chemicals and other invisible human-made materials in the air, water and soil are among the destructive aspects of building activities. In order to conceptualise more sustainable activities for construction, moving beyond the assumptions of destruction, I seriously consider the possibilities for non-destructive construction. Here, circularity can no longer be merely understood in terms of recycling (as the current systems would have it), but need to follow the principles of non-destructivity that (1) attend to the interconnectedness between socioeconomic and biophysical processes, (2) prioritise the long-term needs and wellbeing of humans and natural environments, (3) challenge profit-driven and growth-focused thinking by reducing and refusing material throughputs and (4) include ethical considerations for the material forms of circular economies that can support more sustainable building practices.

The principles of non-destructivity require a radically different ethic to the one underpinning the current model of construction. They need to move beyond the values of economic growth, instrumental rationality and anthropocentrism and move towards relational values, wherein humans and their environments are interconnected and interdependent. In doing so, a non-destructive model rejects current exploitative economic practices where raw material extraction and products manufacturing are merely driven by profit maximisation. The idea is to use the concept of care, focusing on wellbeing rather than on profit, to conceptualise circularity as a site of ethical engagements (Gibson-Graham et al., 2020). In this context, I understand *care* following the definition given by Rottenberg and Rottenberg and Littler (2020, p. 6) as the "individual and common ability to provide the political, social, material, and emotional conditions that allow the vast majority of people and living creatures on this planet to thrive—along with the planet itself." In other words, to imagine non-destructive principles requires taking an ethical and affective stance towards the material dimensions of buildings. The activities of caring for the construction materials forming buildings can expose mundane materials with low monetary value but high significance for the development of more sustainable economies. This affective concern for building materials is an ethical position that can also direct our attention towards the raw materials, or myriad of ecological and geological entities, entangled with the production and consumption of buildings.

2. Materials and methods

In this research, I followed the disposal of plasterboard in order to examine the treatment of the material at the end of its life and to discuss more sustainable economies of construction. *Following* is a method used in social science research that allows an in-depth inquiry into material objects and products, their systems and how they are produced, distributed and consumed (Marcus, 1995; Cook, 2004). It enables researchers to uncover often-overlooked processes, dynamics and connexions between people, materials and infrastructures (Appadurai, 1986; Kopytoff, 1986). In doing so, the process of following things is also used to understand interconnections and to explore and expose injustices, vulnerabilities and complexities (Sodero, 2019). My focus is on the disposal of plasterboard: the processes of its demolition, removal, recycling and landfilling, when the material is particularly apparent, regaining visibility after being sealed behind paint and wet plaster during usage. As plasterboard breaks and crumbles, it becomes physically visible in terms of its circularity, generating frustrations in terms of its transition towards more sustainable economies of constructions.

Following plasterboard enables an understanding of the material in its disposal and may yield new insights into construction and building sustainability (Evans, 2018). When adapted as a method for change, the method of following can illuminate "what works well and what can work better" (Sodero et al., 2021, p. 3). The following process motivates a fine focus on the current materiality of interior walls. By following material states, I am able to make a critique of the current material flows, flows which convey significant knowledge about ecological degradation. The method of following also enables the development of a certain sensibility in regard to alternative material realities. Following can open up opportunities to envision more sustainable interdependences and relationships that consider human and non-human wellbeing. In other words, paying attention to the disposal of plasterboard opens up opportunities to imagine the material and its economic systems differently. As I follow plasterboard in disposal, gypsum crumbs and dust tell a story that can hold the promise of possibilities for more sustainable circularities.

I use a design-informed approach to follow plasterboard and to discuss and imagine more sustainable alternatives to the status quo. My professional background in industrial and product design ensures a sensibility to the material reality of construction. I am aware of manufacturing processes and can understand plasterboard as a product that is part of complex physical processes of production, distribution and disposal. Since I observe material affordances, I am able to raise questions regarding design flaws and material inadequacies (Skjerven, 2016). However, I do not use this design-informed perspective as a problem-solving approach but rather use it as a way to challenge tacit norms and assumptions about construction materials and their circulation (Michael, 2012, 2016, 2017; Jönsson, 2015; Wilkie et al., 2015; Coombs et al., 2018). A design-informed approach enables me to further identify the complex socio-material dimensions of plasterboard. I use the approach to ask questions and explore alternatives to the current economies of construction (Bardzell and Bardzell, 2013; Malpass, 2013) as I trace the journey of plasterboard during its disposal, thinking with and through the construction material while also considering possibilities for sustainable change.

Data was derived from 3 months of fieldwork conducted in Finland in the summer of 2019. In order to follow plasterboard during its demolition, removal, recycling and landfilling processes, I conducted interviews with key stakeholders and made observations of prominent locations in the material's end of life. Access to people directly working with plasterboard and access to sites of disposal—including demolition and removal, recycling and landfilling sites—allowed me to closely follow end-of-life plasterboard. Two developers, a recycling facility manager, a landfill site manager, a construction site manager and a salesperson from a construction material producer agreed to participate in the study. Semi-structured interviews were conducted face to face and lasted for 60–90 min. Open-ended questions were sent to the interviewees in advance, together with the rationale for the study.

The research also included six observations, including two construction sites in Helsinki, a recycling facility located in Tampere, a plasterboard recycling facility located next to the plasterboard factory in Kirkkonummi and a landfill site located in Espoo. I purposely focused on sites where the physical reality of plasterboard was observable as I wanted to focus on the different material states of the material. Each observation lasted for 1–3 h and included walking interviews with people guiding me through the locations (Sheller and Urry, 2006). During the observations, I documented construction practices and material states—including technological, social and economic realities—using photographs. My observation guidelines were based on a conceptualisation of non-destructive circularity that included ethical considerations for humans and natural environments, and non-exploitative construction practices. I gathered data on so-called circular processes and documented humans and non-human entities influencing the disposal of plasterboard.

Interviews and observations were recorded and transcribed, and I also took notes to support the data. The transcribed textual data and my photographs were analysed using a coding process based on my conceptualisation of non-destructive circularity. I used three consecutive codes: (1) the apparent crises, controversies and frustrations generated by plasterboard, (2) sustainability issues related to the disposal of plasterboard and (3) the established economic narratives related to plasterboard and hints about non-destructive circularity. An abductive, iterative process was used for the development of the codes and the interpretation of the findings (Golden-Biddle and Locke, 2006). I generated short written analyses for each code, highlighting how gatherings of people, materials, machines, infrastructures, sites of construction and demolition, gypsum rocks and circular discourses were interconnected (Schadler, 2019). As I wrote my analyses, I also identified recurrent themes which I analysed further—integrating interpretive research and analytic methods—with a visual analysis.

In order to better understand the material states of plasterboard in the processes of disposal, I combined an analysis of interviews and observations with a visual analysis of photographs (Rose, 2014; Pink, 2021). The photographs were taken during my observations as I walked in various locations following plasterboard during its disposal. The pictures enabled me to reflect on a number of the material's states and on its entanglements with technological, social and economic realities. Although the photographs allowed me to show freeze-framed material states, I recognise that end-of-life plasterboard is a situated and dynamic phenomenon, set in motion through its demolition, removal, recycling and landfilling. The photographs were taken with the intent of showing moments in a longer social and ecological trajectory. Hence, my visual analysis requires contextualisation (Pink, 2021). In this article, my intention is to represent the crumbling and ageing of plasterboard in a Finnish context—perhaps destructive moments in the life of a certain type of plasterboard. The photographs work as critiques of the current economies of construction within the specific geographical location. They evoke novel perspectives, drawing connexions with more sustainable realities for the plasterboard. I combined data from interviews and observations with my visual analysis which allowed me to better understand small amounts of the material in the processes of its disposal; these were, too often, hidden in the large quantities of the global flows of construction materials.

My analysis includes a dialogue between two different sustainability discourses. This additional analytical layer enables me to discuss the events related to the disposal of plasterboard (1) from a technical perspective and (2) from an ethical and affective perspective. These two discourses represent different realities of circularity, both present in the phenomenon of the disposal of plasterboard. On one side there are the *hard facts* about plasterboard: chemical processes, compositional and structural qualities, the cost of the material at different stages and things that are included in current economic models. On the other side, there are ethical considerations: the emotional attachment and feelings of shame or proudness towards the material shown by the manual workers who closely handle plasterboard, a sense of care for what cannot be accounted for and what *feels right* to do with the plasterboard in its disposal. As I followed plasterboard, I brought these two discourses into dialogue in order to discuss the different material realities of the circular economies. This enabled me to show that certain technical aspects of the construction practices under study were closely tied to affective encounters with certain material realities.

3. Results

3.1. Tightly sealed

Plasterboard walls reflect the industrialisation and standardisation of a building industry that is moving towards highly complex and multi-layered constructions. In Finland, the pursuit of low, one-time costs from the 1960s onward has resulted in buildings that have been designed to last for only 50–60 years (Mattila, 2014). Conventional construction techniques have also shifted towards increasingly complex construction assemblies, where systems and components are intimately connected (Ghisellini et al., 2018). As a result, buildings have become disposable constructions containing complex material assemblages that are difficult to maintain and dismantle (Mattila, 2014). This multi-layering of materials was underlined by a project engineer working on a renovation project in Helsinki: "It [an interior wall] is going to have a plywood layer and then two layers of gypsum board, and then there is going to be some tiling upon it." In the construction of interior walls, plasterboard is tightly sealed with other materials.

Typically, multi-layer or single-layered constructions of plasterboard interior walls are surfaced with wet binding, wallpaper, paint or tiles, sealing them in place. In the process of assembly, plasterboard sheets are cut to the width and length needed to cover an area, generally defined by metal or wood studs. This work is done by construction workers who score the boards with a utility knife or an electric saw and screw the sheets to the wood or metal frames. Plasterboard enables workers to cover several square metres of wall at once, although it is typically physically demanding work as the workers manually handle large sheets of the material. Once fixed to the wood or metal studs with screws, the plasterboard receives a skim plaster finish to seal the gaps between the boards. This commonly involves taping the joint section and applying a wet plaster-based filler, making a level surface (Turner, 2007). At industrial construction sites, the wet plaster-based joint filler is often sprayed on the entire surface of the plasterboard wall before being sanded flat and painted, providing the desired seamless and smooth interior wall aesthetic.

Aesthetically, plasterboard wall constructions enable the construction of *all-white rooms.* Seamless and white interior walls convey brightness, spaciousness and minimalism and interior design trendsetters, bloggers and magazines praise the feeling of calmness, simplicity and cleanliness that is gained from the colour white (Bonney, 2019). White walls also reflect natural light around rooms during the dark winter months of northern latitudes. Additionally, all-white rooms represent a cultural norm for the Nordic countries, conveying ways of living and reflecting a lifestyle defined by the practices of the Law of Jante, a set of norms that confers negative connotations to individual self-expression (Gopal, 2004). Since white pigments were the latest new trend in the 1930s (Potvin, 2015), white rooms have become a sign of modernity, efficiency and functionality in drama-free, balanced and happy homes. As a result, the construction of seamless and white interior walls has been normalised by a range of stakeholders in the building sector. Developers recommend this aesthetic as a safe and convenient choice for the restoration and construction of buildings while construction material producers provide materials and finishes that enable the construction of this desired aesthetic.

Plasterboard is produced by continuously feeding a mix of calcined raw and recycled gypsum, additives and water between two cardboard layers (VTT Technology, 2013). This wet gypsum slurry reverts to its original stone state when the rehydrated calcined gypsum air dries and recrystallises, chemically and mechanically bonding to the front and back sheet of cardboard (Glittenberg, 2012; Saint-Gobain Construction Products Finland Oy, 2017; Knauf, n.d.). Plasterboard is a composite material as it consists of identifiable materials—gypsum and cardboard—which work together to create a product that can be used for the construction of interior walls (Rae, 2016; Augustyn, 2022). This assemblage of mineral and biological elements makes it costly and technically problematic to separate gypsum from cardboard at the end of the material's life (McDonough and Braungart, 2010). Recycled gypsum often includes pieces of cardboard that require an additional amount of water in the production of new boards. Using recycled gypsum requires more processing and drying time as the cardboard absorbs water. Recycled gypsum is also composed of thinner particles than raw gypsum, which not only increases the need for water and changes the consistency of the gypsum slurry but also decreases the strength of the freshly produced boards. In order to increase the strength of recycled plasterboard, manufacturers increase the quantity of glass fibres, which, in turn, can be problematic during recycling processes as glass fibres coagulates and conglomerates after calcination. As a result, plasterboard manufacturers can typically only include between 12–25% of recycled gypsum in the production of their new boards, the remaining amount of gypsum is sourced from raw gypsum (Saint-Gobain Finland Oy, 2019). In Europe, commercial quantities of raw gypsum are found in Spain (the main producer), Germany, Italy, the United Kingdom and Ireland (Jiménez Rivero et al., 2016). Raw gypsum is extracted from gypsum deposits formed over geological timescales, the result of millions of years of salt precipitation from ocean water (Kurt and Palacio, 2018). Recycled gypsum is sourced from manufacturing (pre-consumer) waste, construction waste (unused or damaged construction materials from retailers and distributors or leftover cut-offs from installation) and demolition (post-consumer) waste (Jiménez Rivero et al., 2016).

A focus on the chemical composition of plasterboard further reflects the complex material realities of interior walls. In addition to raw and recycled gypsum mixed with water, gypsum boards typically include foaming agents, starch and other additives. In line with the material transformation of the building and construction industry at the turn of the twentieth century, and the development of technological innovations and the promise of material novelty, plasterboard reflects the *modern interior* and its chemical innovations (Varner, 2020). As mentioned above, the material includes a range of synthetic additives, used to improve strength and durability, including anti-mildew, anti-flammability and anti-water absorption components. The exact composition of plasterboard, including the specification and amount of the additives, varies from one producer to another, with each producer keeping its specific formulas secret. Although this range of novel synthetic chemicals are only considered toxic once they have hazardous effects on humans (Rodrigues and Römkens, 2018), unknown amounts and qualities of the additives used for construction materials, some of them pollutants, diffusing into the air and entering soil and groundwater is a problem of particular environmental concern (Egeghy et al., 2012; Steffen et al., 2015). In fact, the production of construction materials such as plasterboard increasingly contributes to the extraordinary burdens of toxic chemistry, impacting on natural environments in unpredictable ways (Varner, 2020).

3.2. Destruction

Under the current construction techniques, plasterboard cannot be reused and ends up being destroyed in the processes of disposal. A recycling facility manager who has done some demolition work explains: “I think it’s so hard because you put in so many screws. When you take off one off [each board separately] at a time, it is not good because it takes so much time, and time is money; so, I think it is not . . . Worth it [sigh]”. Separating, sorting and recovering plasterboard is laborious and time-intensive, often making the work costly and unacceptable from an economic perspective. Reflecting on how plasterboard could keep its structural integrity in the processes of disposal, one construction worker highlighted the following point: “When you fix it to the frame, you use screws so... Basically, it is impossible to take all of it away.” The long-established practices of complex construction assemblies result in disposal techniques that destroy the functionality of plasterboard sheets. “There are as many methods as there are people knowing how to work with that [the demolition of plasterboard]” one demolition worker remarked. However, demolition happening within demanding time constraints typically involves hydraulic equipment such as small excavators. Workers mechanically pull interior walls down, tearing apart the plasterboard as it is still attached to wooden and metal studs, then they manually sort and collect pieces of the material.

The only recovery option for these pieces of demolished plasterboard is to potentially enter recycling loops. Although recycling can allow for a rapid reduction of resource consumption, it reduces the quality of the material over time and is unable to avert exhaustion (Korhonen et al., 2018; Giampietro, 2019). Demolition can also generate non-recyclable gypsum waste (Jiménez Rivero et al., 2016). Non-recyclable gypsum waste refers to gypsum waste that does not comply with plasterboard recyclers’ acceptance criteria (Jiménez Rivero et al., 2016). This loss of the quantities and qualities of plasterboard in recycling processes is further described in Section 3.3. In the current economic models, the recovery of gypsum waste depends on the financial value of the material and the competitiveness of the recycling route (which is mainly determined by the cost of landfill disposal or landfill bans) (Jiménez Rivero et al., 2016). In terms of its financial value, plasterboard is one of the most hierarchically inferior construction materials. In disposal, the material has, for instance, a lower financial value than metal or burnable materials, such as plastic, organic waste and wood. In Finland, plastics, organics and wood (which are burnable materials) are perceived as economically more valuable than gypsum, hence they are perceived to be more desirable to sort. This is because Finland heavily relies on bioenergy for the production of heat energy (Statistics Finland, 2018). The low recycling value of plasterboard and small amounts of the material (for example, there might only be a few square metres of plasterboard walling) decrease incentives for its recovery.

In the current consumption-oriented economy, the consequence is a demand for raw materials that exceeds the availability of recyclable materials (McDonough and Braungart, 2010; Allwood, 2014; Mahpour, 2018). The expanding production of plasterboard and its distribution in the building market generates increasing demand for raw gypsum extraction (Global Gypsum, 2022). In 2009, more than 1,600 million square metres of European interior surfaces were covered with plasterboards (EuroGypsum, 2009). The European gypsum industry has an annual turnover in the range of seven and a half billion euros (EuroGypsum, 2018). As Shapiro and McNeish (2021) highlighted, the intensification of capital-seeking investment in real estate goes hand in hand with the increasing production of construction materials and the intensification of the global flow of raw materials. This growing investment in real estate, combined with the demand for plasterboard and need for raw gypsum in the production of new board, is certain to increase in the future (Statistics Finland, 2022). As a result, the growing demand for raw gypsum, coupled with advances in mining technologies, is depleting deposits (Moore et al., 2014; Kurt and Palacio, 2018). Although gypsum resources are understood to be sufficient to meet demand looking into the future, the mineral gypsum cannot be replenished in a human lifetime or even in many human lifetimes (Jiménez Rivero et al., 2016). Raw gypsum extraction and transport also support an industrial system that is principally reliant on fossil fuels (Bocken et al., 2016). In Finland, for instance, the gypsum rocks used for the production of Finnish plasterboard have travelled thousands of kilometres from their location of origin.

Demolition sites with low amounts of plasterboard do not have a designated gypsum recycling container, which means that plasterboard ends up in mixed waste. As a construction worker remarked: “On this site we don’t have designated metal containers for gypsum. Now, if the amount accumulates, I guess we have to get them [gypsum containers].” Only large-sized pieces of plasterboard make their way to such a container. The lack of a container for gypsum means that demolished plasterboard often becomes part of piles of mixed waste. As we searched for a gypsum waste container on a construction site, walking around the different waste containers, a building site manager remarked: “I think it is in the mixed waste container... [they walked around a metal container] Based on the... I will just check the sign.” She searches for a sign saying *gypsum* (*kipsi* in Finnish) and further remarked, “This is mixed waste [*sekajäte* in Finnish], this is metal, so... So, I think they [the demolition workers] put it in here... I don’t know.” On this specific construction site, plasterboard disappears in a container for mixed waste as it does not have a gypsum recycling container.

I discussed the fate of removed plasterboard with a construction worker who explained: “Basically they [demolition workers] put wood in one container, stone in another, iron and metals in yet another and, then, there is mixed waste [nervous laugh].” The nervous laughter of the worker highlights the uncomfortable truth of the situation, as mixed waste is undesirable in terms of sustainability but unavoidable under current construction and demolition techniques. In Finland, between 2018 and 2019, ∼80–85% of plasterboard was collected with mixed waste and sent to landfills, while only ∼15–20% was collected for recycling and used in the production of new boards (Saint-Gobain Finland Oy, 2019). Once removed from construction sites by demolition workers, this plasterboard is delivered to recycling and landfill facilities.

As I walked around a pile of mixed waste at a recycling facility located in Tampere, a manager remarked: “Yeah, everything is here. So they [the demolition workers] don’t sort gypsum out because it is expensive [to sort plasterboard].” Figure 1 shows a pile of mixed demolition waste containing plasterboard. In 2019, delivering mixed waste to recycling facilities cost demolition companies 60% more than delivering separated gypsum waste to recycling facilities. Gypsum is worth 80 euros per tonne, compared with non-sorted mixed waste which is worth 200 euros

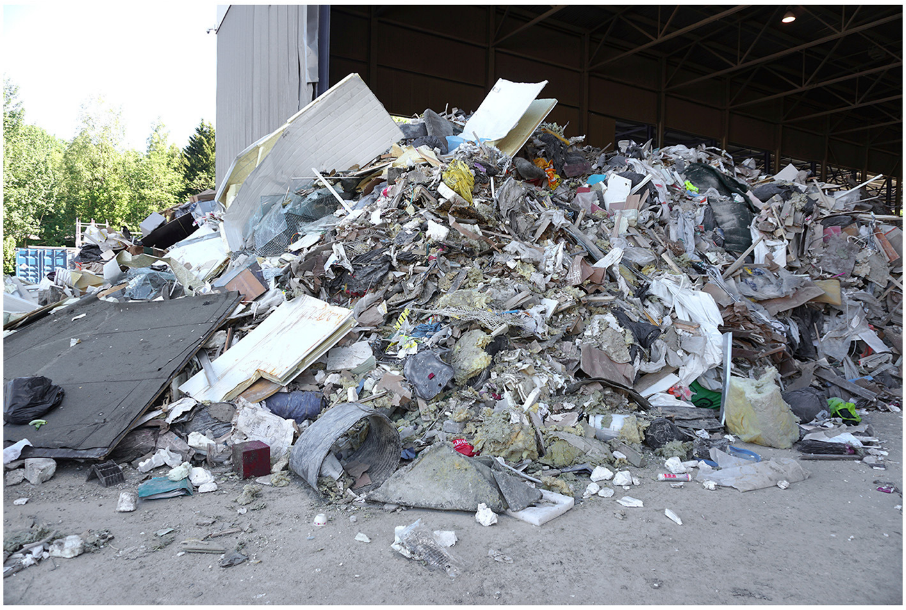

FIGURE 1
A pile of mixed demolition waste containing plasterboard.

per tonne. Despite this, many companies preferred to deliver gypsum to waste processing and recycling facilities as part of mixed waste. In the current economy, the cascading effect of the cost value of plasterboard, combined with the labour-intensive sorting of the material, creates little monetary incentive to consider recovering the material. The financial value of new plasterboard is being destroyed as it becomes gypsum waste. The price of plasterboard might increase during the usage phase, depending on the market value of the building. However, in processes of disposal, the monetary value of plasterboard disappears and turns negative. The clear decline of monetary value from new plasterboard to recycled gypsum waste allows producers to buy recycled gypsum at a fraction of the new product price. In other words, manufacturers erase financial value through the destruction of plasterboard.

In Finland, plasterboard from demolition sites can be delivered to general recycling facilities, to landfill sites or delivered directly to the recycling facility of the plasterboard manufacturer if separated from other materials on the demolition site. Similarly to recycling facilities, landfill sites have been separating gypsum waste from other waste since 2017, following a 2014 European Commission legislative proposal aimed at reducing, and phasing out by 2025, the landfilling of recyclable waste (European Commission, 2022). At recycling facilities, piles of mixed waste, including plasterboard, pass through successive series of tumblers eliminating pieces of material that are unsafe and inconvenient for recycling workers to handle. Tumblers roll and shake construction materials, separating small pieces, the pieces that are too small to count, from the larger pieces that have financial value for recovery. In this process, gypsum crumbs and dust gather on top of and under recycling machines. Larger pieces of plasterboard make it to a conveyor belt where recycling workers separate organic materials, metal, aluminium, plastic and gypsum. Various techniques are emerging with which to separate the gypsum core from the cardboard surface through a succession of tumblers and air blowers. However, only a fraction of the cardboard can be detached from the gypsum core because the cardboard has been mechanically and chemically bonded to the core during the production process.

When brought to a landfill site, mixed waste that includes plasterboard is processed by workers operating heavy machinery who sort out large pieces of materials. To separate plasterboard (already broken in the processes of demolition, then transported by trucks and emptied onto the sorting field) from mixed-waste piles further destroys it. A worker remarked: "It [the plasterboard] is a difficult type of waste because if you start to break it into pieces, the amount of *dust* [emphasise] that comes from it—it is unbelievable. So, you have to look at how you could do something with it [to sort it out] and, at the same time, think about work safety." Contrary to expectations, the seemingly harmless plasterboard, when it reaches its end of life, becomes a work-safety issue. Inevitably, as plasterboard breaks into smaller and smaller pieces and dust, the material also vanishes, becoming unaccounted for, in the form of gypsum crumbs and dust. A landfill worker remarks: "The claw excavator is quite big, so you can't take little pieces from here and there. I don't know how much gypsum is... [separated from the pile] beyond... on those loads." Plasterboard further loses financial value when it is part of mixed waste as sorting processes further break down the material. Blending with the soil of the landfill site, plasterboard becomes more and more elusive and invisible.

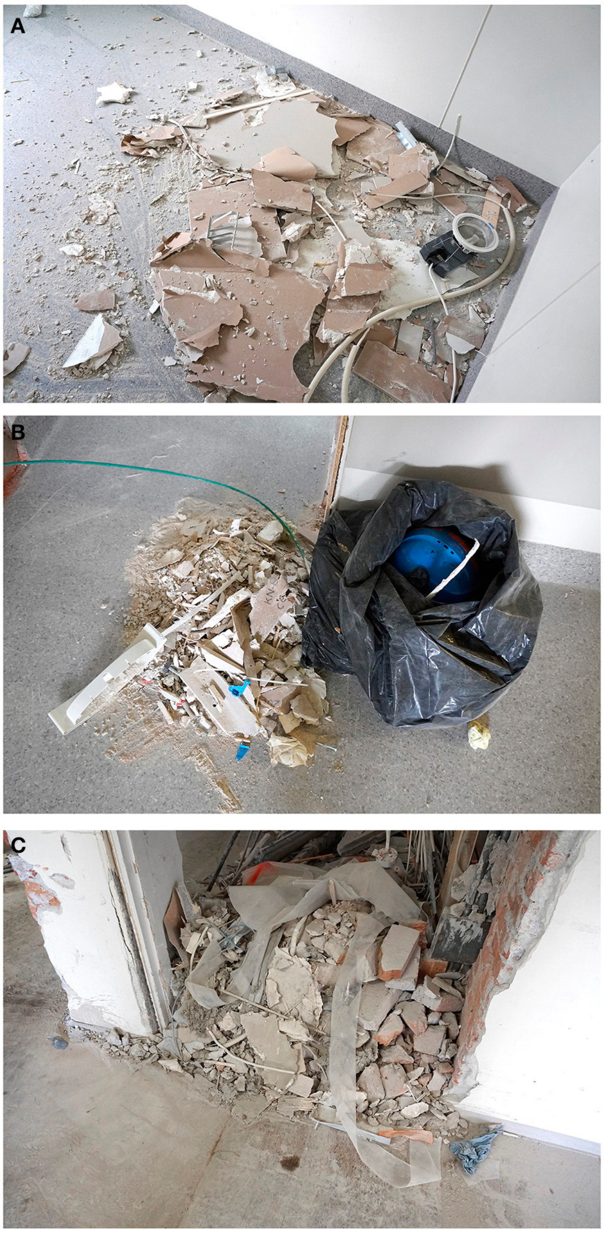

FIGURE 2
(A–C) Crumbled plasterboard and gypsum dust at a construction site.

3.3. Crumbs and dust

As I attend to the disposal of plasterboard, I am concerned with telling a story of the minuscule, the too-small-to-count materiality of circular economies.

The set of three photographs above (Figures 2A–C) was taken during a visit to a construction site, the renovation of an existing building located in Helsinki. The photographs display pieces of crumbled plasterboard and gypsum dust swept into piles on the floor, waiting for more unwanted materials before their removal from the site of construction. The images show ripped cardboard still holding pieces of their gypsum core, and crumbled plasterboard partially screwed to metal studs. Construction workers' footsteps mark the remaining white dust of plasterboard covering the floor after demolition. Figure 2A shows how broken plasterboard has been gathered with plastic pieces (including electric tubes and sockets) and small metal parts in the corners of a room, brushed there by construction workers. In Figure 2B, a small pile of mixed waste has been gathered next to a large plastic garbage bag, mixed waste waiting to be wrapped and removed from the site. Figure 2C displays more broken pieces of plasterboard, some plastic wrapping and part of a brick wall, all shoved into an alcove, out of the way of the construction work. Soon-to-be-removed waste piles capture the quantity and quality of crumbling and dusty plasterboard found at the construction sites. The rubbish bags will hide the last remnants of miscellaneous entities—a small amount of stuff to be removed and forgotten.

While walking in the corridors of the construction site, I paid attention to the similarity (in colour and feel, although far apart geographically) between the plasterboard dust and the white dust of gypsum quarries, where gypsum rocks are extracted. The once valued (in a monetary sense) gypsum rocks have mutated into undesirable dust. This dust holds *memories* of being a structurally sound material that enabled the construction of interior walls. It also holds memories of being a raw material, extracted by mining, through the blasting and drilling of gypsum rock (Jiménez Rivero et al., 2016). In other words, the crumbs and dust hold memories of diverse and rich natural gypsum ecosystems, transformed into vegetation-scarce and degraded soil areas by activities of mining (Ballesteros et al., 2017; Kurt and Palacio, 2018). While observing the plasterboard dust of the construction site, I was surprised to find myself concerned about the soils from which the gypsum was sourced, located thousands of kilometres away from the plasterboard dust, soils that have been irreversibly changed in significant ways. As I pay attention to plasterboard dust on the construction site, I raise affective concerns about the biophysical inputs that are transformed and stocked in buildings.

Crumbled and dusty plasterboard vanishes from sight through its demolition and under piles of mixed waste. The small and minuscule parts are not reusable for the construction of new interior walls, and they are broadly conceptualised as *irrelevant waste* in the disposal process. The term waste refers here to an unwanted or unusable material, which is typically not perceived as financially valuable (for instance, due to its state or size). However, this waste perceived as financially irrelevant can change the work of construction workers (Gregson et al., 2010). People working closely with plasterboard waste and in environments where crumbs and dust occur are impacted in relevant ways. The act of removing crumbling and dusty pieces of plasterboard from a construction site does not come without work and care; small pieces of plasterboard increase the need for protective gear (such as masks, gloves and glasses) and they require working with tools and machines, such as a broom or a vacuum cleaner, in order to manually handle the dust. On the demolition site, the plasterboard requires careful handling as gypsum dust is a safety hazard and containing it is a constant challenge for workers.

The disposal of plasterboard creates safety hazards and a non-reusable material. The inexpensive and often overlooked plasterboard is at its lowest value and lowest point of its fame. However, some people (the workers closely handling the material in the processes of recycling and landfilling) display some ethical considerations towards the material. A recycling worker remarked, while walking next to a pile of used gypsum: "We are dreaming of having a roof [nervous laughter] to cover it." Another worker added: "Yeah, because of course it is bad if it is raining a lot ..." What is bad here is that the amount of rainwater could damage the already crumbling gypsum waste, which could potentially be used as a resource for the production of new plasterboard. The worker's laughter underlines the uncomfortable truth: there was a sense of shame and powerlessness regarding the careless lack of a protective roof for the end-of-life gypsum. Caring for gypsum waste is desirable, but currently, it lacks the type of infrastructure that would enable it. This instrumental relationship with plasterboard reflects a "waste-to-resource paradigm", wherein gypsum is consistently described in terms of being waste or being a potential resource (White et al., 2015, p. 167). However, the above worker's laughter also highlights some affective concerns for the crumbling gypsum waste laying roofless at the recycling facility and emphasises the need for the just handling of the material.

When discussing how plasterboard triggers ethical considerations with a recycling facility manager, I asked what the material would say if it was given the opportunity to have agency in processes of disposal. The manager said, in a soft and quiet voice: "Do something!". They reflected on construction practices which are problematic for disassembly, the multi-layered building techniques which seal plasterboard in with a range of other materials. As the manager envisioned a different life for the material, they expressed affective concerns, a sense of respect for the material and a sense of shame for the current practices that hinder recovery processes. The crumbs and dust of end-of-life plasterboard evoke powerlessness and require apologies as the current economies of construction fail to recognise what is worthy. Plasterboard, even at its lowest value, can still trigger ethical concerns from people: concern for the dust that covers the construction site, concern for the extraction of raw gypsum or concern for water dampening the material. Discussing end-of-life plasterboard with the manager opened ways to think about (and feel for) the materiality of buildings, which threatens the development of more sustainable economies of construction.

4. Discussion

The current economic model supports the ongoing destruction of plasterboard and the continuous extraction of raw gypsum for the production of new interior walls. Raw gypsum is transformed into a widely distributed product, the majority of which, after a building's renovation or demolition, ends up as unusable waste. In other words, gypsum deposits and their ecosystems, after millions of years of precipitation, are physically destroyed in order to produce plasterboard which is, at the end of its life, demolished and cannot be reused for the construction of new buildings. My findings show that the loss of structural integrity and unpredictable crumbling of plasterboard seen in its disposal generates cascading effects, that is, the sequential and consecutive decline of material financial value. I also show how the demolition, removal and recycling of plasterboard generates inadequate sizes, shapes and states of the material which are unsuitable for recovery and which are often neglected because of their low monetary value. As it breaks and crumbles in current processes of disposal (where laborious and time-consuming alternatives are financially unviable), plasterboard cannot easily be processed for recycling or reuse. This study demonstrates how the workers closely handling plasterboard are immersed in a specific material reality as they have a close relationship with the gypsum crumbs and dust. This raises concerns regarding the carelessness of certain construction practices, such as sealing plasterboard sheets behind a wet finish, and demolition processes that destroy the integrity of the material.

4.1. Material reality

Current literature on the theory and practice of circular economies in relation to the built environment still misses opportunities for discussing more sustainable economic models. Although research on circularity highlights the sustainable potential for the adoption of circular strategies in construction, the focus is mainly on waste management (López Ruiz et al., 2020). The research omits consideration of the material reality of construction waste. In this study, I follow end-of-life plasterboard to show the intricate realities of the material. Plasterboard is mainly destroyed in the processes of disposal, resulting in unquantified amounts of gypsum crumbs and dust which *disappear* from current economies. My findings show that the current circular economy makes these small and financially less-valuable material dimensions of construction conceptually invisible. As unknown quantities of plasterboard are brushed aside by construction workers, the amounts of the material in buildings that are now being demolished cannot be fully recorded and the amount of plasterboard being disposed of remains uncertain. In fact, under the current construction and demolition techniques, the material composition of demolition activities cannot always be predicted (European Environment Agency, 2020).

The phenomenon of plasterboard in disposal is more complex than a simplified conceptualisation of circularity, wherein construction materials are accurately accounted for and *put back into loops*. In this research, I expose a different material reality for plasterboard by attending to gypsum crumbs and dust. The disposal of parts of plasterboard that are too small to count highlights the limits of the material's capacity for circulation. Although the crumbs and dust are unable to play a role in the current circular economy, their consideration allows for a better understanding of the current economies of construction and can make plasterboard's inadequate materiality for circulation visible. I draw attention to the large and small amounts of raw materials destroyed in the current economies of construction and suggest that, when discussing opportunities for more sustainable circular economies, the gypsum crumbs and dust are ethically significant. I show that small quantities of the construction material can trigger ethical considerations for the becoming of current constructions, that is, what comes after the crumbs and dust.

4.2. Diverse circularities

The details of plasterboard's material states inform a different material reality for building activities. In this study, I bring to the foreground what current economies of construction make invisible and how it is made invisible. I suggest that mundane and neglected matter, gypsum crumbs and dust, is not merely residual plasterboard rejected from the current circular economy. Where there are gypsum crumbs and dust, there is a certain economy of construction and a certain type of destructive circularity. Hence, the disposal of plasterboard has consequences for the development of more sustainable circular economies (Robbins and Moore, 2015). By examining a certain material reality of plasterboard aim to provide an alternative reading of a simplified story of plasterboard and open an imaginary related to more sustainable economies of construction. I suggest that making sites of disposal visible can be the first step in imagining non-destructive circularities. In this new reality, materials would not merely be resources or waste in a consumption-driven economy, they would also represent and enact a multitude of ethical, social and ecological relationships that reach beyond the specific places in which they are produced, consumed and disposed (Shapiro and McNeish, 2021).

By attending to debris and residues, my analysis sheds light on a different type of economic model wherein it is worth caring about small amounts of gypsum. As Balayannis (2020) remarks, the small is a crucial point for analysis because it can be a catalyst for designing, managing and governing materials differently.

As I pay attention to broken plasterboard that is generally considered irrelevant in events related to its disposal, I suggest that there are opportunities to imagine circularity otherwise. Affective encounters and ethical considerations related to plasterboard create a space in which to discuss the possibility of diverse economies, beyond the mainstream economy, moving towards circularities that are concerned with the results of destructive practices. Small amounts of gypsum crumbs and dust that are unaccounted for in the current economic models can play a role when discussing opportunities for a less destructive circular models. Gypsum crumbs and dust inform us of another conceptualisation of circularity which includes ethical consideration of the material reality of current buildings.

In this article, the disposal of plasterboard gives us hints related to imagining construction materials and their economic systems differently. My empirical research is a starting point for reformulating the current model of circularity. By following plasterboard in disposal, I gathered critiques on current practices and demonstrated possibilities for imagining other responses to unsustainable construction. My findings suggest that destruction can be addressed through consideration of the ethics of the life of plasterboard. For instance, end-of-life plasterboard triggered a sense of care from some of the workers who operated closely with the material. The people interviewed were displaying a sense of care through signs of shame related to material (a lack of gypsum sorting container, a lack of protective roof for recovered gypsum). Decisions about the disposal of the material, although challenged by the current economic models, were (at times) informed by affective concerns for the end of life of the material. These ethical considerations, and the practices of care that follow, are tightly linked to the ways in which materials change and morph during their disposal. Feelings of shame, disempowerment or respect evolve alongside a range of material states as the morphing of boards into crumbs and dust affected workers in physical and emotional ways. As I present different realities of circularity, I unfold a dialogue between the technical aspects of the disposal of plasterboard and affects towards destructive processes. This informs a more complex reality in regard to construction and opens up the possibility for generating some other responses to destruction.

5. Conclusion

In this study, I demonstrate that plasterboard usage is anything but circular—at least it is not circular in a non-destructive sense. The physical outcome of the current circular practices does not correspond to the imaginary of efficient waste management through the recycling of plasterboard. Moreover, the current circular *fix*, a growth-focused and technocratic solution, is failing to address the variety of opportunities for more sustainable construction. International corporations and governments invest in minimising construction and demolition waste streams by transforming waste markets with higher recycling rates (European Commission, 2016; Jiménez Rivero et al., 2016; GtoG, n.d.), while omitting to address both the longer-term consequences of certain construction materials that are made invisible in the processes of their disposal and their interactions with human societies and natural environments. This current circular fix enables financial institutions and large corporations to evade their responsibility in regard to driving the current social and environmental crises.

Moving forward with research on circular economies, I suggest that a fine focus on the current materiality of buildings and a certain sensibility for mundane construction materials might give directions in which to move towards more sustainable economies. The entanglement of the material reality of plasterboard and the work of people closely handling the material when disposing of it can raise questions about the adequacy of a material world that requires attention. One way of moving towards more sustainable economies of construction would be to select materials for more sustainable circularities. A range of stakeholders in the building industry already recommend using construction materials according to their social and environmental performance in terms of reuse, carbon management, water stewardship, use of renewable energy, social fairness and health (Arup, 2018; Green Building Council Finland, 2018; Cradle to Cradle Certified, n.d.). Construction materials which are durable and reusable, where components or substances can easily be separated from one another, are more desirable (Adams and Hobbs, 2017; Green Building Council Finland, 2018). More sustainable economies of construction prioritise the use of materials which can support the long-term wellbeing of humans and natural environments. Ultimately, to discuss opportunities for non-destructive circularities also requires the rejection or refusal of construction materials which cannot support more sustainable and ethical economies.

In this article, I question the presence of plasterboard in buildings, and perhaps, politely ask for its use to cease. The critique of non-destructive circular economies must go far beyond the critique of waste management efficiency and include a broader reflection on what constitutes the ethical modes of constructing buildings. The response to that critique has to do with concepts such as shared vulnerability, responsibility and care—notions that can all have subversive implications for the current economies of construction when taken seriously.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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