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RESEARCH ARTICLE

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Utilisation of certification schemes for recycled products in the Australian building and construction sector

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Abstract

Recycled product certification (RPC) schemes may prove useful to ensure the desired quality and gain buyer confidence in purchasing products with recycled content (PwRC). RPCs are relatively new to the sector and have not been widely adopted. Hence, this study aims to investigate the implementation of RPC in construction projects using a multiple-case study approach. The analysis reveals that a large proportion of respondents were unaware of these schemes. The study finds that while a majority favoured RPC application, there were significant variations in responses among stakeholder groups. Moreover, the study identifies six advantages and seven significant barriers associated with the use of RPC in the sector. This study recommends leveraging education and supportive regulation for the effective implementation of RPC. In particular, the policymakers who intend to embed RPC in procurement policies for purchasing PwRC can learn about the identified loopholes and strategies and address them accordingly.

KEYWORDS

Australian construction industry, circular economy, stakeholders, sustainable supply chain, waste recovery

1 | INTRODUCTION

The issue of construction and demolition (C&D) waste has become a source of concern in many countries. The construction industry now produces about 35% of the total waste sent to landfill worldwide (Zheng et al., 2017). Global efforts have been directed towards sustainable management of the C&D waste stream, which has driven the C&D waste recovery rate to an acceptable level in several countries, though a few countries have fallen behind. Despite the existing disparity in C&D waste recovery rates among OECD countries (Table 1), several estimates have predicted that fundamental changes are underway that would completely alter the C&D waste management environment. Recent analyses project that the global C&D waste recovery market will reach 149–300 billion US dollars by 2027–2028 (Allied Analytics LLP, 2023; IMARC Group, 2023; Report Ocean, 2021).

Another recent change on the global scale has been the introduction of waste regulations banning waste and recyclables exchange between countries, which has further pressurised developed countries to improve their national waste recovery targets (Shooshtarian, Caldera, Maqsood, Ryley, & Khalfan, 2022).

Abbreviations: C&D, construction and demolition; CE, circular economy; GBCA, Green Building Council of Australia; ISC, Infrastructure Sustainability Council; PwRC, products with recycled content; RPC, recycled product certification; UDIA, Urban Development Institute of Australia.

TABLE 1 The latest rates of C&D waste generation and recovery in various countries.

Country	Waste generated (Mt/)	Recovered (%)	Year	Source
Australia	29	77	2021	Blue Environment (2023)
Brazil	48	20	2021	ABRELPE (2022)
China	2600	n/a	2020	Deng (2022)
Germany	229	88	2020	Destatis (2021)
India	150	1	2019	BMTPC (2021)
Japan	n/a	97	2018	Ministry of Land Infrastructure Transport and Tourism (2020)
United Kingdom	67.8	92.3	2018	UK Government Statistical Service (2021)
United States	600.3	76	2018	US EPA (2020)
Russian Federation	15–17	5	2019	The Federal Service for State Statistics (2019)
Italy	59	75.1	2018	ISPRA (2020)
France	227	77	2020	ADEME (2021)

Australia is no exception to this issue, and the waste recovery industry has been under immense pressure to meet the ambitious targets set by Federal and state governments. The building and construction sector is delivering construction projects (i.e., housing, buildings and transport infrastructure) at an unprecedented rate. Between 2009 and 2019, the sector's annual average growth rate was 3.33% (Kelly, 2022). Unsurprisingly, this quantity of construction generates a considerable amount of waste, reaching 29 million tonnes in 2021. In recent years, landfill levies have encouraged waste avoidance and resource recovery, boosting the demand for waste recovery services. The latest Australian National Waste Report (Blue Environment, 2023) indicates that national C&D waste recovery has improved and achieved 80% in 2020–2021. In light of this achievement, the next emerging issue is the low demand for products with recycled content (PwRC) in the sector (Active Sustainability, 2020).

Various reasons have been provided for this low demand, including increased cost of energy and transport, lack of knowledge on PwRC, low quality and possible contamination, lack of market, limitations caused by specifications, standards and permits, lack of a consistent waste data and reporting system, limited acceptability and negative perceptions and lack of government incentives (Active Sustainability, 2020; Ratnasabapathy et al., 2021; Shooshtarian et al., 2020). This issue has been reported to have real impacts on sustainable C&D waste recovery (Shooshtarian, Caldera, Maqsood, Ryley, Wong, & Zaman, 2022). The impacts can include, but are not limited to, unwillingness to invest in cutting-edge waste recovery technologies, failure in reducing PwRC cost units and massive material stockpiling. Poor market conditions for PwRC deter potential investors from funding the modernisation and development of the existing and new waste recovery facilities. The low demand for these products may also limit the supply chain growth, which translates into higher cost units due to the lack of economies of scale. In specific cases where governments financially incentivise recycling as part of national sustainability improvement initiatives, the absence of demand for these products can lead to the accumulation of substantial stockpiles of PwRC.

A recent report commissioned by the Australian Department of Climate Change, Energy, the Environment and Water (Equilibrium, 2019) highlighted several challenges that are hindering the use of PwRC in the sector. These include inconsistent procurement of PwRC among Australian states and territories, imposition of various state product specifications, cheaper virgin alternatives, ineffective communications between parties involved, the lack of regulatory support for using PwRC and ineffective sustainable procurement practices. The latter has a pivotal role in the optimised uptake of PwRC but requires the right tools and policies to occur (Shooshtarian, Maqsood, Wong, & Bettini, 2022).

Currently, PwRC is marketed in two ways: non-certified and certified. In Australia, non-certified PwRC constitutes the majority of the output of C&D waste recycling facilities. Certification is one available tool to fulfil end-users' increasingly stringent expectations for procuring high-quality PwRC. Therefore, in the building and construction sector, the application of recycled product certification (RCR) is recommended as an option to optimise PwRC uptake (Ismail, 2022; Shooshtarian, Caldera, Maqsood, Ryley, Wong, & Zaman, 2022), and more importantly, help governments and the sector achieve C&D waste recovery targets (Bao & Lu, 2020; Pineiro-Villaverde & García-Álvarez, 2020).

RPC is a circular economy-based strategy that is designed to assure PwRC quality, performance, environmental friendliness and safety (Ghisellini et al., 2022). These certification schemes reassure end-users of the satisfactory application of PwRC and may also include parameters such as energy use, air and water, emissions emerging from manufacturing, disposal and use of PwRC. When certification is awarded following technical material testing and quality control, it may optimise the adoption of PwRC, promote the sale of renewable products and ensure the smooth operation of the waste recovery industry (Li et al., 2019).

In the majority of states that use these certifications, there are three processes involved in awarding a project (rather than a product) a sustainability grade. In the first step, materials are created following the specifications normally issued by local authorities for a variety of applications. In the second step, independent auditors and organisations evaluate and grade the PwRC based on their quality, performance and level of purity. In the last step, the sustainability rating awarding organisation grants credits in various forms, such as points accumulating towards a given number of stars, to a construction project in recognition of the project owners' efforts towards the usage of PwRC and overall sustainability (Figure 1).

This RPC initiative has been implemented worldwide, in Europe (EQAR, 2018; Ghisellini et al., 2022; Rochikashvili & Bongaerts, 2018), the UK (Darnall et al., 2018), the USA, Russia (Kravtcova, 2021), China (Su et al., 2020), Singapore (Low et al., 2014) and South Korea (Wang et al., 2019). The initiative has also been recently introduced to Australia, but current programmes are still at the early stage of development and adoption. Some examples include EPD, Good Environmental Choice Australia (GECA) Standard, Global Green Tag Certification, CodeMark Certificates and ViroDecs™ Environmental Product Declaration.

In the Australian context, the majority of national and jurisdictional waste policies such as the National Waste Policy (2018) do not provide support for the application of RPC. However, some publications from the industry and government recommended the use of RPC to enhance PwRC utilisation in construction projects. Table 2 summarises some of these reports.

1.1 | Aim of research and paper structure

This research aims to investigate the potential of using RPC in the building and construction sector. This study's primary research question is: *How do key stakeholders in the Australian building and construction sector perceive the application of RPC?*

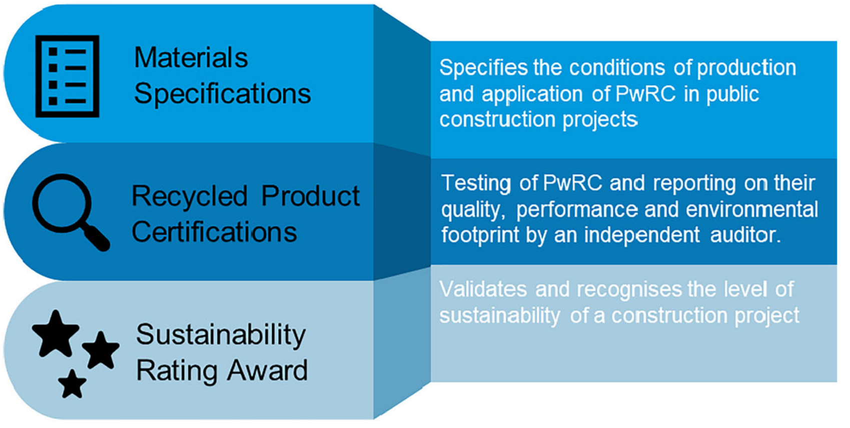

FIGURE 1 Three programmes that are related to PwRC application in construction projects.

TABLE 2 A summary of Australian reports highlighting the necessity of using RPC when purchasing PwRC.

Organisation	Report title	Description	Reference
Australian Road Research Board	*Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure*	• Supports encouraging consistent product evaluation and certification schemes for using PwRc	ARRB (2022)
Green Building Council of Australia (GBCA)	*Recognised Product Certification Schemes and Standards* *Assessment Process for Product Certification Schemes*	• Has officially launched a platform to recognise and promote legitimate green and recycled product certifiers in Australia • Is developing a framework known as responsible products framework, to recognise the use of certified PwRC in building projects. This builds on the previous GBCA attempt to set the criteria for recognising product certification schemes designed to be used for the Green Star rating	GBCA (2015) GBCA (2022)
Australian Parliament	*From Rubbish to Resources: Building a Circular Economy*	• Recognises the need for improving certification and labelling in relation to product stewardship schemes • Recommends national specifications and certification to use recycled content	Commonwealth of Australia (2020)
Australian Packaging Covenant Organisation	*Supporting government procurement of recycled materials*	• Promotes RPC as a supportive strategy for government PwRC sustainable procurement	Action Sustainability (2020)

The remainder of the paper is structured as follows. First, a brief review of the limitations and solutions is provided. Next, the research methodology, including case study projects, is described. The analysis of participants' responses captured in the interviews is then presented, which examines various aspects of RPC application in the sector, such as their current application, stakeholders' awareness, and their support and perceptions. In the following sections, the discussion and conclusions of the findings are provided.

2 | LITERATURE REVIEW: THE APPLICATION OF RPC IN THE BUILDING AND CONSTRUCTION SECTOR

This section provides a brief review of the literature regarding the benefits, drivers and issues around employing RPC in the building and construction sector. Overall, the analysis of the literature revealed that there is scant information on RPC utilisation in the global and Australian building and construction sector. Specifically, the existing research in this area lacks insights into the sector's key stakeholders' perception of using RPC during the procurement of PwRC.

2.1 | Benefits of RPC applications

In some research, the lack of RPC application has been identified as a barrier to optimised uptake of PwRC in the sector (Véliz et al., 2023), sustainable waste recovery (Di Foggia & Beccarello, 2020), stimulating market demand for PwRC (Shooshtarian, Caldera, Maqsood, Ryley, Wong, & Zaman, 2022; Su et al., 2020), and the implementation of a circular economy in the construction industry (Christensen et al., 2022; Debacker et al., 2017). Hence, all businesses operating in a supply chain may benefit from developing RPC to confirm the characteristics of their products required by purchasing organisations or individuals. An evidence-based study highlighted RPC as one of the multiple measures driving the creation and stimulation of end markets for PwRC in Australia (Shooshtarian, Caldera, Maqsood, Ryley, Wong, & Zaman, 2022). Véliz et al. (2023) highlighted that transitioning to a circular economy requires further incentives to promote closed-loop material processes and the application of RPC will impact the desire for short-term profitability in the construction industry.

The extant literature supporting the employment of the RPC offers diverse justifications to substantiate their arguments. For instance, Park and Tucker (2017) recommended that legislated standards of design, deconstruction and product certification should be established around sustainability to optimise the use of PwRC in Australia. Tam et al. (2018) affirmed that the use of RPC will improve confidence in PwRC and solve the issues associated with the responsibility of using these resources. Silva et al. (2017) pointed out that simple aggregate classification together with RPC helps facilitate future client purchases since they will be buying an item appropriate to its future application. Li et al. (2019) reported that the usage of RPC marks is among a few available approaches that effectively improves the level of recycling.

Bao and Lu (2020) argued that by introducing a certification system, PwRC can be traded like any other virgin material in China. Christensen et al. (2022) research suggested that the utilisation of RPC in the Danish construction industry will optimise the process of recycled aggregate selection in alignment with the specific grade required for an intended application. Shooshtarian, Maqsood, Caldera, and Ryley (2022) found that market development and product certification are two strategies that motivate Australian material manufacturers to use waste resources in their production lines.

2.2 | Barriers towards RPC application in the building and construction sector

Within the existing literature, while there is strong support for the use of RPC (Bao & Lu, 2020; Christensen et al., 2022; Li et al., 2019; Park & Tucker, 2017; Shooshtarian, Maqsood, Caldera, & Ryley, 2022; Silva et al., 2017; Tam et al., 2018), due to several issues, including cost complications, there are present concerns over its feasibility in the sector (Equilibrium, 2019; Ghaffar, 2019; Oyedele et al., 2014). A recent review study by Yang et al. (2022) inferred that the current RPC does not support obtaining adequate certificates to allow the use of the remanufactured components. These limitations include the industry's tendency to give secondary priority to RPC over the cost (Oyedele et al., 2014), the lack of a simple but measurable definition of RPC processes (Park & Tucker, 2017) and little effect in the absence of an independent third party auditing operation (Darnall et al., 2018).

Ghaffar (2019) indicated that mandatory RPC expenses in the EU add to the price of PwRC and may negate any cost savings from reusing it. In the Australian context, a recent report by Equilibrium (2019) shows that PwRC is not independently validated through robust support testing. Product certification is cost-intensive, and with little uptake and a lack of opportunities to use these products, justification of the expense of certifying these products is difficult. This finding was also echoed in another study in the Australian context (Action Sustainability, 2020).

2.3 | Drivers of the RPC application

Some academic resources have offered solutions for the effective implementation of RPC in the building and construction sector. For instance, the use of digital tools and technologies such as blockchain and material passports can facilitate RPC application (Xie et al., 2022). Blockchain can provide a platform for registering, tracing and communicating the information on the PwRC's supply chain from extraction to repurposing including PwRC testing and quality certification (Xie et al., 2022).

Furthermore, the government should also initiate promotional activities via the media to change the general public's attitudes towards PwRC driving the need for using RPC. Government may also organise regular training to change the industry stakeholders' attitudes (Bao & Lu, 2020). Lastly, Mungkung et al. (2021) suggested that the regular update and further development of life cycle inventory databases are very essential to support the implementation of environmental certification schemes.

2.4 | Significance of exploring the stakeholders' views

Understanding how stakeholders of a sector perceive new initiatives is important for several reasons. First, the stakeholders play a key role in shaping the sectors' direction and exploring their perspectives on new changes helps decision-makers make informed choices that align with the industry's needs and goals. Second, stakeholders can provide valuable insights into the challenges and opportunities that arise from new changes. This knowledge allows for proactive measures to address potential issues and capitalise on favourable circumstances. Third, new changes often face resistance or slow adoption in the industry. By involving key stakeholders and addressing their concerns, it becomes easier to gain acceptance and promote the successful implementation of various initiatives (Sim & Putuhena, 2015). Fourth, stakeholders represent different segments of the construction market. Understanding their preferences and needs ensures that new changes align with market demands, making them more relevant and competitive (Shooshtarian et al., 2023). Fifth, recognising stakeholders' viewpoints helps identify potential risks associated with new changes. By understanding these risks, project managers can develop strategies to mitigate them effectively.

Lastly, it is important to understand stakeholders' perceptions of RPC implementation in the application context to avoid any disruptions in the operation of involved industries. In Australia, the waste recovery industry and building and construction sector is essential to the economy's growth and development. According to the latest data (Kyriakopoulos, 2022), the waste management and resource recovery industry has a current revenue of $7.5 billion (AUD) and employs about 16,000 people across relevant businesses. The building and construction sector is the fourth-largest contributor to the country's economy (Trading Economics, 2022) and currently provides one million employment opportunities within 396,000 businesses (Kelly, 2022).

2.5 | Research gap, rationale and contribution

The demand for the use of PwRC in construction projects is expected to increase in the coming years. However, the associated risks necessitate the implementation of a quality assurance system. While the literature suggests that RPC application may offer such assurance, concerns persist among key stakeholders regarding its feasibility. Therefore, understanding the challenges, enablers and drivers of these certificate programmes in the building and construction sector becomes vital.

Currently, RPC utilisation in the sector remains insufficiently researched, particularly in the Australian context, and most studies lack this information from the key stakeholders' perspectives. The authors consider this a significant gap with several potential implications. It is reported that any uninformed changes to the ecosystem of C&D waste recovery can cause unwanted consequences for two large industries, waste recovery and construction (Liu et al., 2021), particularly if it is bound to cost increases.

This paper presents the findings of a scientific study done for the first time in the Australian context with an explicit focus on the use of RPC in the building and construction sector. In terms of scope, this study only attempted to investigate RPC's application for construction materials recovered from C&D waste resources.

This study makes several contributions to the fields of C&D waste recovery and construction management. Firstly, it presents an opportunity for further assessment of the necessity for RPC implementation in the industry. Secondly, it provides a foundation for future research aimed at determining the efficacy of RPC in facilitating the sustainable procurement of PwRC by end-users. Thirdly, the results of this research can be used by professionals in the sector to refine their business models and practices, thereby maximising the adoption of PwRC in construction projects. Finally, policymakers can utilise the findings of this study to create evidence-based policies that ensure a level playing field for all stakeholders operating in the PwRC supply chain.

3 | METHODOLOGY

This research adopted a multiple case study approach to address the research question. This approach was grounded in inductive reasoning to make generalised conclusions based on specific scenarios. Multiple case studies are rich and comprehensive empirical portrayals of specific occurrences of a phenomenon, which are commonly drawn from a diverse range of sources of data including interviews and observations (Eisenhardt & Graebner, 2007). In recent years, the use of this approach has increased in the field of construction management, including the investigation of virtual reality (Almahmoud et al., 2012; Ozcan-Deniz, 2019), the use of information technology in the construction industry (Ahlam & Rahim, 2021; Alshorafa & Ergen, 2021), reverse logistics (Gustafsson & Bengtsson, 2020) and C&D waste management and circular economy (Adjei et al., 2018; Çetin et al., 2022; Rose & Stegemann, 2018). The overall research process employed in this study is depicted in Figure 2.

3.1 | Case study description and selection criteria

The criteria for the selection of the case studies included (1) the use of a significant quantity of PwRC, (2) reasonable access to the project

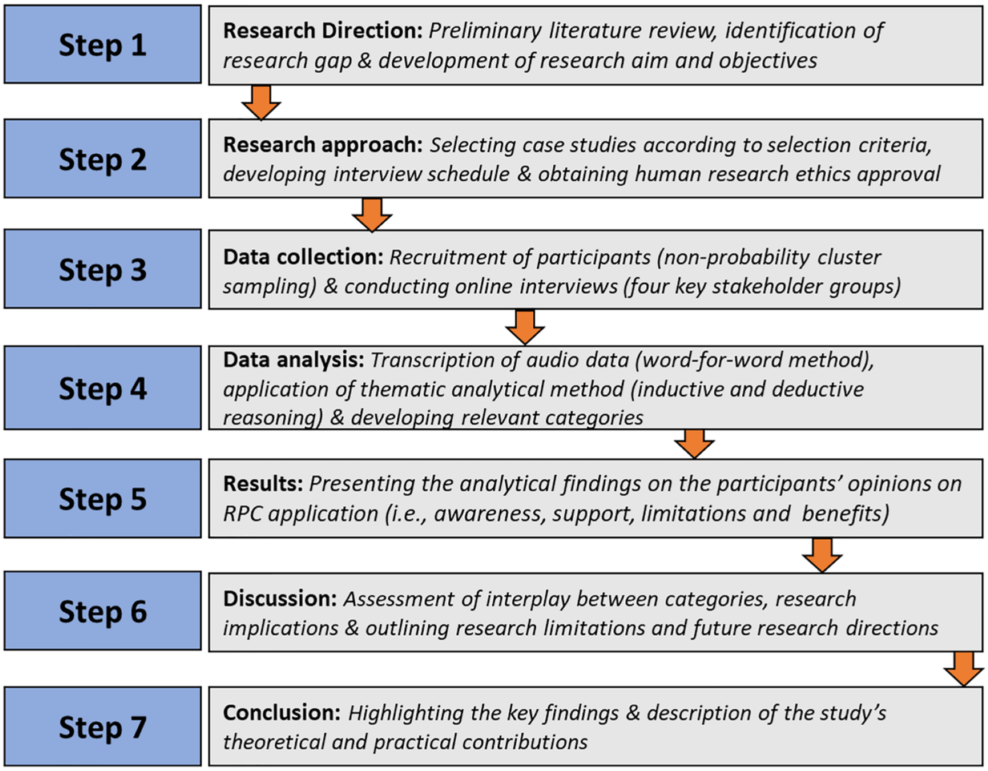

FIGURE 2 Summary of the research process in this study.

FIGURE 3 Approximate locations of the case studies.

information and (3) the ability to recruit intended research participants from each selected project.

The process of selecting the case studies involved extensive consultation within the research team network including communications with industry and public organisations such as Victoria Big Build (ecologiQ), Infrastructure Sustainability Council (ISC), Waste Management and Resource Recovery Association of Australia, GBCA and Development Western Australia. Each of these organisations was asked to nominate projects in which PwRC were used. The proposed projects were shortlisted against the selection criteria and the final four case projects were selected in consultation with the project steering group members that involved individuals representing various public and private organisations.

As per the above criteria, the case studies were selected from recently completed construction projects. The states where the projects are located are among the largest producers of C&D waste, have a high recycling rate and thus produce large quantities of PwRC in Australia. According to the Australian National Waste Report 2022 (Blue Environment, 2023), in Victoria, about 8.7 Mt of C&D waste was generated in 2021, an increase of 57%, from quantities recorded in 2017. For WA, these values were 3.04 Mt and 1.6 Mt, respectively. As a result, these states accounted for more than 40% of total C&D waste generated in Australia in 2021. Such figures are the product of the recent extensive construction activities that were primarily planned in response to COVID-19's negative impacts on the sector (Caldera et al., 2022; Kelly, 2022; Shooshtarian, Caldera, Maqsood, & Ryley, 2022).

The case studies included two infrastructure (road transport) projects, one commercial project and one residential project. Except for one project (Burwood Brickworks Shopping Centre), all projects are government-owned projects. These projects were built in two Australian states: Western Australia and Victoria (Figure 3) between 2018 and 2023 with budgets ranging from \$2.7 million (AUD) to \$400 million (AUD).

Table 3 characterises the project's key information.

The construction projects investigated in this study utilised notable quantities of PwRC (Table 4). In two case projects, Case Study 1 and 4, salvaged materials were also used to build the new construction. Particularly, in Case Study 1, the demolition waste extracted from the existing old buildings was reused in building civil works.

As indicated in Table 4, the selected projects used significant quantities of PwRC in their construction activities. Furthermore, these projects have been recognised for their outstanding levels of commitment to sustainability through different national sustainability recognition programmes such as the ISC, GBCA and Urban Development Institute of Australia (UDIA). The projects are referred to as demonstration projects for the implementation of circular economy principles on national and international levels.

3.2 | Data collection

The method of collection of data in this study was a semi-structured interview. When examining a phenomenon that occurs infrequently or episodically, interviews can be a highly effective method of collecting detailed and empirical data (Eisenhardt & Graebner, 2007). As identified by Eisenhardt and Graebner (2007), to address the challenge of interview bias, engaging a diverse set of highly knowledgeable participants with varied perspectives, including actors from different hierarchical levels and functional areas, is necessary. Such an approach reduces the likelihood of convergent retrospective sensemaking and/or impression management among the participants (Graebner & Eisenhardt, 2004; Yin, 2018).

Hence, after conducting a thorough analysis of the existing literature and consulting with subject matter experts, the research team identified four stakeholder groups: design, client, PwRC supplier and builder. The individuals from these groups were considered critical to the effective use of PwRC in construction projects. The recruitment process was non-probability cluster sampling and was undertaken according to the Australian National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2007) and the requirements of the RMIT University Human Research Ethics Committee.

To further guarantee the internal reliability of the interview questions, a pilot interview was conducted with waste-related professionals. The feedback from the pilot interview assisted the research team in optimising the interview schedule. The interview is widely accepted as an appropriate technique for qualitative inquiry to seek the insights of those who have experienced or are experiencing the phenomenon in question (Collingridge & Gantt, 2008; Wimpenny &

TABLE 3 Summary of the characteristics of the selected case studies.

Project features	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Name of project	Burwood Brickworks Shopping Centre	Mordialloc Freeway	Tonkin Gap Highway	OneOneFive Hamilton Hill
Construction type	Commercial	Infrastructure	Infrastructure	Residential
Client	Frasers Property Group	Major Road Projects Victoria	Main Roads Western Australia	WA Development
Budget (AUD m)	\$120 m (AUD)	\$375 m (AUD)	\$400 m (AUD)	\$2.7 m (AUD)
Project duration	2018–2019	2019–2021	2021–2023	2018–2019

TABLE 4 Summary of application of PwRC in the case studies.

Case Study 1	Case Study 2	Case Study 3	Case Study 4
PwRC quantity and application areas			
• The use of crushed concrete in the sub-base of bitumen • The use of materials from slab form working as hanging timber and timber cladding in the ceiling • The use of second-hand brick purposed into tiles and concrete in floors • The use of crushed brick leftover as a finish on facades	• The use of 600 t of plastic waste in noise walls • The use of 270 kt of pavement material incorporating the maximum allowable recycled content • The use of 30 t of plastic waste in 100% recycled polypropylene plastic (PP) concrete reinforcing mesh • The use of 75 t of plastic waste in 100% recycled high-density polyethene (HDPE) stormwater drainage pipe	• The reuse of 296 kt of sand • The reuse of 105 kt of spoil (treated ASS) • The use of 27 kt of crushed recycled concrete • The use of 1.2 kt of reclaimed asphalt pavement	• The use of salvaged timber in landscaping features, for example, shade structures and seating • The reuse of 40,000 clay bricks and roof tiles as aggregates underneath the drainage infrastructure • The reuse of old bricks to create brick walls and a brick toilet block • The reuse of crushed brick, tiles, concrete etc in the road sub-base, replacing the need for newly mined materials like crushed limestone • The use of 2425 m^3 of recycled concrete in retaining walls, replacing the need for newly mined limestone • The use of 400 t of PwRC in different applications including constructing temporary truck access roads
Recognition of sustainability (tool)			
• Living Building Challenge® • GBCA	• ISC	• ISC	• UDIA

TABLE 5 The summary of experience and expertise of the research participants in the case studies.

	Case study			
Participant	Client	Head-contractor	Designer	Supplier
Case Study 1	C_1P_1: 20 years of experience in construction project development	C_1P_2: About 6 years of working experience in the organisation	C_1P_3: 11 years of experience in architectural management	C_1P_4: 7 years of working experience in the organisation as the sale manager
Case Study 2	C_2P_1: Senior project manager with extensive experience in project managing public infrastructure projects	C_2P_2: 20 years of experience in the construction industry as a site engineer, project engineer and manager	C_2P_3: 15 years of experience working as a design consultant	C_2P_4: Highly experienced corporate communicator with a background in government, corporate, industry and community organisations, with a 4-year employment history in the organisation
Case Study 3	C_3P_1: Experienced sustainability advisor responsible for overseeing projects and initiatives using or promoting the PwRC application	C_3P_2: 4 years of working experience in the construction industry with a focus on major road infrastructure projects in the organisation	C_3P_3: 18 years of working experience in the organisation and was involved in the project as the technical director and oversaw the structural design of the work	C_3P_4: Working in the organisation as the director since its establishment and as a director of the organisation for 10 years
Case Study 4	C_4P_1: A senior development manager involved in the property industry for more than 30 years	C_4P_1: A civil engineer and the director of the organisation with 20 years of working experience in the organisation	C_4P_3: The director of a private company that specialises in landscape architects, urban design and sustainability consultancy	C_4P_4: The director of the organisation, with more than 27 years' experience in waste recovery in Western Australia

Gass, 2000). Therefore, piloting for interviews is a critical step to evaluate the questions and to obtain some practice in the interviewing process. Within this context, to ensure the internal reliability of the study's interview questions, a short series of pilot interviews was conducted with waste-related professionals. The feedback from the pilot interviews assisted the research team in optimising the interview schedule. The finalised interview questions are attached in Table A1.

The interviews were carried out online through Microsoft Teams between April 2022 and January 2023. In total, 16 individuals from the four projects were interviewed. Table 5 summarises the participants who took part in the interviews. Most participants were substantially involved in the case projects, allowing them to provide valuable information on the application of PwRC in the respective case projects.

In addition to questions related to the participants' demographic details, working experience and relevant expertise to the use of PwRC in construction projects, they were asked about the main motivations, challenges and opportunities related to the increased application of these materials in the selected case studies.

3.3 | Data analysis

Audio data captured from 16 interviewees were carefully transcribed by a professional transcriber using the word-for-word method before the quality verification of the text data by the research team. The transcripts were analysed using the NVivo Pro 12 software (Di Gregorio, 2000), which facilitates codifying text-based qualitative data. The following steps underpinned the actual data analysis procedure in this study.

Firstly, a data reduction method, thematic analysis, was used to condense the data while retaining the essential elements that are necessary for addressing the research question (Miles & Huberman, 1994). The thematic analysis provided the emerging themes (Braun & Clarke, 2006).

The research paper then utilised a combined approach of inductive and deductive reasoning for the analysis of the qualitative data. A deductive (theory driven) coding system was initially employed, using NVivo 12 software, while new codes were generated inductively from the interview data. The deductive codes were informed by the established concepts established in the previous literature including barriers to optimised uptake of PwRC in the sector (Véliz et al., 2023) and enablers for increased uptake of PwRC (Park & Tucker, 2017). The initial coding involved pre-established codes (a-priori codes) to guide the analysis (Figure 4). Simultaneously, new codes (in-vivo codes) were generated inductively based on the emerging interview data. The process then proceeded to axial coding, where the data was categorised in new ways, resulting in 13 distinct codes. This enabled the identification of associations and connections among the original 29 codes. The following diagram illustrates the coding process with exemplary data.

The analysis was conducted by a team of three authors to minimise bias and validate the emergent themes (Savin-Baden & Howell-Major, 2013) and to ensure saturation level was achieved. The inter-coder reliability rating achieved a satisfactory level of agreement, with 80% consensus among the authors (Tinsley & Weiss, 2000). This meticulous approach resulted in a robust and rigorous analysis, contributing to the credibility of the study findings.

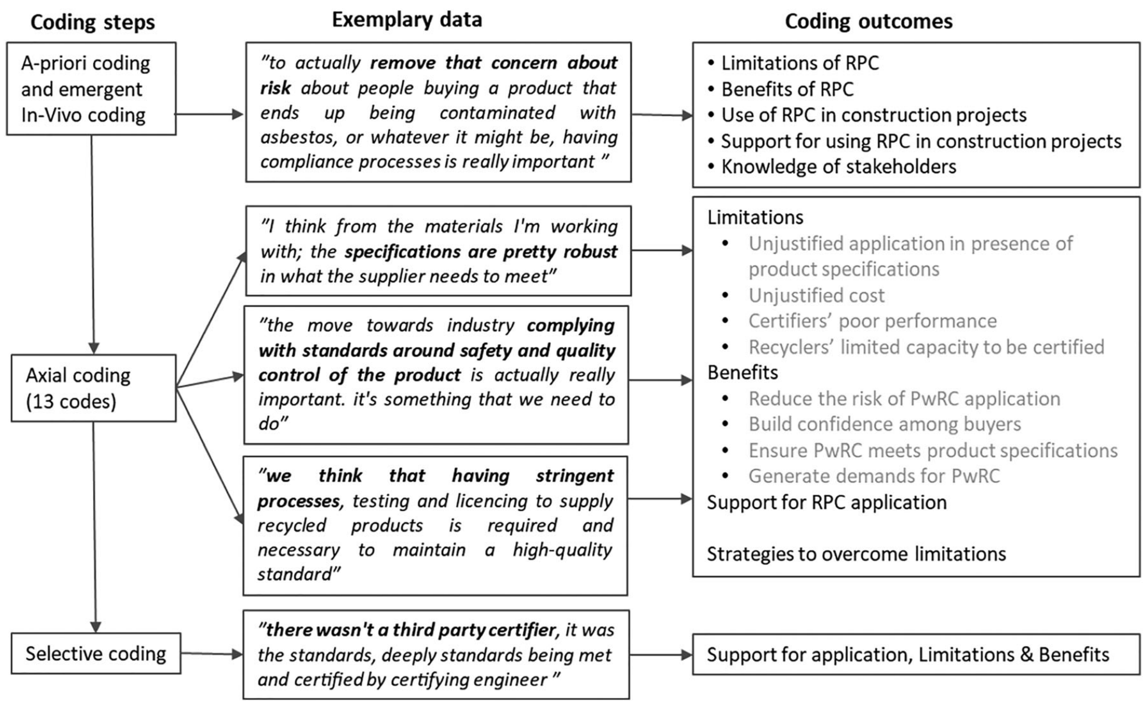

FIGURE 4 Coding diagram illustrating the formation of concepts from data.

4 | RESULTS

4.1 | Within-case analysis: Application of RPC in the selected case studies

Among the four case studies, only one project (i.e., Tonkin Gap and Associated Works) employed some sort of RPC to endorse the utilisation of PwRC. The process of certification was done internally by the client organisation.

In Case Study 1, the project team focused on meeting the requirements of a sustainability rating tool to be recognised for sustainability, including the use of PwRC. Particularly, the project used Living Building Challenge (International Living Future Institute, 2023) and GBCA's Green Star to demonstrate the utilisation of these resources in Brickworks Shopping Centre. The latter, which has seven petals (themes), required the project to apply SM/PwRC in at least 30 application areas. In addition, based on the building's gross floor area, the project team had to use one PwRC per 500 m^2 in the project. As part of this challenge, the suppliers of materials had to provide product certification that showed their level of environmental sustainability. However, according to the responses, for SM and PwRC, no RPC was used except for the materials manufacturers' statements.

In Case Study 2, the project owner did not use any RPC. However, they obtained suppliers' self-certified documents for certain materials such as plastic noise walls. Furthermore, they conducted a wide range of testing on PwRC—for example, UV stability to fire rating to durability impact testing—to get approval according to the Victoria Department of Transport (Dot) Specifications (Vicroads, 2022).

In Case Study 3, an RPC was employed to verify the quality and compliance of the PwRC used in the project. The applied RPC was developed under the Roads to Reuse (R2R) Programme (Shooshtarian, Maqsood, Wong, & Bettini, 2022), which was managed by a collaboration between Main Roads Western Australia and the WA Department of Water and Environmental Regulation. This certification is currently used in several WA government projects to ensure the quality compliance and safety of PwRC applications in state road infrastructures. In WA, projects that utilise PwRC are incentivised, provided that they achieve the requirements set in this initiative (O'Mahony, 2022).

However, this certification was only used for crushed recycled concrete, to test its quality and compliance against WA's state materials specifications. For other materials, particularly recycled steel and slug, the project required the supplier to provide RPC that contains information that can be used in the organisation's assessments. Furthermore, the use of PwRC was recognised through the ISC V.2 rating that was awarded to the project.

In Case Study 4, no RPC was used to verify the quality of PwRC. However, a series of testing was done to ensure the demolition waste was contaminant free, particularly tests targeting the existence of asbestos in the waste resources. Furthermore, the application of PwRC in this project was recognised through UDIA as part of the process of sustainability demonstration in this project. Lastly, the project client engaged consultant engineers to ensure that PwRC to be used in this project would have the quality specified in the applicable specifications.

4.2 | Cross-case analysis: Stakeholders' awareness of RPC

In terms of the stakeholders' awareness, the findings suggest that 9/16 interviewees were aware of the existence and objectives of RPCs, whereas 7/16 of the interviewees indicated that they had no or limited prior knowledge about their application in the industry. As presented in Figure 5, suppliers and designers were the two stakeholder groups that had more knowledge of the RPC application.

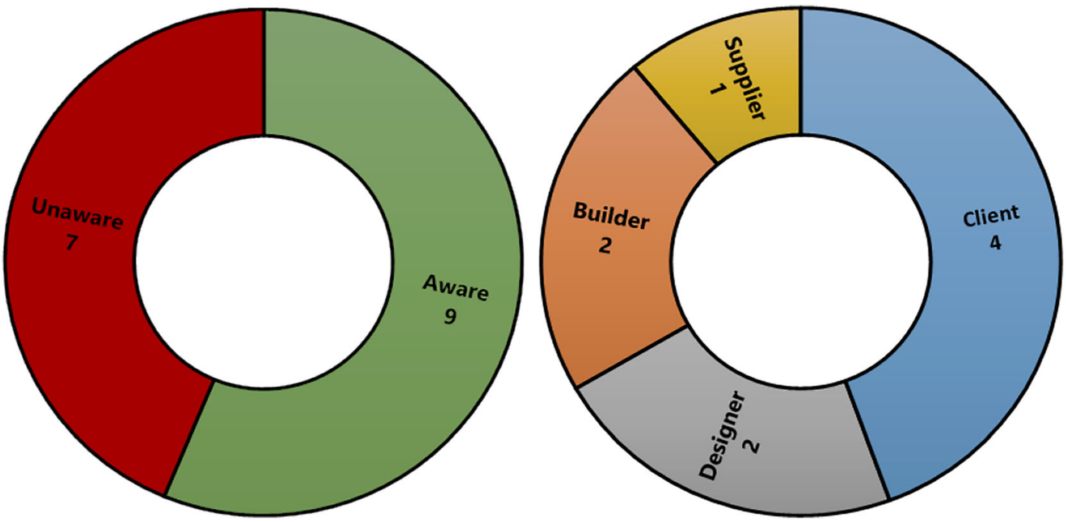

FIGURE 5 Awareness of the existence of RPC; left, overall ($n = 16$) and right, by different stakeholder groups ($n = 4$).

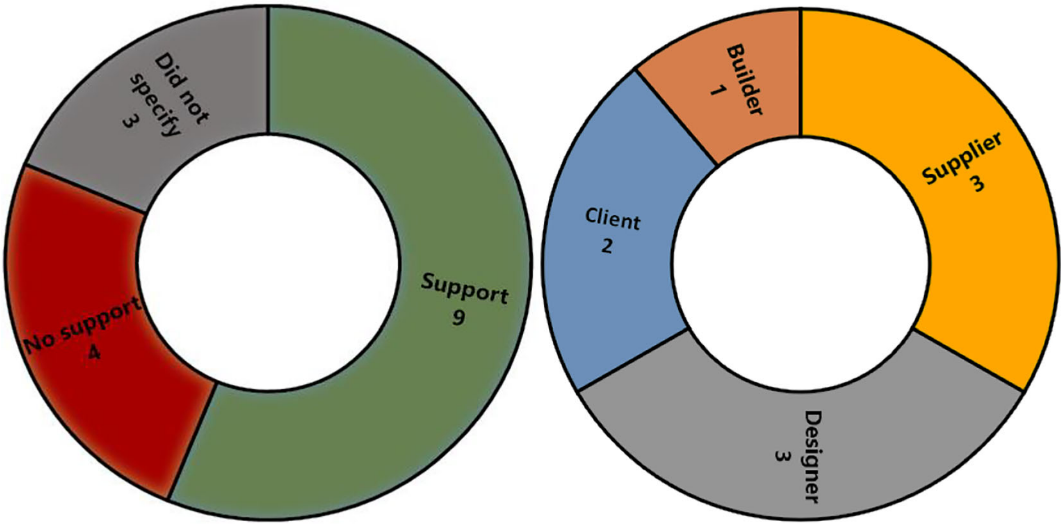

FIGURE 6 Support for the utilisation of RPC; left, overall ($n = 16$) and right, by different stakeholder groups ($n = 4$).

4.3 | Cross-case analysis: Stakeholders' support for the RPC application

The response to whether or not research participants supported the application of RPC showed that a larger portion of them considered RPCs a useful tool during purchasing PwRC (Figure 6). Stakeholder analysis suggests that clients and suppliers were the most and the least interested stakeholders in using these schemes, respectively.

For instance, C_2P_2, the builder stakeholder, said that RPCs are effective in reducing the risk of using PwRC in construction projects: ‘One of the impediments to using recycled products is that [whether or not] these things are going to perform … to some extent, we're taking on the risk that these things are going to perform. But if some certification body takes on that risk for us, and we can say well, we're relying on their certification, well that would be removing any barrier to using the product. That's what we need, we need to know that these things are going to perform’.

4.4 | Cross-case analysis: Benefits of the RPC application

Those who supported the use of RPC in this study indicated six benefits emerging from their application. These benefits, summarised in Table 6, are strongly interconnected. For instance, by assuring safety and quality control, the purchasing organisations can reduce the risk of PwRC, which in turn generates demand for these materials, followed by minimising C&D waste disposal. In terms of the nature of benefits, there were three categories: (1) risk management, (2) material technical properties and performance, (3) environment, and (4) market and economy. The indicative statements extracted from the interview for each of these are provided in the following table.

4.5 | Cross-case analysis: Limitations of RPC

As indicated above, not all stakeholders expressed their support for using RPC in the sector (Figure 6). Even some of those who supported the RPC application or had limited to no prior knowledge of it referred to the limitations of relevant applications. As shown in Figure 7, stakeholders highlighted seven major limitations relating to various aspects of RPC applications. Three of these limitations were linked to the schemes themselves: the abundance of RPCs with different requirements (Limit. #2), lack of transparency in their requirements (Limit. #3) and limited applicability for certain products (Limit. #4). The other limitations included unjustified application in the presence of product specifications, unjustified cost, certifiers' poor performance and recyclers' limited capacity to be certified.

While supporting their application, C_1P_1 and C_3P_1 explicitly indicated that the abundance of RPCs with different requirements is a major barrier to the wide application of RPC. According to these participants, different requirements can be confusing and make it difficult to compare PwRC certified by different organisations. C_1P_1 stated that *one of the challenges is that there are obviously so many different kinds of certifications*. Although their organisation does not have a preference for a specific RPC, C_3P_1 highlighted that *the limitation is, different certifiers will assess different aspects to give that certification. So, you can't necessarily compare like-for-like between the two competing certifications*.

Furthermore, the complex nature of some RPC programmes and their untransparent process and testing criteria can be a barrier (*Limit. #3*). C_1P_1 noted that *some of the certifications are a little bit opaque. So, you often find certification, you just get some sort of points or star rating system, but you don't really even know what that even means, you know, Level A or number three, four. It doesn't tell you anything, it just tells you that there's some sort of rating system*.

Another major barrier to RPC application was the certification cost being deemed unjustified (Limit. #5). The builder's representative

TABLE 6 Summary of benefits of RPC application and relevant indicative statements extracted from interview data.

Nature of benefit	Description	Indicative statements
Risk management	Reduce the risk of PwRC application	• *We're taking on the risk that these things are going to perform. But if some certification body takes on that risk for us, and we can say well, we are relying on their certification [C_2P_2]* • *[Using RPC] to actually remove that concern about risk about people buying a product that ends up being contaminated with asbestos, or whatever it might be, having compliance processes is really important [C_4P_3]*
Material technical properties and performance	Ensure safety and quality control	• *The move towards industry complying with standards around safety and quality control of the product is actually really important. it's something that we need to do, I think, to build confidence among end users within the industry, certainly [C_4P_3]* • *So from our point of view, we wanted to ensure that there was testing for hazardous materials because obviously, we are in a residential environment [C_4P_1]*
Market and economy	Build confidence among buyers	• *It would give confidence for the supply of crushed recycled concrete to projects such as Tonkin Gap … [it helps] to make sure that the crushed recycled concrete meets our [organisation] requirements plus health and safety requirements [C_3P_1]* • *So Main Roads as an organisation spent a lot of time working on the Roads to Reuse product certification scheme … which then we knew that we could cover multiple projects off to be able to use crushed recycled concrete [C_3P_1]*
Material technical properties and performance	Ensure PwRC meets product certification	• *We did not have that certification and it only sort of came through in the design window and once the product had been approved, then it was appropriate to pursue that option for this project hence why the design was kind of changed later in the process rather than right at the beginning [C_2P_4]* • *So we did use an independent Geotech company to actually sample that [recycled] material. To ensure that it was going to be suitable for reuse for you were using the roads [C_4P_1]*
Market and economy	Generate demand for PwRC	• *We think that having stringent processes, testing and licencing to supply recycled products is required and necessary to maintain a high-quality standard which in turn builds confidence in the products which in turn will self-generate greater demand for the recycled products [C_3P_4]*
Environment	Minimise waste disposal	• *Long-term [it] is beneficial, and it does minimise a lot of the waste [C_3P_2]* • *I know the benefits of using the recycling plastics are that they are lightweight, they have got the certification behind them in terms of testing for UV resistance and chemical resistance… You're already starting with a recycled product to begin with, rather than creating something, and then going on to recycle it later down the line [C_2P_4]*

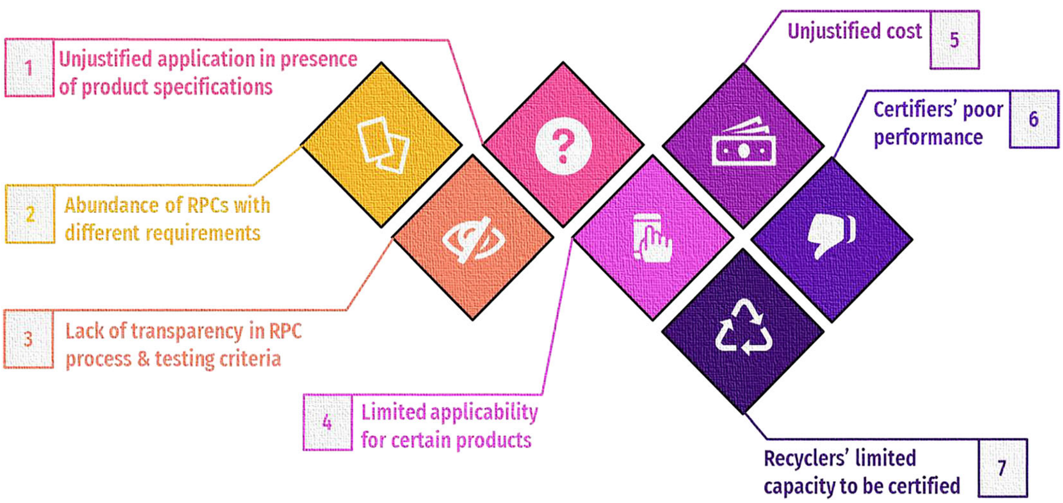

FIGURE 7 Major limitations of RPC application in the building and construction sector.

of Case Study 2, C_2P_2, noted that *the problem would be if the product starts coming at a huge premium because of the certification process, well, that might be problematic*. C_4P_3 explained that *the trick is, how do you do it? So it's robust and reliable, but it doesn't make the whole process unwieldy so becomes uneconomic. So it's always, what's the right level of rigour? You want to minimise the risk, but you never eliminate risk, but you don't want to make it so expensive that no one's going to do it*. The low demand for PwRC making their application unreasonable was another reason. C_3P_2 stated that *the demand for large infrastructure projects using this material is fairly low still, so there might be three* *or four Main Roads projects happening in Perth at the moment and there [might be] only be one or two using this material. If demand is low, there's only going to be two or three suppliers that go through getting certified to produce the material.*

The non-necessity of RPC in the presence of existing product specifications was another reason (Limit. #1). C_3P_2 mentioned that *I don't know what value they would actually add to be quite honest; I think from the materials I'm working with; the specifications are pretty robust in what the supplier needs to meet. A certification body to me is just a blood-sucking organisation.* C_2P_4 indicated that *we have specifications for a reason. We need to maybe think about how we make those specifications more responsive, and more agile would be far more useful than creating certification on top of certification to say that a product is potentially viable, that has nothing to do with the actual road-building specifications*.

Lastly, C_1P_4, who represented the supplier that supplied recycled timber to Case Study 1, indicated that RPCs might be not suitable for some PwRC (Limit. #4), such as timber, due to their physical nature. The participant added that *it is a natural product, especially with timber there can be movement with timber, it's a live product, it does move so it moves to its surroundings and stuff like that … in terms of certificates and certifications and stuff like that we could never warrant or give anything*.

5 | DISCUSSION

5.1 | Impact of limitations on realising RPC benefits

This section explains how the seven limitations identified above can diminish the benefits of RPC that were reported by the research participants:

Limit. #1: In the Australian building and construction sector, when purchasing and applying PwRC, the common practice is to refer to state-developed product specifications (Equilibrium, 2019). Many infrastructure projects now procure PwRC that meet the requirements stipulated in these documents. However, as indicated in the case studies, compliance with product specifications may not be sufficient to prove PwRC quality, performance, environmental footprint and other criteria that would have been otherwise tested when RPC is applied (Benefit #2). As a result, it may be less likely that many end-users would be willing to purchase PwRC for their construction project if only product specifications are to be used (Benefit #5).

Limit. #2: The variation in the requirements embedded in different RPC programmes can diminish the value of their application and be counterproductive in building confidence among the end-users of PwRC (Benefit #2). It is apparent that dealing with various requirements and testing criteria is a source of confusion for both producers and buyers and adds to the complexity inherited in the current PwRC supply chain ecosystem.

Limit. #3: Lack of transparency in the RPC process may cause issues when the criteria of product specifications are to be met. This limitation is intertwined with a decreased trust in the organisation or individuals who are responsible for approving proposed PwRC. If the RPC process is unknown to these parties, the provided information on the demonstration of PwRC characteristics is unclear or there are uncertainties about whether or not the certified materials pass product specifications (Benefit #4), then they are less likely to approve RPC application in their projects.

Limit. #4: At times, certifying certain PwRC may not be plausible due to various factors. In the short run, this means the market for RPC becomes limited to traditional PwRC for which there are established methods and procedures for testing and quality assurance. As a result, the application of unconventional non-certified PwRC is subject to various risks (Benefit #1), as there is no level of assurance of their safety and quality (Benefit #2) that can persuade some end-users to purchase them (Benefit #5).

Limit. #5: As indicated previously, in some instances, RPC costs may seem unjustified (Limit. #5). This limitation can demotivate individuals operating in the construction materials supply chain to choose PwRC over readily available and sometimes cheaper brand-new materials. This pattern in the short-run results in less demand for purchasing PwRC in the sector (Benefit #5), which in turn triggers less waste recovery and more waste landfilling (Benefit #6).

Limit. #6: Some PwRC certifiers' poor performance is directly translated to losing confidence in purchasing PwRC among buyers (Limit. #3). In particular, the lack of due diligence shown by certifiers during testing and control to ensure PwRC safety and quality (Benefit #2) will result in increased risk severity and the likelihood of the application of improperly certified PwRC in construction projects (Benefit #1).

Limit. #7: The application of PwRC has yet to be fully embraced in the Australian building and construction. Therefore, many recyclers are unable to be certified externally and/or produce PwRC as required by end-users or specified in some RPC programmes. This means that they are at the potential risk of losing markets to brand-new materials that can better satisfy end-users' needs. In practice, this risk leads to lower demand for PwRC (Benefit #5) and will reduce waste recovery activities (Benefit #6).

5.2 | Strategies to address the limitations of the RPC application

To optimise the use of RPC, the existing limitations need to be carefully addressed. Hence, as shown in Figure 8, this section focuses on the main practical strategies to serve this purpose. Overall, six strategies were identified that assist stakeholders in minimising the impact of limitations identified in this study. These included robust legislation, promotional activities, education of stakeholders, contractual

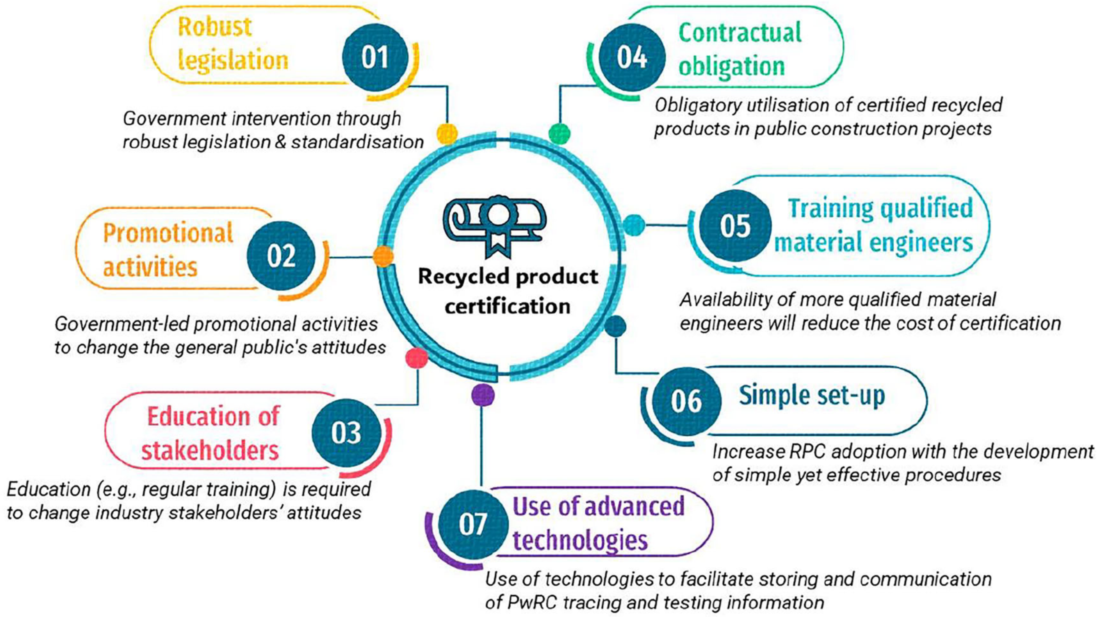

FIGURE 8 Main strategies to address limitations of RPC programmes.

obligations, training qualified material engineers and simple set-up. These strategies are fully described below:

5.2.1 | Robust legislation (Strategy 1)

Effective quality monitoring and certification of PwRC by suppliers are required to instil and maintain stakeholders' trust in the PwRC application. This must be accompanied by more vigorous government action in the form of legislation and standardisation (Silva et al., 2017). Primarily, this strategy deals with three limitations (i.e., Limit. #1, #2 and #3). The government regulations can drive RPC application in conjunction with current or future product specifications and set a regulatory assessment framework to proctor and standardise the operation of certifying organisations (Limit. #2 and #3). The latter can be assigned to specialised public agencies that can be established in light of supportive regulations.

5.2.2 | Promotional activities (Strategy 2)

Together with the industry associations, the government should also initiate promotional activities via the media to change the general public's attitudes and help them better understand the potential benefits and objectives of RPC. The end-users' improved understanding will result in the creation of demand for purchasing certified PwRC, reducing the cost of certification and thus addressing Limit. #5. In previous research, this strategy was described as a facilitator of environmental behaviour by motivating people to pay a premium for products labelled as green (Oyedele et al., 2014). Furthermore, promotional activities can inform stakeholders of specific objectives of RPC that are different from product specifications (Limit. #1).

5.2.3 | Education of stakeholders (Strategy 3)

The government, in collaboration with organisations running environmental sustainability rating systems, may also organise regular training opportunities to promote changes in industry stakeholders' attitudes and work practices (Bao & Lu, 2020). This strategy can create opportunities for the waste recovery industry to overcome the challenges related to capacity building that is required to take advantage of RPC for higher PwRC sales (Limit. #7). Furthermore, education can result in the advancement of RPC programmes to cover a wider range of PwRC (Limit. #4).

5.2.4 | Contractual obligation (Strategy 4)

Contractual obligation or other client requirements to use certified PwRC is another effective strategy for the broad application of RPC (WSP Environmental and TRL Ltd, 2005). Currently, in the EU, it is illegal to use uncertified PwRC in construction projects (Ghaffar, 2019), resulting in more frequent uptake of RPC in the sector across the European territory. According to a report by the WSP, the advantages of mandatory RPC include the eradication of rogue traders (Limit. #6), greater confidence in the data provided for all parties (Limit. #3), less room for manipulation and provision of the credibility required to make the RPC valuable (WSP Environmental and TRL Ltd, 2005).

5.2.5 | Training qualified material engineers (Strategy 5)

This refers to the availability of qualified material engineers at reasonable prices. According to anecdotal evidence, these professionals are scarce, highly in demand and expensive to employ. By educating more individuals to become qualified materials inspectors, not only will sustainable jobs be created, but audit costs will also be reduced. Therefore, this strategy can be considered to reduce the impact of Limit. #5, 6 and 7.

5.2.6 | Simple set-up (Strategy 6)

This strategy addresses the simplicity of certification methods for PwRC. The waste recovery industry's interest in RPC will be piqued by certification processes that are simple yet effective and require a fair amount of administrative work (WSP Environmental and TRL Ltd, 2005). This strategy specifically targets Limit. #3 by providing a better platform for improved end-user understanding of requirements, which organically leads to optimised uptake of RPC in the sector. Evidently, the classification of PwRC into easily comprehensible categories, together with correct certification, facilitates future client purchases (Silva et al., 2017), as they will be able to acquire a product suited to its intended use.

5.2.7 | Use of advanced technologies (Strategy 7)

The final strategy concerns leveraging the capabilities of advanced technologies to facilitate information exchange for various stages of PwRC production and certification. Using easily accessible digital tools provides further transparency about the RPC process and criteria and hence will address Limit. #4. The end-users of these technologies can store information about the origins of PwRC, the handling and repurposing conditions, material composition and other environmental and technical descriptors.

5.3 | Research implications and contributions

This section discusses the research findings from both theoretical and practical perspectives. Figure 9 is a snapshot of the interaction between the key findings, providing grounds for the research impact and uptake. Furthermore, the following paragraphs suggest multiple ways to leverage the research findings to improve the capability of various entities to properly embrace RPC for optimal uptake of PwRC.

First, this research provides opportunities to further evaluate the need for RPC application in the sector. Those in the public or private sector that are interested in establishing a new RPC programme or refining their existing ones can use this information to develop a framework that guides their business models and practices. Particularly, drawing on the findings, private organisations can develop business strategies that enable them to achieve sustainable outcomes including the implementation of sustainable procurement policies.

Second, the research is a basis for future studies to determine the effectiveness of RPC in the confident procurement of PwRC by end-users. Researchers and educators who focus on environmental sustainability in the building and construction sector can use this information to further explore and communicate the role of RPC in the optimised uptake of PwRC in the sector. Additionally, these stakeholders can utilise the research findings in developing educational materials that aim to cultivate environmentally conscious mindsets in aspiring future construction managers. In the present climate, with governments and the general public exerting pressure on the construction industry to improve its environmental sustainability, this becomes an increasingly important strategy. This research also addresses the limited number of studies on the use of RPC schemes

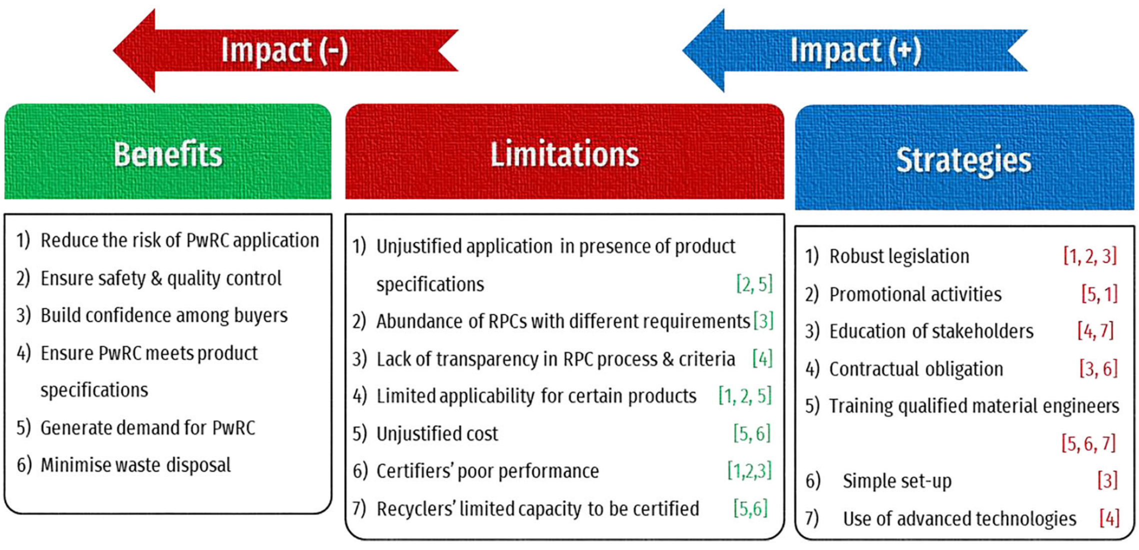

FIGURE 9 The interplay among the benefits, limitations and strategies for effective use of RPC in the building and construction sector.

in the construction industry. To bridge this gap, this study analysed the results of three previous studies that examined eco-labelling schemes drawing on stakeholders' perspective (Low et al., 2014; Mungkung et al., 2021; Saarinen, 2021). The study's findings complement Low et al.'s (2014) results, which indicated variations in stakeholder perceptions of certification scheme values in Singapore. Additionally, Mungkung et al.'s (2021) factors limiting eco-labelling adoption in Thailand overlap with the RPC uptake barriers identified in this study. The findings of the study around the drivers of adopting RPC align with Saarinen's (2021) findings on eco-labelling benefits and cost barriers.

However, the managerial implications for the use of RPC are very limited. By addressing the limited managerial implications of RPC and offering practical strategies for its effective use in the building and construction sector, various stakeholders can harness the potential of RPC to foster and promote sustainable practices within the construction industry. Furthermore, by understanding the potential risks associated with the RPC application, project managers can develop strategies to mitigate them effectively. The insights provided by the research participants can guide the allocation of resources, such as funding and manpower, to support the implementation of RPC effectively.

Third, policymakers may leverage the findings in this research to develop informed policies that provide a level playing field for all those operating in the PwRC supply chain. The policymakers who intend to embed RPC in procurement policies for purchasing PwRC can learn about the loopholes and strategies—and tackle them. In particular, it will assist them in developing informed policies that will reduce the risks of PwRC application and provide a level playing field for all stakeholders involved in the PwRC supply chain.

Fourth, as the application of RPC is aligned with the sustainability rating organisations' agenda, this information lends itself to reforming their sustainability assessment procedures that target the utilisation of PwRC in construction projects.

6 | CONCLUSIONS

This study sought to explore the understanding of stakeholders operating in the building and construction sector concerning RPC application. To the best of the authors' knowledge, this study is the first of its kind in the Australian context reported in a scholarly article. This study revealed useful information about the characteristics of RPC with a focus on the Australian context and generalisability to similar contextual conditions by analysing four case studies in which PwRC were utilised.

The key finding of this research is that, currently, the application of RPC is limited in the sector. Analysis of four case studies showed that only one out of four case projects applied this scheme. The study also listed the top seven limitations of RPC application, namely unjustified application in the presence of product specifications, the abundance of RPCs with different requirements, lack of transparency about their requirements, limited applicability for certain products, unjustified cost, certifiers' poor performance and recyclers' limited capacity to be certified. To address these limitations, this paper proposed several strategies aimed at various key stakeholders (government, end-users, industry associations, waste recyclers, certifiers, education providers and sustainability rating organisations) to make the RPC application business-as-usual, when proven useful.

The study findings demonstrated that individuals who possessed knowledge about RPC schemes were more inclined to endorse its implementation within their organisations. Consequently, this study puts forth a proposition statement that can be examined in future research: 'By enlightening industry stakeholders about the advantages of RPC, its utilisation for procuring PwRC in construction projects can be extended'.

As with all research endeavours, this research faces inevitable limitations. The researchers, however, attempted to the best of their capacity and within the inherent constraints to minimise these limitations' impact on the research outcomes. The study was subject to two main limitations. First, the nature of the research methodology allowed for the collection of responses from only limited participants. Second, some participants' had limited prior knowledge of RPC, preventing them from commenting on the benefits and limitations associated with the application of RPC in the sector. Therefore, where possible, future research should capture the opinions of a larger sample size of stakeholders to gain a clearer insight into the necessity and effectiveness of using RPC in purchasing PwRC.

The future research agenda should include an investigation into the effectiveness of the strategies provided in this research in reducing the identified limitations. Moreover, a cost–benefit analysis can be performed to estimate the certification cost under various scenarios. This will help stakeholders such as product suppliers and end-users obtain a deeper grasp of what they receive in exchange for the costs associated with PwRC certification. Such an attempt will eventually determine the usefulness of RPC application in the sector.

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APPENDIX A: INTERVIEW PROTOCOL

Introductory comments: Explain about the research, direct and indirect benefits and obtain consent for recording.

TABLE A1 Interview questions.

Context	Questions
General	• Please introduce yourself, including your employment history and recent activities in the field of construction and demolition (C&D) waste management? • Can you please tell me a bit about the project and your respective involvement?
Organisation experience	• Can you please tell me about your organisation's experience using products with recycled content in this project? (e.g., amount, organisational decision-making process, relevant policies and procedures, parties/individuals involved, risk management plan, items considered when procuring these products)
Use of PwRC	• What were your main motives to use recycled content in this project? (e.g., cost, social image, contractual obligation etc.)? • What were the main five challenges to using recycled content in this project? • In your opinion, how could these challenges (and their impact) be overcome? • What is the process of procuring waste materials and repurposing them into usable products in this construction project?
Use of RPC	• Did your organisation consider recycled product certification during planning for this project? If so, what was it? • What is your opinion about product certifications for recycled products? Do you know of any product certifiers in Australia or overseas? What are their limitations?
What else?	• Has your organisation published any relevant documents describing the project planning, design and execution that you could share with us? • Do you have anything else to tell me that will assist us in furthering our research? • Can I get back to you in case if I have further questions from the data analysis?