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Understanding Construction Stakeholders' Experience and Attitudes toward Use of the Structurally Insulated Panels (SIPs) in New Zealand

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Abstract: New Zealand faces a housing shortage with construction struggling to meet demand. Structurally insulated panels (SIPs) have been demonstrated internationally as a method of construction which could reduce construction time frames, improve the standard insulation in housing, as well as reduce the amount of waste generated on construction sites. However, anecdotal evidence shows that the SIPs' adoption is lacking, which is, perhaps, attributed to its industry-wide acceptance level. Thus, in this study, the construction stakeholders, such as architects/designers, builders, territorial authorities and homeowners were targeted to shed light on current status of SIPs use, benefits offered and any barriers inhibiting its industry-wide implementation. This was done through a survey, which was designed to understand the construction stakeholders' experience levels regarding SIPs use in New Zealand as well as their opinions about any problems associated with the SIPs adoption. Although the stakeholders were happy with the thermal performance offered by SIPs, the results indicate that lack of familiarity and understanding are one of the main barriers to the widespread use of SIPs in New Zealand. Moreover, proper training and clear design information are reported to be crucial to make the building and consenting processes efficient, which will ultimately improve the cost-effectiveness. Despite the barriers (to SIPs adoption) documented by stakeholders, the common belief is that SIPs offer wide-range of benefits to improve performance of the built environment; hence, the stakeholders expressed their willingness to design/build/recommend SIP homes. It is hoped that the findings of this study will guide the industry practitioners in investing their efforts in wider adoption of SIPs in New Zealand.

Keywords: structural insulated panels; drivers; residential construction; New Zealand

1. Introduction

New Zealand has been experiencing an increasing trend in the number of residential construction consents in the last decade. In 2008, for instance, the number of approved consents was 13,353, and in February 2019 it increased up to 34,262 [1]. It can be seen that the increase continues to put pressure on the construction practitioners to supply the documented housing demand in the country [2]. Currently, timber framing is the most common method of construction utilised by over 80% of the residential construction projects in New Zealand [3]. Although this method has been proven to be environmentally friendly and energy-efficient, and there is widespread acceptance among the authorities and home developers [4], that erection of wood-frame construction is considerably slower [5], which will fail to meet the increasing housing demand. Therefore, there has been an increasing worldwide interest in the adoption of pre-fabricated construction technologies, which provide faster erection, higher dimensional quality, easier on-site assembly and hence, improved on-site construction productivity [4,6–8]. Likewise in New Zealand, governmental support for innovative construction methods and technologies, such as prefabricated housing, is a significant step toward the supply of documented housing demand in a more sustainable way [9].

Structural Insulated Panels (SIPs), which were first developed in North America, are prefabricated systems that offer incorporation of the structural and the insulation performances into a single system [4]. SIPs as a new construction material offers increased thermal and structural performances [10], while as a system it offers improved productivity, reduced on-site construction waste and improved sustainability performance [11]. Several studies across the world have reported on SIPs. Mullens and Arif [5] reported the findings of a case study, which focused on the impact of SIPs on the delivery process of residential construction. While the savings from the cycle time and the site framing labour were found to be similar, SIPs' impact on other metrics (material waste, workmanship, safety) of construction performance were not significant. Kermani [4] presented a study that assessd structural performance of SIPs. The assessment results illustrated that SIPs have a sufficient strength and stiffness; hence, can be used as a load-bearing component. In terms of its thermal performance, Wyss et al. [12] presented a study from the Canadian extreme climatic conditions under which SIPs have demonstrated good thermal performance.

Despite the support for the adoption of SIPs—particularly in residential and small commercial buildings—and several benefits of SIPs, the number of projects that have utilised SIPs (domestically and internationally reported), shows the lack of industry-wide acceptance in New Zealand construction context. Possible reasons for the lack of acceptance are reported to be client acceptance, supply chain issues, long-term durability and concerns over how it will impact the construction process [5]. Yet, to the authors' knowledge, no research has investigated the current implementation status of SIPs in New Zealand construction industry as well as drivers of, and barriers to, its slow implementation.

This paper aims at providing hard data regarding experience levels of the construction stakeholders' to implementing SIPs in New Zealand, as well as their feedback on what has driven them to use SIPs, any problems they faced during the implementation and how would it be possible to achieve SIPs' industry-wide acceptance. To achieve the aim, firstly, a robust review of the literature on SIPs has been conducted. Secondly, the methodological approach is explained, which is followed by the presentation of survey responses and discussion of the research findings. The paper ends with the recommendations made for industry practitioners and researchers in academia regarding the implementation of SIPs.

2. Structural Insulated Panels (SIPs)

SIPs are pre-manufactured sheathed panels which combination of structure and insulation in one building component (refer to Figure 1). SIPs, which are available in different sizes and R-values, have been used as various building components (e.g., floor, wall and roof) in residential construction [12]. SIPs are manufactured and pre-cut at a factory according to plans submitted by a builder and can include features such as window openings, headers, and posts to the panels [13].

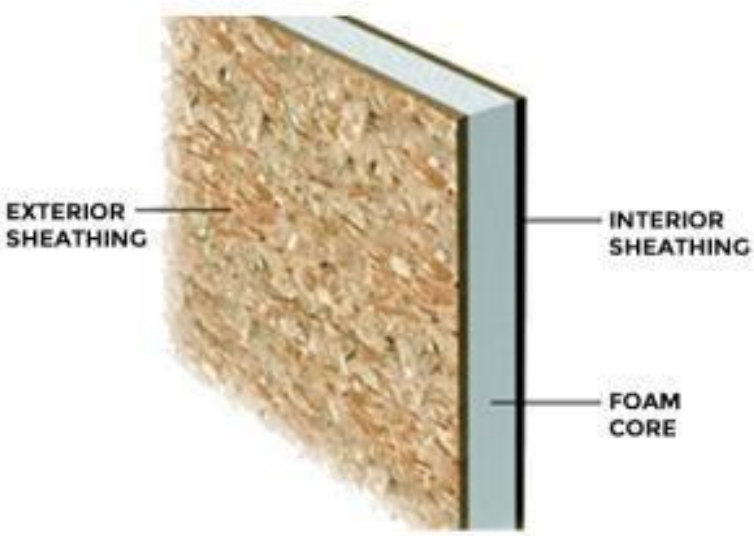

Figure 1. Structural Insulated Panel (SIP) [14].

Reportedly, SIPs have various benefits; they have been claimed to offer various advantages over the conventional timber-framed construction. The findings from research in 2006 showed that it is possible only to require two-thirds of the labour required by using SIPs when compared with conventional framing [5]. Some of the structural benefits which have been identified in international studies are best summarised as "the strength and design flexibility of SIPs may be of benefit in the U.K. because larger and complex buildings can be constructed without increasing the weight of materials" [4]. One of the significant benefits of SIPs is the contribution to the sustainable development of the construction industry. As such, this label has been featured by the SIPs' manufacturers for the industry-wide promotion.

Prefabricated housing has been demonstrated as a method of reducing the amount of waste material through the factory manufacturing process and reduced on-site construction waste by minimising the amount of off cut waste material, which would typically be sent to the landfill [7,15,16]. Noteworthy mentioning that the average residential construction project in New Zealand produces on average 4 tonnes of waste during the construction process, which is sent to landfills around the country [17]. Thus, being a prefabricated construction material, SIPs reportedly offer a considerable potential to reduce construction waste in the country. The production of timber framing utilises 60% of the tree, and this equates to 40% that is regarded as waste. This waste is typically required to be transported to other processing facilities and then processed into useable products. From the 60% of usable timber, even less of the milled timber is suitable for structural framing and must be tested for density and imperfections before being able to be utilised as framing in a structural wall [18]. During the construction of OSB board which is the most common structural facing of SIPs panels, 90% of the tree can be utilised for the creation of OSB panels with the remaining 10% being able to be processed for paper or cellulose insulation [18]. While both methods of manufacture would claim that they use 100% of the tree material, a more significant number of trees are required to be cut down and processed to gain enough structural timber to frame a standard residential timber-framed house when compared with the amount of tree material required to produce OSB for the same building.

Another advantage of SIPs over the traditional framing is that SIPs are assembled on-site as a whole panel and delivered on-site ready for installation. As such, the reduced number of joints improves airtightness [19]. Reportedly, SIPs have higher insulation values compared to their conventional counterparts. A report by Kosny and Christian [20] found that SIPs have approximately 42% higher R-value compared to a typical timber-framed wall.

Internal air quality and temperature are shown to affect occupant's health through exposure to cold, damp and mouldy conditions which can result in an increased risk of respiratory conditions such as the common cold and asthma [21]. Another significant advantage of SIPs is less air infiltration, which gives the dwellers to take a higher control over the indoor environment [22]. The test results reported by the U.S. Department of Energy (DoE) show that SIP dwelling has about 20% less air infiltration than timber-framed building. Insulated homes have shown to result in improved health of the occupants through improved self-health ratings and reduced absences from work and school as well as reduced visits to doctors when compared with uninsulated or poorly insulated houses [23]. The study demonstrated that when installing insulation into older homes, the indoor temperature increased significantly and corresponded with a decrease in humidity and the occupants reported a higher level of comfort [23]. Thus, increase in the thermal performance of a dwelling provides a healthier environment for the occupants and will likely reduce the chances of poor health and can result in less time away from work or school as a result.

3. Methodology

3.1. Survey

This study uses an online survey method, which has been widely used as an appropriate and cost effective method [24,25], to primarily target four critical groups in the construction industry that have an integral part in the implementation of SIPs. The purpose was to determine the level of experience and interest of the survey participants regarding SIPs. These groups were architects who were based on their ability to specify products for construction, builders based on their construction knowledge and ability to help homeowners understand new technologies, building consent officers based on their key role in approval of building consent applications which are necessary for construction, and finally and most importantly, homeowners, who are the group that can decide at concept stage if the product will be used but also have to live with the final constructed facility. The survey aimed to find out answers to the following questions:

1. How widely have the SIPs been implemented within the construction industry in New Zealand?
2. How experienced are the construction stakeholders regarding SIPs and their levels of awareness?
3. Are the various stakeholders satisfied with the performance of SIPs?
4. What are the factors that are driving/inhibiting the construction stakeholders from implementing SIPs in New Zealand?
5. Does experience with SIPs affect the construction stakeholders' attitudes toward this new material?

3.2. Survey Development

The survey development process started with the review of the literature, from which the studies with a similar scope were reviewed and the factors that are driving/inhibiting the implementation of SIPs were derived. A sample group, which was mainly comprised of suppliers of SIPs, was then chosen to ensure questions were relevant and presented in a manner that was easily understood by the industry players. The survey was designed with the purpose of attaining feedback from various construction stakeholders disciplined in different areas. Therefore, the survey was designed in such a way so that every individual could answer the questions are relevant to his/her discipline. Based on the participant's answer to the question "How would you identify yourself?", the survey tool redirected him/her to the questions that are relevant to his/her discipline. Moreover, each participant was asked ("Have you had an experience with SIPs before?") whether s/he has had any experience with SIPs before. This helped to facilitate the separation of the participants into different groups (with and without any experience). Moreover, the survey sought to cover three main areas with three of the user groups to cover who is instigating SIPs in the design process, how readily available technical information is, how easily SIPs can incorporated into design/construction and what are the perceived benefits of SIPs. It was also used to reflect on possible consent and compliance-related issues and to see if there is a perceived increased difficulty in obtaining building consents to enable construction.

Respondents were also provided a section for general comments to obtain feedback which they felt may be of benefit to the survey.

3.3. Data Collection Approach

Through the literature review process, it was evident that it would be necessary to engage with a broader spectrum of the key stakeholders, which would help produce more definitive results. A survey was identified as the best method of engaging with each key group and recording their individual results within the appropriate group for analysis of the more extensive group data [26]. The survey was prepared electronically and was separated into four subsections which related specifically to each group identified above and was designed for the results to be anonymous. The survey was distributed to architects, builders, and homeowners through the New Zealand Institute of Architects, New Zealand Master Builders Association, New Zealand Institute of Quantity Surveyors and through SIPs suppliers by advertising in their newsletters which contained a link to an internet website for the survey. Building consent officers (named in this study as territorial authorities (TAs)) were more challenging to try to maintain anonymity for, as each council needed to be approached to ask if they would partake. Where possible, the survey was sent to generic email addresses rather than to specific people's emails. Another method to increase anonymity was to invite multiple councils from each region, which would reduce further any possible individual identification.

4. Survey Results and Discussion

As of the cut-off date set for the survey, 195 responses were received from all targeted disciplines. As highlighted above, it was not easy to collect feedback from the building consent officers (named as Territorial authority) due to the anonymity reason; hence, we ended up with 15 (8%) responses (refer to Figure 2) and the majority has had some experience with SIPs. While the high participation number (43%) from the architects/designers were expected, the homeowners showed the second-highest interest (28%) in sharing their feedback on their experiences with SIPs. Slightly above the one-fifth (22%) of the responses were provided by the builders. Thus, the distribution shows that the results are biased toward the perceptions of architects/designers in New Zealand.

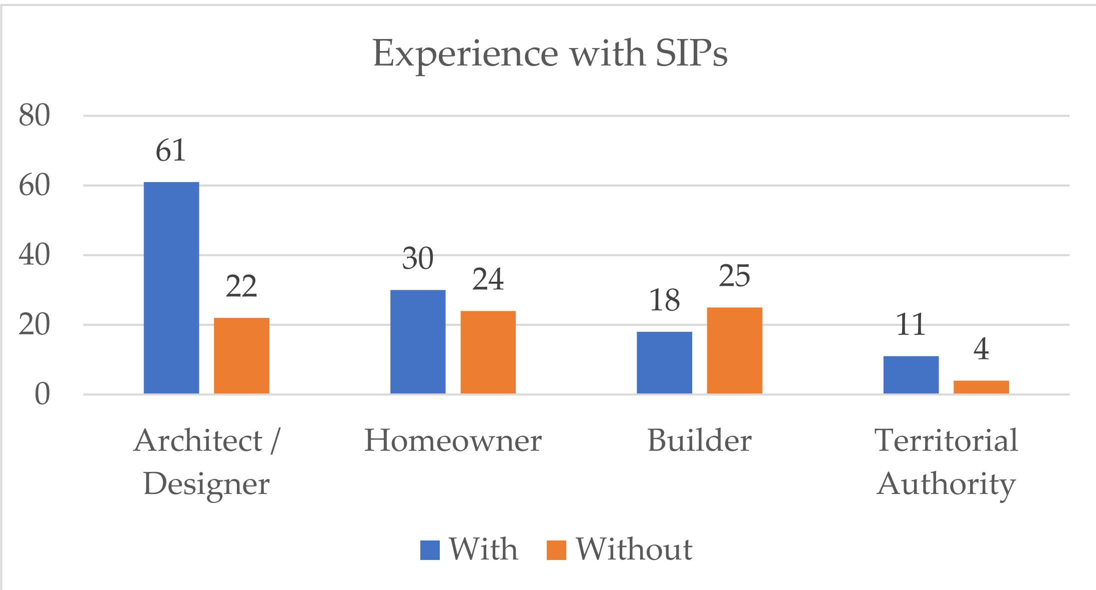

Figure 2. The participants' experience with SIPs.

The first question asked in the survey was if respondents have had an experience with SIPs. Overall, about 62% of the respondents revealed that they had experience with SIPs (at least one

SIP home project); hence, this contributes to the reliability and quality of the feedback. In order to determine the current status of SIP implementation in New Zealand, the participants were then asked the number of SIPs homes they have been involved in the past 12 months, which is illustrated in Figure 3. It can be seen that the architects/designers have been more active in designing SIPs homes, while almost two-thirds of the builders have not constructed any SIPs homes within the past 12 months. It is noteworthy to mention that slightly above the half of the homeowners who participated in the survey built at least one home using SIPs system, while about 75% of the TAs indicated that their offices had processed at least one consent for SIPs housing. The answers that were given to the third question of the survey justify that the architects/designers have been the most active stakeholder in promoting SIPs implementation. The architects/designers indicated that they designed only a few (less than 5%) projects in which the use of SIPs was driven by the homeowner, while 91% of the homeowners indicated that the architect/designer was the driving factor in using SIPs in construction of their homes. The remainder of this section addresses the responses that are specific to each stakeholder and compares against the findings of the studies reported on the subject.

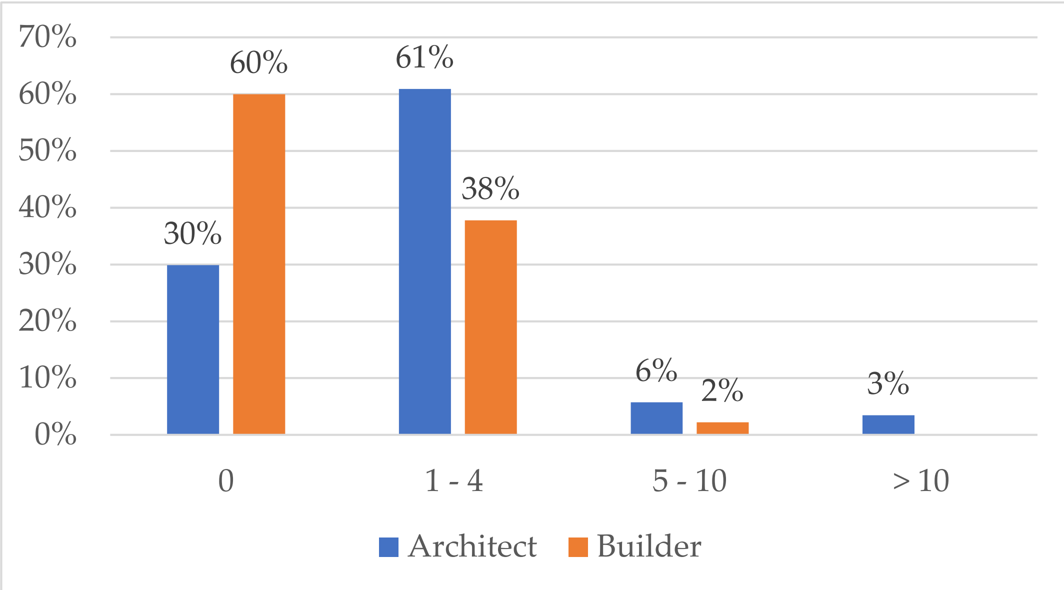

Figure 3. The number of SIPs homes the architects and builders have been involved in the past 12 months.

4.1. Architect/Designer

The architects/designers were asked to answer the questions that were specific to their areas of expertise. Wide-range of questions that are aimed to capture their (of those who have had first-hand SIPs project experience) opinions concerning the benefits and challenges associated with the use of SIPs in New Zealand.

Environmental sustainability is a topic which is becoming more widely discussed, from widely publicised chains removing single-use plastic bags at some supermarkets to rising sea levels and other climate change issues, the environment and the impact of society on it, are growing topics. McIntosh and Harrington [11] highlight the possible benefits of factory-based construction in the reduction of construction waste and therefore improved sustainability. To best realise these benefits the designers of buildings need to look closely at the materials being used and where possible, optimise the design to reflect the materials available and reduce waste in the processing of materials for construction. McIntosh and Guthrie [18] also looked at the possible benefits of SIPs with regards to the production of the materials used. It was noted that orientated strand board (OSB) was able to utilise more of the tree material than was able to be used in the manufacture of structural timber. With this in mind, the designers were asked to rate perceived environmental benefits provided by SIPs, and it can be seen that (refer to Figure 4) the majority of the respondents adopted SIPs in their projects due to the benefits (e.g., better thermal performance and reduced construction waste) they offer, particularly the environmental ones. While 70% of architects/designers with experience indicated that SIPs was beneficial to the environment, 21% of architects/designers with experience indicated a natural position with perceived environmental benefits.

"*I have decided to use SIPs for the benefits that they provide.*" (Architect/Designer)

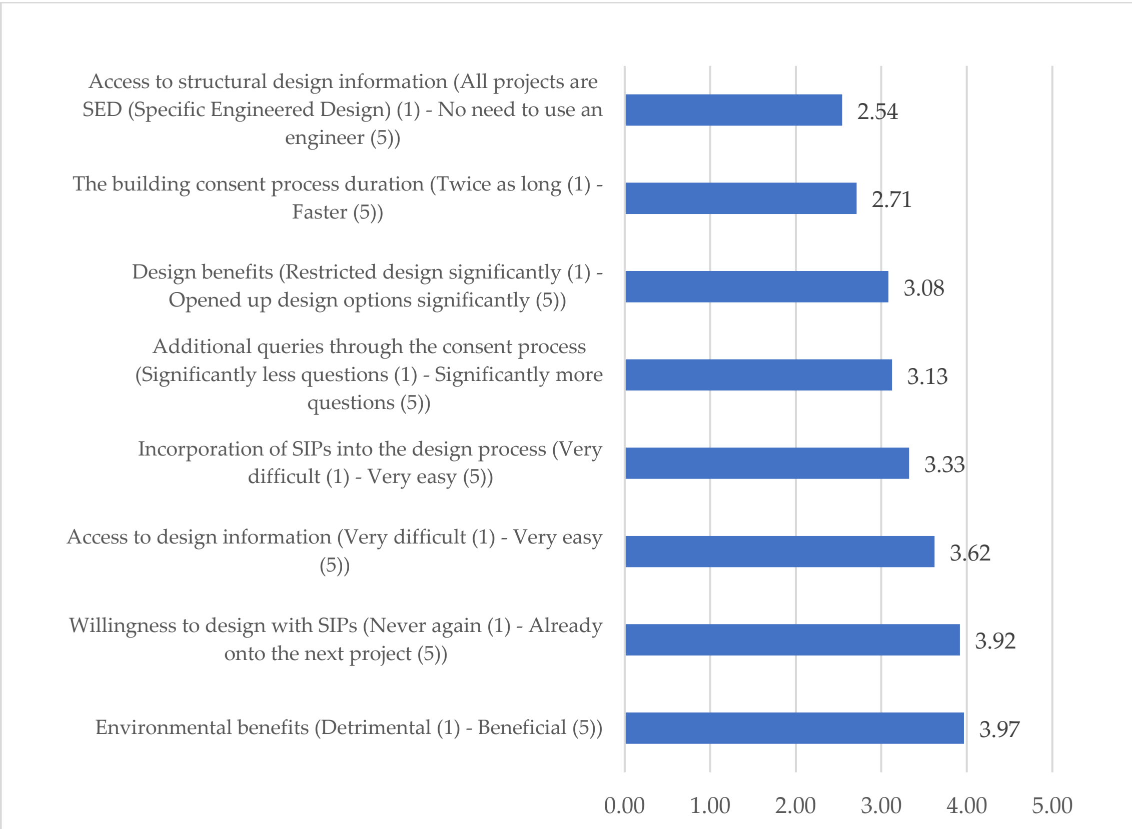

Figure 4. Responses from architects/designers.

Winter (1993) discussed a survey carried out by the Structural Insulated Panel Association (SIPA), which surveyed over 100 architects in the United States about their views on SIPs, most responded that they would consider SIPS; however, there was a concern with the possible design limitations. The survey results show that the respondents indicated that they found it easy to incorporate SIPs into their designs. The survey produced similar results when designers were asked if SIPs had been able to provide a design benefit over conventional methods of construction, 35% of designers with SIPs experience agreed while only 23% without experience believed that it might provide a benefit. Disagreement with the question had a similar spread of opinion with 20% of designers with experience and 32% without experience saying that it restricted the design options available to them. Winter [10] indicated that there needed to be better information for architects regarding the availability and design fixability of SIPs structures. With 73% of designers with no prior SIPs experience and 56% of designers with SIPs experience indicating that they had either a neutral or negative view about being able to incorporate SIPs easily, the results seem to support that SIPs is still generally seen as potentially being difficult to incorporate during the design phase of construction. These results have also been justified by the lack of and limited access to structural design information. As can be seen from Figure 4, the architects/designers indicated that it is not that easy to access to structural design information. As one of the participants commented:

"*Most SIP products on the New Zealand market seem to lack comprehensive engineering data, which as most of these houses need engineering sign off makes it twice as hard as it should be for engineers and architects.*" (Architect/Designer)

Limited adoption of SIPs in the New Zealand construction context was also attributed to relatively longer building consent duration, which can be linked to the additional number of queries throughout the consenting process, as indicated by the respondents:

"*Building the consent process was the most difficult.*" (Architect/Designer)

"*Councils need more instructions on the processes of construction and need to adhere to the code mark provided.*" (Architect/Designer)

4.2. Builder

It was essential to seek for builders' feedback as they are the ones at the forefront of the construction activities. Overall (refer to Figure 5), the builders believe that SIPs have a great potential to improve the construction industry performance in terms of sustainability and productivity.

"*I have chosen SIPs for better thermal performance and a healthier home.*" (Builder)

"*Essentially, you are building a better envelope for the building.*" (Builder)

The perception is that SIPs are potentially a significant game changer and will impact the industry performance. The results reveal that the impact is perceived to be primarily in terms of construction waste reduction, reduction in construction time, and workforce as well as simplicity of construction.

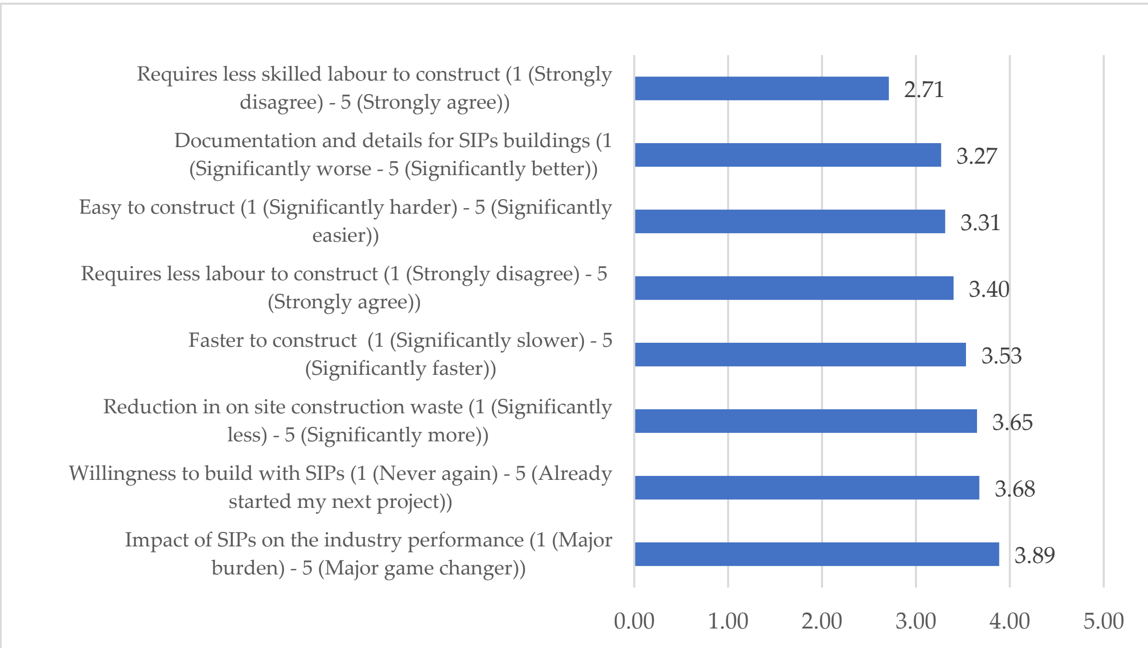

Figure 5. Responses from builders.

As highlighted above, one of the essential marketing strategies for SIPs focuses on its environmental performance. Offsite manufacturing has been widely reported as one of the significant ways to reduce the amount of waste [6,16,27] for which the built environment is responsible [28,29]. Thus, SIPs, offering the same method to manufacture the structural components [5], is no exception. Through this survey, our aim was to ascertain whether the perceived waste reduction correlates with the observed experience. While assessing responses from builders with SIPs experience, it was noted that 56% of the respondents observed a reduction of the waste produced on site. This illustrated by Figure 5, where the builders responded that SIPs have the potential to reduce the construction waste.

In terms of time-saving benefit, it is noteworthy to mention that the majority (76%) of the respondents, who had no previous SIPs experience, indicated that they believed that SIPs would help to speed up the construction. This is a clear indication that SIPs are perceived to provide similar benefits that do pre-fabricated standard panels. Although several studies [5,7] reported that SIPs are able to reduce construction time on site, the results of the survey for builders with prior SIPs experience showed that the builders found the system more time consuming with 44% indicating that it took them longer to construct compared with 22% who indicated it was a faster system. According to the comments of the builders, lack of familiarity and understanding and too many engineering requirements and design issues are the issues which make the application of SIPs time-consuming.

Mullens and Arif [5] discussed the possibility of utilizing more less-skilled labour supervised by a skilled tradesperson. This was explored further, and builders were asked if there was a lower requirement for skilled tradespeople to construct SIP homes. Only 22% of respondents with experience in SIPs agreed that it reduced the need for skilled labour on site, while 56% responded that it took more skilled labour to install.

4.3. Homeowners

The survey results show that the homeowners are driven by the thermal performance offered by SIPs, as illustrated by Figure 6. In this regard, the homeowners were asked if they have noticed any saving in their power bills. Half of the homeowners indicated that they had noticed saving in their power bills at various levels, which aligns with the findings of DoE [30]. The report states that the tighter insulation, which is provided by SIPs, results in a considerable amount of 14% decrease in energy bills. The homeowners shared their experiences in the easiness of finding relevant information, how the structural benefits impacted their decision and whether they had to compromise on the design due to limitations of SIPs. It can be seen that there is a significant impact of architect/designer behind their experiences, which justifies the above-mentioned survey result showing that the majority of the homeowners were motivated by architect/designer. Moreover, the homeowners' feedback indicates that the more awareness and knowledge they have the easier adoption of SIPs could be achieved. Lastly, the homeowners were also asked if they had experienced any cost increase in building a SIP house. Slightly more than half of the homeowners found SIPs costly comparing to the conventional panels, while only a few of them did not have any cost increase by implementing SIPs in their projects. According to the builders' and architects'/designers' feedback, an increase in cost can be attributed to various reasons:

> "*Too much engineering required, which in turn made it more expensive.*" (Builder)

> "*Council's lack of understanding the structural integrity of the SIP that some time was not practical/unusable led to go over these element several times to get right, eventually costed the client.*" (Builder)

> "*Until SIPs become commonplace, costs will inevitably be higher.*" (Architect/Designer)

> "*Unfamiliarity of the stakeholders with the system adds a premium to cover a perceived level of complexity.*" (Architect/Designer)

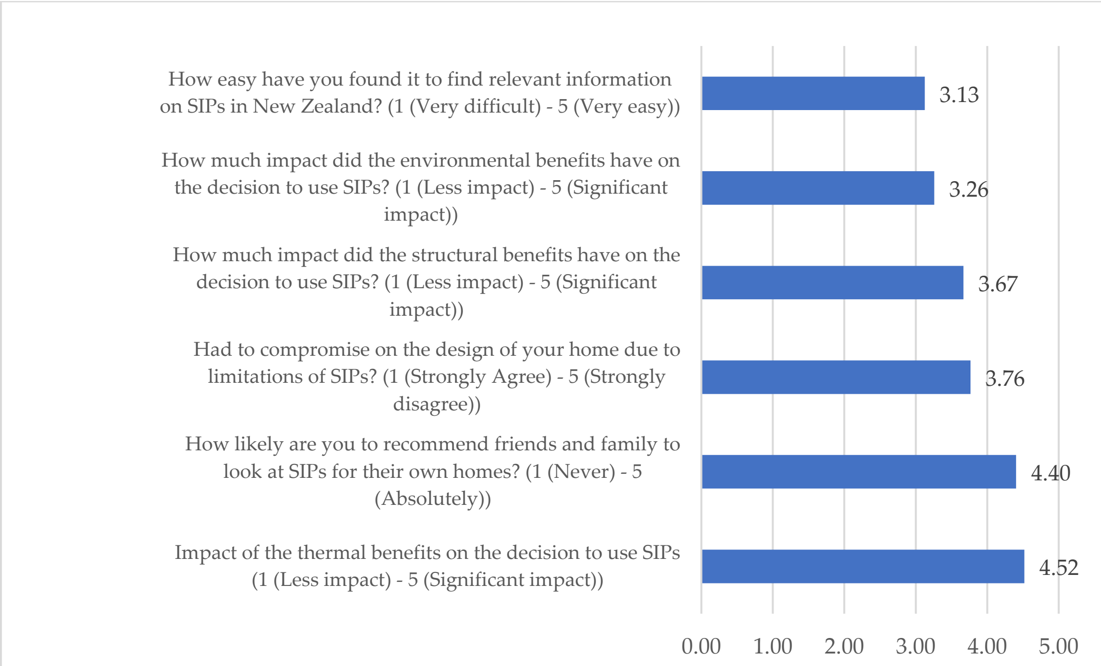

Figure 6. Responses from homeowners.

4.4. *Territorial Authority*

The officers of the territorial authorities across New Zealand were asked how difficult the consent and inspection processes are when implementing SIPs. It can be seen that the territorial authorities have been experiencing difficulties in consenting the SIPs (refer to Figure 7). These difficulties are attributed to various reasons, such as a requirement for additional consideration, precise specifications from the manufacturers and code compliance risks due to being untested in New Zealand climate conditions, as commented by some of the respondents in this category:

> *"A Territorial authority and Building Consent Authority cannot possibly know all products and materials on the market without full documentation. One thing, which designers do not understand is we need as much information as possible to make an informed decision as to how the system works as an alternative solution to the Building Code. Relying on the information on the internet, which is not always available to the level we need to ascertain how much testing the system or product has undergone. Also, how the system relates to the NZ Building Regulations."* (Territorial Authority)

Moreover, the results show that there is a need for additional training for the inspectors, which the respondents believe can be provided by the industry if necessary:

> *"I think the industry can provide territorial authorities with training in new products to make the consenting process smoother."* (Territorial Authority)

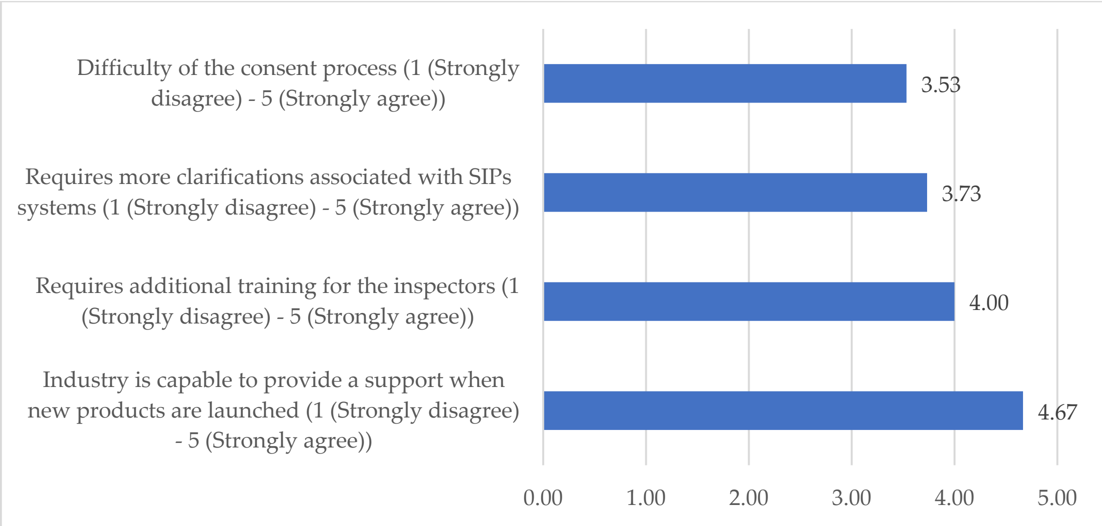

Figure 7. Territorial Authorities' responses.

4.5. Willingness to Design/Build with SIPs

As the respondents of this study indicated, SIPs contribute to improving the environmental performance of the construction projects. Despite its benefits, widespread adoption of SIPs requires the willingness of the key stakeholders to adopt SIPs. Thus, those (architects/designers, builders and homeowners) who are at the forefront of the implementation, based on their experience with SIPs, were asked if they would prefer SIPs to the conventional timber-framed construction. All groups had affirmative responses, which indicates that architects/designers, builders and homeowners are willing to design, build and recommend SIPs, respectively. It is worth mentioning that the homeowners had more positive feedback, which is vital as this group of stakeholders is those who could drive the country-wide adoption of SIPs. It has also been reported that project owners play an important role in making decisions [31,32] and therefore, their willingness/motivation is crucial to ensure their constant engagement in SIP projects.

5. Conclusions

The literature on SIPs contains a considerable amount of studies reported on its construction performance, thermal performance and sustainability performance. As a relatively new construction technology, SIPs offer various benefits but at the same time some barriers are inhibiting its implementation, and these have been reported by several studies in the literature.

As in other countries, reportedly, the New Zealand residential construction industry, which is deeply entrenched with conventional timber-framed houses, has also been known as a poor performing industry in terms of productivity, sustainability as well as re-using the construction waste generated on sites. However, this survey shows that attitudes are changing and there is a growing trend to invest in new technologies and methods and it can be seen that SIPs can contribute to tackle the above-mentioned problems associated with the construction industry. While it has been reported that the time savings observed during a SIPs home construction, the survey results show that in New Zealand, these same savings are not necessarily achieved. The builders who reported cost savings and reduced construction times typically have constructed a number of SIPs homes previously which provides them with experience which new contractors lack.

It is likely that three or more SIPs projects need to be completed before benefits and savings are realised based on feedback from builders. Where contractors have commented about increased time, it has generally been observed that the contractor does not have significant experience in SIPs, which may be affecting the outcomes as they learn a new system.

While 56% of respondents with SIPs experience indicated that more skilled labour was required, the survey did not clarify if the increasingly skilled labour was trained to a higher level than a carpenter. It is possible that the increased, skilled labour required for SIPs houses could be product-specific, and it may be possible to train people to erect SIPs faster than a conventional apprenticeship. This is an area which would benefit from further research to understand if there is any benefit to running specialised training for SIPs installations which may reduce the need for trade qualified carpenters.

The level of support documentation which is provided by SIPs suppliers in New Zealand varies. This variance in the quality and content may be affecting the perception of some designers and builders. This is supported by 20% of SIPs experienced designers who indicated that they had difficulty around structural design. Since the completion of the survey, one supplier has received a Code Mark approval for their design manual, which answers many standard engineering questions. It is recommended that it is investigated further in the future to see if this design guide has had an impact on designers or not.

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