Recovery Strategies to Bypass the Grave

Seven questions and answers for your next project

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ABSTRACT

As a building nears the end of its life, steel recovery strategies can result in recycling or reuse of steel. In the latter case, the process involves the reuse of elements of the original structure for another building project, the reuse of the steel structure in situ (which may include a structural design upgrade) or the dismantling and reuse of the structure at another location. In this article, the unique nature of steel as a building material (and its infinite life) is reviewed, in terms of recovery, more specifically reuse, by answering seven questions, presenting three case studies on successful reuse projects, and concluding with comments about the future. The future of steel recovery is very green, both in terms of recycling and reuse. In terms of reuse, more work needs to be done with respect to the sharing of information on potential reuse projects and the availability of recovered steel. At the moment, finding reused steel requires a one-of-a-kind individual effort. However, projects with Natural Resources Canada are currently under way to improve material flow. As we await such developments, it makes good sense to involve structural engineers and fabricators early in the design of a green steel building, as they are more likely to have knowledge of possible demolition sites or other sites – an added contribution to a more integrated design approach, better LEED™ ratings, effective recovery results and consequently better green buildings. Steel recovery strategies will no doubt help a building bypass the grave.

Once ore is extracted and steel is produced for the first time, its life never ends, providing effective sustainable strategies for green building projects (**Figure 1**). From the onset of conceptual development, steel contributes towards sustainability most efficiently when its design is integrated with other building systems and conditions during the building process. As a building nears the end of its first-time use, steel recovery strategies can result in the reuse of elements of the original structure for another building project, the reuse of the steel structure in situ (which may include a structural design upgrade) or the dismantling and reuse of the structure at another location. Steel recovery strategies also include the recycling of steel building products (combined with other post-consumer steel products to produce other structural steel members). Recovery strategies should be considered not only at the end of a structure's life, as it is commonly done, but they should be integrated from the onset during the conceptual phase. Reuse of an existing structure or recycling of steel products extends the sustainable life of a structure and the material through multiple recovery cycles thereby honouring the "from cradle to cradle" concept and avoiding "the grave".

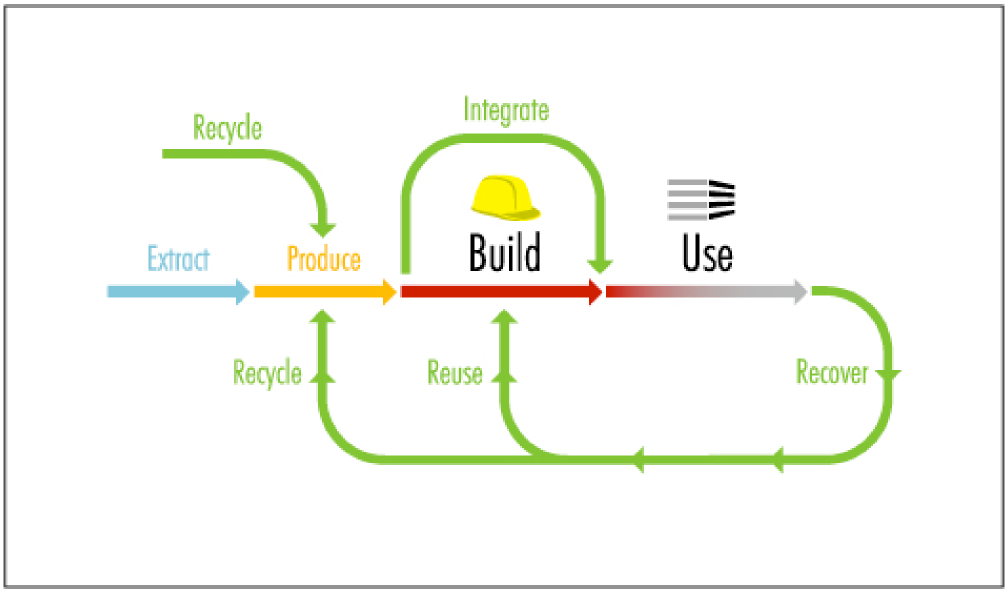

Figure 1 – The Multiple Life Cycles of Structural Steel

In this article, the unique nature of steel as a building material (and its infinite life) is reviewed, in terms of recovery, more specifically reuse, by answering seven questions, presenting three case studies on successful reuse, and concluding with comments about the future.

1. **Where does one find "second hand" steel?**
2. **How can one be sure of the quality of the reused steel?**
3. **How does one go about testing steel for reuse? Is it expensive?**
4. **When can one consider reusing a steel structure "in situ"?**
5. **When can one recover an entire steel structure by dismantling?**
6. **How do demolition crews go about recovering steel?**
7. **How easy is it to recover steel for recycling?**

Case 1 Bits of the *Royal Ontario Museum (ROM)* become pieces of the *University of Toronto Scarborough Student Centre* Date of reused steel girders: 1970s
Case 2 The *Eaton* Building in Montreal becomes *Le Complexe Les Ailes*
Date of reused steel building in situ: 1920's – 1950's
Case 3 Cassiar School in British Columbia, Canada, gets dismantled and reused 1000 km away
Date of dismantled/reused steel: 1990s

1. WHERE DOES ONE FIND "SECOND HAND" STEEL?

Either from a steel service centre, a fabricator's yard or more likely, from a current or future demolition site. Some steel service centers have made it their business to warehouse "second hand" steel, which can now represent 10% of their inventory. The second hand steel inventory consists mainly of W shapes and angles, some tubular sections, and occasionally joists. However, one cannot expect to call a service centre, ask for 10 identical I-beams of a specific length and specific strength, and have it delivered the next day. Although the major motivation for holding "second hand" steel is the cost – approximately half the cost of new steel – the possibility of reuse for obtaining LEED™ points is promising, even if at this point the option appears more feasible for smaller projects. Through leads from structural engineers who track previous projects and keep close contacts with demolition companies (see **Case 1**), one can find and pre-select some members. What about joists? One's best chance is to have good contacts with demolition crews before a building is torn down, and make sure the joists are handled with care. One suggestion is to find the used joists first, and then finalize the layout according to the available lengths instead of vice-versa – a lesson learned from the *Mountain Equipment Coop* project in Montreal (**Figure 2**). However, engineers from *Saia Deslauriers Kadanoff* were still able to integrate reused tubular sections for the fabrication of the main trusses and the climbing sculpture. They were larger than what was needed – as is almost always the case when one reuses steel – but that did not prove to be a problem. One should also consider asking what is available to the fabricators involved in your project (possibly another member of the early integrated design process).

Figure 2 – The main trusses of the Montreal Mountain Equipment Coop include reused HSS

2. HOW CAN ONE BE SURE OF THE QUALITY OF THE REUSED STEEL?

The quality of the reused steel is provided by a mill test certificate or the results from a coupon test. Any batch of steel produced today comes with what we call a "mill test certificate". A mill test certificate provides important information about the chemical and physical properties of the steel. If you have a mill test certificate, even a few decades old, and the steel meets today's required chemical and physical performances, testing is not needed. Hence, it would be wise to make it a practice to keep those certificates for the future. Another, yet conservative, approach is to rely on clause 5.2.2 of the steel standard CSA S16-01, which specifies that the yield capacity used to calculate the resistance of unidentified steel shall not exceed 210 MPa. However, you will want to test the steel if you need to know either of two criteria, or both: weldability and strength. Weldability dictates whether we can attach steel elements through welding to make connections or improve capacity. Of course, bolting is always an option if welding is undesirable. By strength, we mean the yield strength, F_y, and the ultimate tensile strength, F_u, of the steel. If you are only concerned about weldability, you may decide to have just the chemical test performed. In such a case, you only need a small sample of steel. However, if physical properties are required, you will need to take one or more test samples of the steel, called "coupons" (see below). It is important to note that the recycled content of the reused steel cannot be determined through testing. Traces of certain impurities might give you hints but that is not a reliable measure. With regards to steel performance, the homogenous nature of steel allows the information coming from a coupon test to assess the capacity of the steel within the high-level of confidence of current standards.

3. HOW DOES ONE GO ABOUT TESTING STEEL FOR REUSE? IS IT EXPENSIVE?

One needs to cut out a test coupon generally 300 mm long and 50 to 75 mm wide, located in a neutral zone. A neutral zone is an area where the stresses are not too high, and preferably not too visible. However, the decision to take one, four or twelve coupons on existing steel members is usually based on the structural engineer's confidence in the material and the apparent diversity of sources. One basic test will generally cost less than 500$ if the coupon is delivered to the testing company, and up to 1000$ if the testing company is asked to take the coupon on site. A typical palette includes a chemical test, and a mechanical test. The chemical test indicates the carbon, iron and silicon content, which will result in an "equivalent carbon" content, to evaluate the weldability of the steel. The usual mechanical test is a tension test to determine the stress-strain characteristics, e.g., yield strength, ultimate tensile strength and elongation (see Clause 5.2.3 of CSA S16-01 and CISC Commentary for more detailed information).

4. WHEN CAN ONE CONSIDER REUSING A STEEL STRUCTURE "IN SITU"?

It depends on the condition of the original steel, the age of the structure, the information you have from archived drawings, and whether you need to reuse it "as is", retrofit it to satisfy current seismic criteria, or reinforce it through welding. Data about where and when the steel was produced, and to what standard,all help the engineer assess the structure. A recent example of a complete stripping of a steel building frame and the transformation into a new use is the BMW showcase building in Toronto. It is interesting to note that historically, the steel industry made technological leaps as early as the turn of the 20th century. Hence, as far back as the 1910s, steel was already a relatively homogeneous and reliable material, and for that reason, steel of that vintage can still be reused today (see **Case 1**). On the other hand, concrete became an improved building material only after the 1950's, and that is one of the reasons why there are fewer concrete buildings or bridges before that period that can be reused or refurbished without major rework. The testing company *X-per-X* says that steel coupons from older structures are regularly tested, and are rarely assessed as unusable. The most concern engineers have with steel produced prior to the 1950’s is its weldability, which is a function of the higher carbon content present in many of the grades produced during those years. Even then, higher carbon steels can be welded successfully with slight modifications to standard welding procedures. Incidentally, *X-per-X* and engineers such as Pasquin, St-Jean et Associés (see **Case 2**) find that engineers of that era tended to design "adult" size columns and beams, that is, heavier sections were employed creating a reserve capacity compared to the newer lighter designs. In addition, the occupancy loads for which the original structure was designed may have been much higher than those of the new occupancy. What can sometimes be more difficult with the steels of that era is obtaining the proper dimensions for calculating their capacity. Fortunately, reusing steel has been relatively common since the turn of the century and a guide published by *AISC* indicates sizes, yield strengths and other useful information for rehabilitation purposes. Steels produced after the 1950's generally pose few problems, except that the yield strength might be lower. Irrespective of carbon content, steels made after 1910 can always be recycled.

5. WHEN CAN ONE RECOVER AN ENTIRE STEEL STRUCTURE BY DISMANTLING?

Bolted structures are very conducive to being disassembled and moved. Fortunately, that is the case for most steel structures, where most of the welding takes place in the fabricator's shop and transportable pieces bolted together on site. There are several factors that will influence the process: the types of connectors, the bracing elements, the spans of beams, the complexity of the column splices, and, the use of composite construction. Basically, when planning for relocation, use mechanical fasteners and avoid composite construction. Steel erection specialists rather than demolition crews will generally be required to perform the dismantling and erection of the structure at a new location. This area is rapidly evolving and already some specific standards addressing these issues are being considered by the Canadian Standards Association. Although designing for deconstruction is not yet an established practice, it has been, and is presently being done for several structures: in the 1990s, an entire school in BC was moved 1000 km south (see **Case 3**), in this decade, several small industrial buildings in the Maritimes have been dismantled and relocated for a new use, and still standing today, is the Montreal Expo 67 Russian Pavillion …. in Moscow!

6. HOW DO DEMOLITION CREWS GO ABOUT RECOVERING STEEL?

It depends if the steel is to be cut into pieces for recycling or dismantled for reuse. *Murray Demolition* has the policy of leaving no steel behind. To extract steel members for reuse, *Murray Demolition* comments that there are basically two methods: unbolting or shearing. In the case of the *ROM* building (see **Case 2**), the beams to be reused were unbolted. Since the floor system was composite (i.e.: shear studs welded to the top flange of the steel beams and imbedded into the concrete slab), some supplementary cleaning was required. The 38 ft long beams from the *ROM* were shortened by the fabricator to 32 ft long and reused for the *University of Toronto Student Centre*. Shearing (using a giant metal scissor-like equipment) the member near the connection or support introduces residual stresses. Hence, the member is further cut back 2 or 3 feet in the fabricator shop using more refined cutting equipment and new connection material applied. The impact of shortening the members is that most reused sections will be deeper than required, often creating reserve capacity. Demolition crews find that the behaviour of steel buildings is more predictable than a similar concrete building whose behaviour under demolition is directly attributable to the behaviour of the exposed rebars. If you compare a 3 million s.f. steel building to a 3 million s.f. concrete building, the steel building will cost 0$/s.f. to demolish compared to 2-3$/s.f. for the concrete building. The reason is simple: most of the steel can be salvaged and becomes revenue, whereas there are only costs associated to the disposal of the concrete.

7. HOW EASY IS IT TO RECOVER STEEL FOR RECYCLING?

Although the answer depends on the initial site, in general the skeletal and assembled nature of a steel structure facilitates the process. In an unusual situation such as the steel from the *World Trade Center* twin towers – 95% of structural beams and plates were recovered, and 50% of the reinforcement bars. These ratios also correspond to the estimated recycling rates of both of these products according to the *Steel Recycling Institute*. When recovering cars, some shredders can reduce an automobile into small chunks in 45 seconds, or approximately 80 to 100 cars per hour! In 2001, 14.5 million cars in the US fed the open loop of recycling this way. In fact, approximately 96% of all steel from automobiles is currently recycled. Steel is collected not only from used auto parts yards, but also from demolition sites and industrial manufacturers. Companies such as *SNF* (*Société Nationale de Ferrailles*) specializing in the recovery of steel, rely on electromagnetic cranes, powerful guillotine shears and huge machinery for sorting, shredding, shearing, crushing and reducing metals to bits, pieces or fragments. Recovery of steel from demolition sites is fairly straightforward provided it is not contaminated, or that no other material is attached (see **Case 1**). Additional processing (energy) is needed to separate attached materials, which explains why the recovery rate for rebar is more expensive and about half the rate of that of steel beams and girders.

CASE 1 - BITS OF THE *ROYAL ONTARIO MUSEUM (ROM)* BECOME PIECES OF THE *UNIVERSITY OF TORONTO SCARBOROUGH STUDENT CENTRE*

(date of reused steel: 1970s)

In 2003, *Dunlop Architects* were asked by *University of Toronto* students, who are members of the building committee, to provide a building that reflected a sustainable approach for their new *Student Center*. In fact, the students did not understand why such an approach was not adopted by default for all buildings under construction today. *Dunlop Architects* and *Halsall Engineers* came up with the idea that part of the material could come from existing sources. *Halsall*, who was working on demolishing part of the *ROM* building, proposed reusing *ROM* girders for the new Student Centre. Since *Halsall* had done that part of the ROM building in the late 1970s, they had all the necessary archives for demonstrating the material quality of the steel to be reused – therefore no testing was required. A greater challenge was for the architect to find the right official from the *ROM* building to speak to the right *University of Toronto* official, for accepting the (donated) steel. This administrative aspect had to be factored into the project scheduling of this reuse. The reused steel amounted to approximately 18 tons of saved steel.

photos: Halsall Engineers

The Royal Ontario Museum - top - is getting stripped of its steel girders so they can be reused at the University of Toronto Scarborough Student Centre - bottom.

CASE 2 - THE *EATON* BUILDING IN MONTREAL BECOMES *LE COMPLEXE LES AILES*

(date of reused steel: 1920's – 1950's)

In 2002, *Lemay & Associés* took the *Eaton* building in Montreal and refurbished it into the new and elegant *Complexe les Ailes*. Although part of the structure was gutted to create an ovoid atrium, much of the structure was reused. Most of the steel, which dates from several eras, ranging from the 20's to the 50's, could be reused – as concluded by the engineering firm *Pasquin St-Jean* which had coupons of the steel tested for its yield strength, and carbon content. It turns out that the low yield strength of that period could be compensated by the fact that many of the members were oversized, a common practice for that period. Even the columns could be reused. Although the steel had higher carbon content than the new steel, it was still possible to weld onto it. The roof was refurbished as a floor, necessitating extra joists between the existing ones. As far as the rest of the building is concerned, a major portion of the complexity was due to problems with interfaces between different parts of the building built at different periods, and the new parts, complicated by non-typical geometries. The team explained that they would have all benefited from more extensive visual assessments and testing earlier in this fast-track project.

photo: Lemay & Associés, architectes

Connecting new beams of the Complexe Les Ailes to old columns of the Eaton Building in Montreal

CASE 3 - CASSIAR SCHOOL IN BRITISH COLUMBIA, CANADA, GETS DISMANTLED AND REUSED 1000 KM AWAY

(date of reused steel: 1990s)

When the mining town of Cassiar in northern B.C. was shut down in 1992, its steel-framed secondary school was abandoned after only one year of service. The school was nearly forgotten until a fire destroyed the Roy Stibbs elementary school in Coquitlam. The need for a replacement by the Fall of 1994 was so urgent that it was decided to dismantle and reuse the Cassiar school, located 1000 km away. Approximately 75% of the steel frame in Cassiar was shipped piece by piece, with each member labelled according to the mark number on the shop drawings. The higher seismic requirements in Coquitlam and the different classroom layout requirements of an elemenbtary school posed an immediate challenge, according to *Bush, Bohlman & Partners*. The bracing system had to be modified. Prior to the erection at the new site, the structural steel was inspected by independent materials

The Cassiar High-School in northern British Columbia becomes the Roy Stibbs Elementary School in Coquitlam testing consultants, to ensure that any damage caused by dismantling or transportation was proprerly identified. This unique reuse of an existing building on a new site not only contributed to a greener building, but also saved significant time and money.

THE FUTURE

The future of steel recovery is very green, both in terms of reuse and recycling. In terms of reuse, more work needs to be done with respect to the sharing of information on potential reuse projects and the availability of recovered steel. At the moment, reused steel requires a one-of-a-kind individual effort. We would like to suggest that structural engineers together with demolition companies and fabricators, can greatly contribute to the development of steel service centers' warehouse database for reused steel – which would offer links to available material, to the design and construction industry. Some warehouses could cater exclusively to reusable steel that has already been tested and whose dimensions are known. To evolve in this direction, the Canadian Institute of Steel Construction, Natural Resources Canada, as well as academic and industrial partners are collaborating on a project to get a better appreciation of material flow (**Figure 1**). Specifically, just how much steel gets reused? What are the obstacles encountered? How can we improve the process of reuse through better communication?

The industry catering to recycling has a strong history, which can only continue to contribute to a future of possibilities. Although information needs to be more readily available, all signs indicate that improvements will continue given the many advantages, both environmental and economical, that recycling steel offers, particularly as it is an 'open loop' material. As we await such developments, it makes good sense to involve structural engineers and fabricators early in the design of a green steel building, as they are more likely to have knowledge of possible demolition sites or other sites (to be inventoried and explored for possible recovery) – an added contribution to a more integrated design approach, better LEED™ ratings, effective recovery results and consequently better green buildings. Steel recovery strategies will no doubt help a building bypass the grave.

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