THE CONDITIONS AND CONSTRAINTS FOR USING REUSED MATERIALS IN BUILDING PROJECTS

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ABSTRACT

Examining two Swedish case studies of buildings that were built with a large share of reused materials, such as concrete frames, we analyzed the conditions that made these pilot projects possible. We also examined the constraints of the projects. The analysis is structured around four central themes: the project organization, the participating actors, the financial issues, and the technical issues. The authors played different role in the projects, and we arranged a semi-structured discussion and interviews with the actors involved in one of the projects. The paper suggests that there were no significant structural driving forces behind the realization of the projects; however, individual commitment from some key actors made these reuse projects realized. This study outlines some aspects that would be useful to consider in new projects.

KEYWORDS: Actors; Building; Concrete; Conditions; Constraints; Deconstruction; Financial; Organization; Reuse and Technical

INTRODUCTION

In industrial countries such as Sweden, people are moving from industrial towns and smaller communities to cities and suburban areas often associated with universities, to find work in the service sector and in high-tech industry. This development results in empty buildings in some places, and housing shortages in other places (1). Because empty apartments are expensive to heat and maintain, they are often demolished long before the building's technical-life expectancy is reached. Reusing the materials from such buildings in areas in need of housing makes sense; however, this is not a common practice. Generally, buildings are demolished and virgin raw materials are used for new buildings. Such building practices do not maintain the quality of the materials and waste natural resources and energy.

Wood, steel, and concrete are the Swedish building sector's most important materials, when you combine their embodied energy and mass (2). Improved recycling practices that use reused materials instead of virgin materials would significantly improve the environmental performance of the building sector. However, concrete is typically recycled as aggregate used for landscaping or road construction. In such applications, concrete mainly substitutes crushed rock that is an abundant material in many countries. Furthermore, the energy used to produce crushed rock is less than 10% of the energy used to produce concrete. If reused concrete instead substitutes concrete produced from virgin raw materials, the environmental performance of the reuse practice would be significantly improved.

In two cases in southern Sweden, concrete and other materials have, after deconstruction, been reused in new buildings. This article analyzes the conditions for reuse in these two cases and discusses them in a more general context. Furthermore, there are many constraints for reusing materials in building projects. We examine the constraints of reusing materials in these two building projects.

METHOD

The authors have been involved in different roles in the projects. In 1996, the idea for the first project (Udden) was formed by Gunnar Sundbaum. The second project (Nya Udden) was completed in 2002. The authors come from the company owning the new property (Stångåstaden), the project management company (Sundbaums AB), and Linköping University, who evaluated the environmental performance of the projects. In 1999, the Udden project was evaluated in a Swedish report (4), focusing mainly on the technical and environmental aspects of the project. During a meeting in 2002, the authors identified the conditions they believed were necessary for the realization of these projects. We met with many of the actors that had been involved in the completion of the projects. This approach was modeled on the focus group approach (5), which can add a new dimension and generate new information, compared to traditional interview methods. Before the interview, the participants were asked to complete a survey that addressed conditions and constraints according to these categories: organization, actors, technical aspects, and financial aspects. During the meeting, the participants were asked to prioritize conditions and constraints for the projects. Finally, the participants were asked to discuss the optimal conditions and organization for future projects involving reusing materials.

THE PILOT PROJECTS

The Udden Project

The Udden project was started in 1996, when Gunnar Sundbaum was exploring ways to deal with empty buildings in Finspång, Sweden. This town has a long industrial tradition, but improved productivity in industry has decreased the need for labor. In Finspång, multi-family units are owned mainly by a municipally-controlled company that faced a difficult financial challenge for the first time. In 1996, 325 of the 2400 apartments were empty, costing the company a great deal of money. The company's earlier strategy to meet such problems was to improve the housing; but this was no longer sufficient since the causes of the problem of empty apartments was related to the economy and the location of the apartments (cf. 6). It became obvious that the buildings had to be demolished to decrease the number of apartments and to simultaneously try to improve the quality of living in those areas by creating more space between the remaining buildings. It was decided that five buildings containing more than 100 apartments would be demolished. They were built in the 1960s, but they were renovated several times since then and were in good condition.

Figure 1. *This is one of the apartment buildings in Finspång, Sweden that was torn down and functioned as a material source for a new building in Linköping, Sweden.*

Gunnar Sundbaum suggested that the "apartments should be moved" to Linköping to address a housing shortage there (especially a housing shortage for students). That is, the materials that could be reused should be moved to another site to be reused in the construction of new apartments. This would require the building to be deconstructed carefully so the materials could be reused. This suggestion was made to the managing directors of the housing company in Finspång and to the largest housing company in Linköping. In 1997, they decided to develop the project and requested bids from three large contractors.

In order to make use of as much of the materials and products as possible, the general contractor carefully deconstructed two of the buildings in Finspång. The buildings were constructed mainly out of concrete and beams cast in-place. To reuse these materials, they were cut with a diamond saw. The deconstruction was predicated on what the new building could use. Materials and products from about 50 larger apartments in the two buildings that were deconstructed were used to construct a building containing 22 smaller apartments (totaling 1070 m^2). In the Udden project, reuse was not restricted to concrete walls and beams (Table 1), although this is the most conspicuous feature of this building (Figure 2).

Table 1. *Selected products and materials reused in the Udden project. Data refers to number of items unless specified.*

Concrete wall elements	73	Kitchen sinks	12
Concrete beams	41	Water taps	39
Concrete foundation	30 m^2	Sanitary ware	46
Doors	45	Radiators	63 m^2
Windows	89	Clay bricks	220 m^2
Wood flooring	600 m^2	Window ledges	26
Kitchen cupboards	92	Mineral insulation wool	236 m^3
Wardrobes	78	Mineral insulation	636 m^2

Figure 2. *Concrete elements cut from cast in-place concrete walls delivered to the building site in Linköping under the supervision of the county governor, Björn Eriksson.*

The environmental performance of the Udden project was evaluated; for the impact categories studied, it turned out to be a better option than using conventional building techniques and materials. If the elements would have been transported a distance longer than 140 km, the emissions of nitrogen oxides would be higher for the reuse project due to the truck transport (1).

The Nya Udden Project

The Nya Udden project, a student housing project, was completed in November 2001 . However, there are many significant differences from the Udden project. First, the material source was an area in Norrköping where the buildings were built with pre-cast concrete elements, which meant that time-consuming cutting of elements was not needed. The organization of the deconstruction and building process also differed substantially. In this project, there were different actors responsible for the deconstruction and the building processes. The building process was not coordinated by a general contractor. Instead, a project management firm that hired several subcontractors performed the coordination of the building process.

In 1999, the property owner in Norrköping, Hyresbostäder initiated a 100 million euro refurbishment project involving 1600 apartments in the district of Ringdansen, Norrköping. The area was built from 1968 through 1972, and was the home of about 5000 people. However, the area had gained a bad reputation and was not considered attractive. The refurbishment project aims at an attractive district with about 1000 apartments. This is accomplished mainly by removing upper floors on many of the buildings, which means that a careful deconstruction was needed.

The new building had 54 new small apartments, but the original idea was that 500 new apartments would be built using the concrete elements from Norrköping. Because the careful deconstruction turned out to be more expensive than deconstruction that aimed at crushing concrete, the agreement between the material supplier and the user of the material was terminated. This led to the conclusion that most of the new 500 flats had to be built with conventional technique and using materials and products of virgin origin.

Reuse in the Nya Udden project focused on the concrete elements more than the Udden project did (Table 2) (Figures 3 and 4).

Table 2. *Reused materials and products in the Nya Udden project, Linköping, Sweden.*

Reused materials	**Number**	**Tons**
Concrete partition walls	138	524
Concrete outer wall elements	72	208
Concrete beams	224	684
Concrete stair-cases	8	16
Iron banisters	16	
Windows	34	
Window ledges	100	

Figure 3. *The concrete elements from the refurbishment project arrived at the building site in Linköping, Sweden.*

Figure 4. *Frame construction in Nya Udden. Additional steel supports were used to further reinforce the building.*

ORGANIZATION AND ACTORS

To realize building projects like these that involve deconstruction and construction, a number of actors have been involved in the organization of the project. In the Udden project, resulting in 22 small student apartments, twelve actors have been identified - the four most important are listed in Table 3. These twelve actors are involved directly in the deconstruction and construction of the project. Furthermore, regional and national agencies have granted money for the projects, and the projects have gone through a conventional planning process by the local government. These two processes were crucial for the accomplishment of reuse building projects. The issue of governmental grants is discussed below under financial aspects; but regarding the spatial planning process in the local authority it is worth noting that a reuse building project differs from a conventional building project. First, the timing of deconstruction and construction of a new building is difficult to manage by itself. Such a project needs to go through a spatial planning process that could complicate the issue of timing. However, this was only a slight problem in these projects. On the other hand, building with reused concrete elements demanded more flexibility in the spatial planning process, because the builders were much more tied to the building size and design than in a conventional building project.

Table 3. *Main actors of the integrated deconstruction/construction projects (Udden and Nya Udden) involving deconstruction in Finspång and Norrköping and construction in Linköping. Several smaller companies were responsible for heating, sanitation, electricity, etc.*

	Udden	Nya Udden
Owner of the new property	AB Stångåstaden	AB Stångåstaden
Project management	Sundbaum Bygg och Miljö AB	Sundbaum Bygg och Miljö AB
Main contractors	NCC AB	Idébyggarna (concrete frame) and Åhlin and Ekroth
Reused building materials supplier	Vallonbygden AB	Hyresbostäder AB

In the Nya Udden project, the responsibility for the deconstruction and the frame assembly was not in the same organization. The refurbishment project was done without proper coordination with the building process in Linköping.

Owner of The New Property

The owner of the new buildings, Stångåstaden, is a municipally-controlled company in Linköping, Sweden, and is a key actor in the two projects. This section describes some of the features of the company that potentially could have influenced the decisions to build apartment buildings with reused materials. The first issue is public ownership. Have the owners influenced the company to take these initiatives? The informants working for Stångåstaden state that the politically-appointed owners did not interfere with these decisions, and the ownership involves only management on a strategic level, emphasizing the importance of a high environmental

profile of the company in general. This ambition was further manifested in the two projects by recruiting an environmental manager.

Instead of ownership, the informants at Stångåstaden stressed the size and financial power of the company as a condition that made these projects possible. Its turnover in 2002 was about 115 Meuro, and its return exceeded 12 MEuro. Such conditions make it possible to take an increased risk and to take on pilot projects such as these. In both these projects, no decisions about any grants were made before the projects started. It was possible for Stångåstaden to go ahead with the building process because of their financial stability.

However, our informants also emphasized that the managing director was committed and liked the ideas very much. He also saw the opportunity to strengthen the environmental profile of the company through these projects. The two projects described here were securely anchored and driven by the top management of the company, rather than by individual employees in the organization.

Project Manager

Gunnar Sundbaum at Sundbaum Building Consultants came up with the idea of solving the two problems of empty dwellings in one town with housing shortage in another with an integrated deconstruction and building project. Previously, he worked in property management and refurbishment of unattractive housing areas, with the aim of improving their quality. His company was responsible for the project management of the Udden project and the Nya Udden project. Gunnar Sundbaum was the main innovator behind the project. His experience with surplus and shortage problems made him an integral designer of the project. He acted as a catalyst for both projects by presenting the idea to the key actors: the managing directors of the housing companies that experienced both surplus and shortage problems. Through his efforts, the concept became firmly anchored within a purchaser organization with sufficient financial stability to engage such projects. He also employed skilled people to act as project leaders, and provided the project buyer with an organization to tackle all the practical problems that would arise.

Reused Building Materials Suppliers

The owners of the buildings that could potentially be deconstructed and their motives are, of course, crucial if deconstruction of buildings will be chosen over demolition of buildings.

Vallonbygden (the municipally-controlled housing company in the Udden case) was ambivalent about the project. It was difficult for them to communicate a positive message regarding a project that included deconstruction of their property. From the view of the local authority that indirectly influenced the company's decisions, it was difficult to accept that buildings needed to be removed. This is partly because of a psychological effect associated with admitting that the town was in an economical recession (4). The unpleasant but necessary decision became easier, thanks to the idea of a deconstruction approach. The company management believed that it was better to be associated with a project where new buildings were constructed using materials from deconstructed buildings, than to simply demolish their empty buildings. Therefore, their role in realizing the project was not as a main force, but they were still a positive project partner.

Hyresbostäder, who managed the large refurbishment project in Norrköping, was the material supplier for the Nya Udden project. Their refurbishment project has an overt environmental profile. Because of this, the government granted 26 million euro to the project. One of the environmental aims of the project was a high degree of recycling of the materials that the deconstruction would generate. This goal was also a condition for the governmental grant. During the deconstruction work, careful handling was needed when the elements were to be reused in a new building, making this process more expensive than expected (cf. 3). The agreement regarding concrete element deliveries to the building projects was broken after the Nya Udden project. Instead, after deconstruction of the top floors, the concrete was crushed and mainly used for local landscaping. At present, it is not clear whether the governmental grant will be affected by this practice. One can conclude that this material supplier focused on its own refurbishment project and did not become involved in the process of building new apartment houses.

The Main Contractors for Deconstruction and Building

The Udden project had general contractor responsibility for both the deconstruction and construction of the new apartment building. This made it possible for the contractor to use the same staff for the deconstruction as for the building process. Depending on progress in the project development, staff could be used in a flexible manner, either at the deconstruction site or at the building site. The incentives for the workers responsible for the deconstruction to be careful with the concrete elements and the other products were obvious. Any problems related to the reused materials and products would become their own headaches later.

The company Idébyggarna was responsible for the transport of the elements and the erection of the concrete frames in the Nya Udden project. They had to solve several problems in the process (see below in Technical aspects). The main problems regarded coordination with the deconstructors about how the elements should be handled and stored. Because the storage site was not planned, the handling and loading of the elements was inefficient. The informant from this company stated that they have learned a lot from participating in this project, and they would be happy to make use of their experience in similar projects.

Åhlin & Ekroth was the company responsible for the main part of the Nya Udden except the concrete frame. Their representative in the focus group stressed that it was not very different or more difficult than a conventional building project. However, the reuse practice still influenced all the other building contractors. The demand for coordination and cooperation between the different builders was greater than in an ordinary project. In this project, it actually contributed to the creation of a cooperative atmosphere at the building site. Being involved in the Nya Udden project led to an increased commitment to environmental issues among the employees. In all the projects Å&E has been involved in since then, there has been an improvement of waste management at the building sites, resulting in lower costs for the company. According to our contact, this organizational improvement can be attributed to their participation in the Nya Udden project.

TECHNICAL ASPECTS

The contractors in the focus groups stressed that they have not met any serious, immediate technical problems in building with reused materials. The technical problems encountered are related to the organizational and financial aspects more than any other aspects. The focus groups noted that timing was a serious issue that needed to be addressed in future projects. In the Nya Udden project, there was significant time pressure at both the deconstruction site and at the building site that made the preparatory planning process too short. Furthermore, different actors were responsible for the deconstruction and the construction. This made the temporary storage sites at both locations inefficient, and it caused many problems because there were no immediate incentives for the people deconstructing the buildings to handle the elements carefully. They were not aware of the problems caused by storing the elements. Wall elements were stored and transported standing, which did not cause any problems, while beams were stored lying down. Four beams were stored on top of each other, and if this was not done properly, cracks could arise. When this problem occurred, concrete beams had to be discarded.

To make sure that the construction at Nya Udden would suffice in terms of pressure failure, some tests were performed on the beams. It was no problem to satisfy standards in this respect, but to ensure safety over-dimensioning of supports was also applied.

Building standards have changed in many respects since the buildings were constructed. In both the projects, noise reduction standards were not met using the old elements. In the Udden project, a new concrete layer was added on the beams; in the Nya Udden project, this was solved by using insulation materials and gypsum board. Extra insulation and surfacing of the outer walls had to be added to meet insulation standards in both projects.

Comparing the two projects, partial deconstruction of element buildings seems better than having to saw cast in-place concrete walls and beams. However, to some extent, the technical problems in the Nya Udden project were easier to solve and were outweighed by the organizational problems regarding the different incentives of the deconstruction team and the builders.

FINANCIAL ASPECTS

For both projects, using a large degree of reused concrete elements cost roughly 10% to 15% more than building with conventional building practice. This additional cost has been compensated for by governmental grants for “green building practices,” so that the cost for the property owner roughly equals that of a conventional building. However, in both cases, the grants were awarded at the time the decision to build was made. The property owner, Stångåstaden, thereby took a risk of starting two building projects without knowing the financial outcome. This uncertainty was also 10% to 15% of the total project cost. The focus groups urged a rapid and flexible process for awarding grants for building projects. The informants believed that such a practice would facilitate decision-making significantly, and would lead to more reuse building projects in Sweden.

The additional cost for reuse should be viewed in the context of the pilot character of these projects. No contractor had any experience with projects such as these, and their response in the focus group was that a 10% to 15% cost reduction could be easily accomplished in future projects. These projects were performed on a relatively small scale. Because only 26 and 54 small apartments were built, the projects do not make it possible to make significant large-scale profits. The participants in the focus group concluded that projects such as these could be profitable if the scale is increased and if the contractors benefit from earlier experience and knowledge.

In the Udden project, the total cost for the concrete frame was 80% higher than if virgin materials would have been used. This increase can be attributed to cost for labor that is doubled in this reuse project, compared to a conventional building project. On the other hand, the materials cost was only 20% higher than projects using virgin raw materials.

It is worth noting that the customers, the tenants, would not be prepared to pay extra for the benefit of living in a building made of reused materials. Rather, it has been noted that the quality demands from the tenants are higher in the reuse buildings, while the quality demands raised by the property owner are slightly lower than in a conventional building project.

CONCLUSIONS

Generally, environmental initiatives like the use of environmental management systems or environmental investments in companies often have their origin in either market demands or changes in legislation. However, some authors also refer to the simple explanation that committed and influential individuals often want to do something they believe is good. The latter explanation is largely applicable in the cases described in this article. However, some conditions of a more structural kind–for example, financial aspects–also have to be met if reuse projects are to be realized. As for policy implications from this finding, the focus should be placed on creating favorable conditions for the committed individuals, rather than exclusively stressing the importance of the structural conditions.

There are several aspects that should be considered for future building projects with reused materials to address the constraints experienced in the these two pilot projects.

The informants emphasized that a large-scale use of reused materials in the Swedish building sector will not take place unless it is possible for actors to profit financially from this practice. In this context, three conditions for further development were identified as crucial.

(i) The size of the individual projects. Projects the size of 20 to 50 small apartments do not make it possible to use technical improvements and techniques to produce a significant financial return.

(ii) Benefit to the contractors. The building contractors need to know that there will be more projects of the same kind if they develop technology and building techniques for use with reused materials.

(iii) The endurance of governmental bodies that influence the financial boundary conditions through grants or subsidies. The two pilot projects that this article deals with were decided under uncertainty about whether any subsidies would be granted in a process that was difficult to manage and predict the outcome.

In the Nya Udden project, the governmental grants required deconstructed materials to be recycled. It still seems, however, that no quality demands regarding the kind of recycling were raised, which made it possible to break the agreement and instead crush the concrete elements to save some money. In the future, such refurbishment grants could be more explicit about grant requirements. This would create more favorable conditions for reuse projects.

According to our informants, the realization of a new project of this kind should be predicated on the manager of the building project controlling the building/s that should be deconstructed. This would help cope with the timing problem and would mean that the builders will not have to depend on actors who are not involved in and committed to the building project.

The two pilot projects described in this paper involve significant changes to the layout of the apartments. The material source buildings contained two to four-room apartments, and the new buildings are smaller one or two-room apartments for students. In a new project, the material source building and the planned building should be as similar as possible. The focus should be on deconstructing a building so that as much source material as possible can be reused in the new building.

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