Construction & Demolition (C&D) Waste Diversion in California

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1. INTRODUCTION

Construction and demolition (C&D) waste comprises approximately 12% of California's landfill content, compared to a national average of approximately 25%. However, during construction booms in some California regions, C&D wastes have been found by the California Integrated Waste Management Board (CIWMB) to approach 30% of landfill contents. Statewide, California landfills are heavily impacted by over 4 million tons of C&D debris each year.

With nearly 400 C&D recyclers throughout the state of California, contractors are finding cost benefits in achieving high levels of C&D waste diversion. California's Department of General Services (DGS) with excess of $2 billion of building projects currently in design or under construction encourages high C&D diversion rates. The DGS has implemented a recommendation from the (CIWMB) to divert a minimum of 50% of the C&D waste in construction projects it oversees. Through implementation of even higher C&D waste diversion requirements on several large capital projects, DGS has found that high diversion rates are not only possible in California, but often are economically beneficial and motivate project teams to select, and use materials that are both recyclable and recycled.

On the Capitol Area East End Complex, recently completed in Sacramento, DGS diverted over 18,000 tons of C&D debris from landfills, equaling over 91% of the project's total C&D waste. Interestingly, some steel diverted during site demolition may have returned to the site in the form of recycled steel rebar used in new foundations.

2. METHODS OF C&D RECYCLING

2.1. On-Site Source Separation, Recycling, Storage & Reuse

This highly effective method of recycling can also be very cost-effective, when available site conditions allow. When contractors can store, recycle and reuse C&D materials on-site, this represents one of the most efficient methods of recycling, saving transportation, storage and some processing costs. Some smaller or urban sites may not allow on-site materials processing and storage. For sites that can coordinate this process, however, financial benefits can be significant. This process is most applicable for inert materials such as concrete, asphalt paving, brick, stone and soil, as well as for green waste. It can be very cost-effective to bring recycling equipment on-site on large sites with large amounts of waste concrete, asphalt paving or green waste. The recycling equipment can crush, grind or chip these materials into a usable medium such as road base, aggregate, landscape mulch or fill.

2.2. On-Site Source Separation Combined with Segregated Recycling

When site space allows, on-site source separation of C&D materials can yield reduced or even eliminated tipping fees. In the case of steel and other metals, revenue can be received from salvage value. Further segregation of heavy gauge (1/4 inch or thicker) steel material can yield a much higher salvage value than for mixed steel. In California, some segregated materials are even accepted at zero cost by recycling facilities. These materials include brick, and sometimes concrete, asphalt and corrugated cardboard. Some segregated materials such as wood and greenwaste have reduced tipping fees compared to mixed C&D material.

Time-based removal of C&D materials can be an effective method of segregating materials on smaller projects. The waste remover is contracted to remove materials during or near the end of a project's construction phase, before they become mixed or contaminated with materials from another phase. For example, during a project's framing or steel erection phases, construction activities include primarily wood framing or steel. Consequently, bins would probably not need to be kept on-site for drywall, or other finish materials. These bins of time-based materials can then be removed prior to subsequent phases. Care would still need to be taken by crews not to contaminate bins.

2.3. On-Site Commingling of C&D Waste with Off-Site Waste Segregation

Some recycling facilities are capable of sorting and processing mixed C&D debris at off-site facilities. When these facilities are available, this service can help construction projects obtain high C&D diversion rates when site constraints do not allow on-site separation of materials. Tipping fees for commingled C&D waste are usually higher than for segregated C&D waste, to cover the cost of off-site separation of materials. These tipping fees for commingled C&D waste, however, are still normally lower than landfill tipping fees. Recyclers of commingled materials at many facilities around the nation are now recycling 80-95% of the C&D waste they receive. The tipping fees for commingled C&D waste at one such facility in Sacramento, California are 21% lower than tipping fees for the same debris at the local landfill. With such simple economics at work, why would a contractor pay 21% more to have C&D waste hauled to a landfill, when this option exists?

3. SITE WORK

3.1. Soil & Stone

While not typically placed in landfills, soil and stone excavated from sites during site preparation can normally be used locally as fill. Oftentimes, land sites will gladly accept fill dirt and rocks, and, in some cases, clean fill may even have market value to be sold. Topsoil removed during initial scarifying of sites can be stored nearby, if space is available, and returned to the site to be used while landscaping the new site, reducing the need to purchase topsoil for finish landscaping near project completion. During the site work at Sacramento's Capitol Area East End Complex, over 300,000 tons of excavated soil was utilized by other contractors at a nearby Home Depot, and other local sites.

3.2. Asphalt Paving (Asphaltic Concrete)

Asphalt is one of the most recycled materials in the United States. According to the National Asphalt Pavement Association (NAPA) over 80% of asphalt removed is recycled, mostly from road and highway construction. In some paving processes, asphalt is ground off deteriating roadways, sifted, remixed and reapplied as new pavement in one procedure. Asphalt is often ground up and used as road-base under new roadways or parking lots. On larger projects this recycling of asphalt can be accomplished on-site utilizing mobile grinding equipment. This can yield substantial savings by eliminating transportation costs and tipping fees while providing raw materials and road-base that would have needed to be purchased.

3.3. Concrete

Waste concrete is often crushed, screened and used as road-base. Aggregates can be recovered from this process and used in the production of new concrete, in regions where aggregates are not readily available. This crushing and recycling process can be accomplished on-site in a similar manner described above under asphalt, saving tipping fees as well as the cost to purchase and transport new aggregate or road-base.

3.4. Green waste

Vegetation removed during clearing of the site can be ground up on-site and used as landscaping mulch saving tipping fees, as well as the cost of purchasing new mulch for landscaping. Some sites may have site constraints, however, that do not allow the on-site storage of mulch until the site is ready for finish landscaping. At the State Offices at Butterfield Way for California's Franchise Tax Board, DGS contractors recycled and reused 100% of green waste on-site as landscaping mulch. Woodchip mulch composed of green vegetation will, however, continue to compost if left in large piles, and caution needs to be taken to turn and/or spread this compost to avoid the buildup of heat and potential smoldering.

3.5. Wood

Wood waste generated during site work can be ground up and recycled with greenwaste (if clean) or with other wood recycled during demolition and construction phases (see below).

3.6. Case Study 1: State Offices at Butterfield Way, Sacramento, CA

The site work construction phase for the California Franchise Tax Board's State Offices at Butterfield Way realized tremendous financial benefits from recycling C&D debris. This led the project team to an extremely high 99.6% (by weight) C&D waste diversion rate for this phase. Sixty-nine percent of this waste (over 15,000 tons) was recycled, stored and reutilized on-site by the contractors saving $104,000. These savings resulted from eliminated tipping fees, and a reduction in road base and landscape mulch materials the project would have needed to purchase.

The Butterfield site included a former industrial site composed of over 20 acres of old asphalt parking lots, as well as concrete, trees and vegetation. The new construction will include 850,000 square feet of new office buildings, a central plant, warehouse and new parking areas. Among the sustainable site features of this facility are landscaped bio-swales using mulch from recycled greenwaste that naturally cleanses storm water runoff from parking areas prior to its return to storm drains. Table 1 provides a summary of quantities and costs, including savings resulting from recycling efforts during the site work phase.

Table 1 Site Work Recycling Efforts for State Offices @ Butterfield Way

Description	**[2]Wood/ Green Waste**	**[3]Concrete**	**[4]Asphaltic Concrete**	**[5]Misc. Const. & Land Clearing**	**TOTALS**
C&D Waste (cubic yards)	1,200	2,500	8,200	364	**12,264**
Equiv. Tons	300	5,000	16,400	91	**21,791**
Recycled On-Site	100%	20%	84%	0%	**69.2%**
Recycled Off-Site	0%	80%	16%	0%	**30.4%**
Total Recycled by Weight	100%	100%	100%	0%	**99.6%**
On-Site Recycling Cost	$15,000	$4,269	$158,319	$0	**$177,588**
Off-Site Recycling Cost	$0	$6,820	$16,693	$0	**$23,513**
Landfill Costs	$0	$0	$0	$3,396	**$3,396**
Avoided Material Costs	($11,880)	($14,000)	($192,864)	$0	**($218,744)**
Net C&D Recycling & Disposal Cost	$3,120	($2,911)	($17,852)	$3,396	**($14,247)**
Potential 100% Disposal Costs	$12,000	$17,500	$57,400	$3,396	**$90,296**
Total Recycling (Savings)	**($8,880)**	**($20,411)**	**($75,252)**	**$0**	**($104,543)**

2 The cost to recycle green waste on-site equated to ~$12.50 per cubic yard (cy). The cost to purchase and transport new woodchip mulch was ~$9.90 /cy, and the avoided cost to dispose of this debris offsite equated to $10/cy. This equated to an incremental savings of $7.40/cy for on-site recycled green waste, totaling savings of $8,880.

3 The combined cost to crush & recycle concrete on-site (20%) was ~$8.54/cy. The cost to crush & recycle concrete offsite equated to $3.41/cy. The cost to dispose of concrete waste would have been ~$4/cy for clean concrete and $7/cy for "semi-clean" concrete (<30% dirt). The cost to purchase aggregate base was approximately $28/cy. The C&D concrete waste on this project was "semi-clean". This equated to an incremental savings of $26.46/cy for on-site recycling of concrete debris and $3.59/cy for off-site recycling of concrete debris, totaling savings of $20,411.

4 The combined cost to crush & recycle asphaltic concrete (AC) on-site (84%) was ~$23.55/cy. The cost to crush & recycle AC offsite equated to $12.72/cy. The cost to dispose of AC waste would have been ~$4/cy for clean AC and $7/cy for "semi-clean" AC (<30% dirt). The cost to purchase aggregate base was approximately $28/cy. The C&D AC waste on this project was "semi-clean". This equated to an incremental savings of $11.45/cy for on-site recycled AC debris and an incremental costs of $5.72/cy for off-site recycled AC debris, totaling savings of $75,252.

5 The cost to dispose of mixed waste was ~$10/cy

4. DEMOLITION

According to the US EPA, building demolition accounted for 48% of the national C&D waste stream in 1996, while renovations accounted for 44% and new construction for 8%.

4.1. Concrete

As described earlier, demolished concrete can be crushed and recycled as road base. Aggregates can be reclaimed and used in the production of new paving or concrete, and like virgin aggregate must pass the engineer's performance specifications. The recycling of aggregate can be cost effective in areas where aggregates and tipping fees at landfills are expensive. Some jurisdictions and sites accept sized concrete debris and other inert materials in engineered fill.

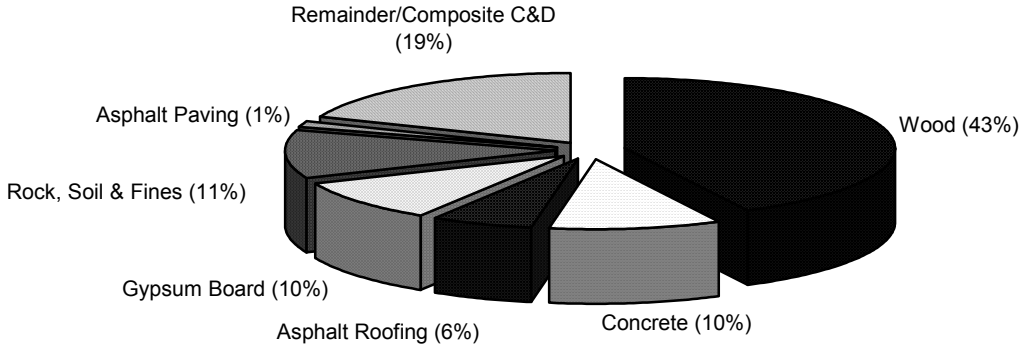
4.2. Steel

Nationwide, 68% of all steel products are currently recycled by recyclers. Steel C&D debris is very recyclable due to its lack of contamination by dissimilar materials. The Steel Recycling Institute estimates that 85% of C&D steel is currently recycled by recyclers. Good markets exist for ferrous metals such as iron and steel, as well as other non-ferrous metals such as copper, brass and aluminum. When separated, heavy gauge (1/4" or thicker) steel may have a much higher salvage value (2-3 times more) than light gauge, cold rolled or mixed steel. Steel produced on the market today is composed on average of 95% recycled content. A database at the Steel Recycling Institute, references over 30,000 steel recycling locations throughout the U.S.

4.3. Wood

Wood from the demolition process sometimes requires more labor-intensive disassembly of materials to remove fasteners and finishes. Such wood should also be screened for lead paint and CCA treated wood, which require special handling procedures. Structural wood (6x or larger) often has salvage value if deconstruction is practiced prior to demolition by salvage companies. Recycled wood can be ground into wood chips or wood flour and used to make composite or engineered lumber products, mulch, animal bedding, compost or many other products. Unseparated waste wood is sometimes burned to produce electricity. In 1999, waste wood accounted for 43% of California C&D waste. Figure 1 illustrates the C&D composition in California landfills, as determined in a 1999 statewide CIWMB waste characterization study.

Figure 1 California Landfill C&D Composition (by weight -1999)



4.4. Brick

With a salvage value of about $400 per ton (clean and stacked on a pallet), brick has salvage value for C&D recyclers. The process of cleaning mortar from brick, however, can be labor intensive, removing much of the profit from this process. Brick remains, however, a very recyclable C&D material that recyclers will often accept at no cost. Non-salvageable brick can be crushed and used as aggregate base or backfill material.

4.5. Gypsum Board

Many landfills discourage the disposal of gypsum board, as it can produce hydrogen sulphide, a poisonous gas. Preferably, gypsum board is recycled by removal of the paper backing (which is also recycled), and the grinding up of the gypsum. This material can then be used as a soil amendment, cat litter component, or sometimes in the production of new gypsum board. Due to the low cost of raw gypsum, the use of recycled gypsum in the production of new gypsum board is often economically unsound. Gypsum board from new construction processes is more easily recycled, due to its being clean of nails and finishes. Recycling of water-resistant and fire resistant gypsum board is more restricted due to additives in the products.

4.6. Carpet

Some carpeting has salvage value and can be reused, restored and/or resold (typically tiles). Nylon carpet face fiber (type 6 and type 6,6) can be separated from backing and recycled into numerous products including carpet, carpet pad, carpet backing, and car parts. Backing components can be recycled to make new carpet backing. The entire carpet composite (face fiber and backing) can be re-processed and used as a raw material for other products including carpet backing, erosion control products, industrial flooring, parking stops, synthetic plywood and building materials, railroad ties and marine timbers. Some researchers are even looking into carpet fiber as an added filler or reinforcement for concrete or asphalt paving. Several carpet manufacturers now offer to take back and recycle old carpet when consumers purchase new carpeting. Sometimes this "recycling", however, consists of use as a fuel source in waste-to-energy (WTE) operations instead of using coal to produce energy. Carpet has low SO_x emissions, and can also be used as a feed for cement kilns.

4.7. Roofing

4.7.1. Asphalt Composition. Eleven million tons of asphalt shingle C&D waste is generated by the construction industry each year. Tear-offs from reroofing accounts for 91 percent, and manufacturing waste accounts for 9 percent. Oftentimes, builders install roofing over old roofing that is already 20 years old. Consequently, when builders tear off old roofs, it is not uncommon to find some roofing below that is ±40 years old. This material is composed of asphalt (19-36%), mineral filler (8-40%), mineral granules (20-38%) and felt backing (2-15%). Roofing debris is ground to a specific size for the product being made, and contaminants such as nails and wood are removed by recyclers. Such products include aggregate base, asphalt pavement and pavement cold patch.

4.7.2. Metal Roofing. Most types of metal roofing are not only highly recyclable, but have salvage value as well. (See section 4.2 Steel)

4.7.3. Tile Roofing. Clay roof tile is very salvageable and in high demand. Due to the brittle nature of aged clay tile, careful deconstruction is needed to remove tile from roof areas without damaging them. Likewise, concrete roof tile can be salvaged for reuse. Damaged tiles can be recycled by recyclers and combined with other inert materials such as brick, asphalt and concrete.

4.8. Glass

Glazing can sometimes be salvaged, but typically is restricted by sizes and thermal properties. Tempered or laminated glass cannot easily be cut to size, and the thermal properties of new glazing today can be far superior to yesteryear's glazing. Construction glass is usually separated from other glass such as drinking glass. Float glass is highest in quality, followed by rolled plate glass, container glass and fiberglass. The higher the quality of glass is, the higher the demand. Glass can be recycled back into flat glass or into other glass products including container glass, fiberglass, floor tile, or even as aggregate for concrete. Glass recycling can be a very complex industry, and is affected by contaminants, laminated or fire resistant glass, and tinted or colored glass. You will need to check with recyclers to determine the types of glass they will accept, and determine measures that avoid contamination.

4.9. Case Study 2 – CalTrans

A new office building for CalTrans, District 7 is currently under construction by DGS in downtown Los Angeles. The urban site used for this project included numerous old, deteriorating buildings. Extensive demolition occurred on the large city block to make way for the new 13-story office building. Many of the existing buildings were of double brick construction. With an abundance of recycling facilities within the LA metropolitan area, a large market exists for salvaged and recycled C&D materials.

The net result was the recycling of over 10,200 tons of C&D material during the excavation and demolition phases, equating to 95% C&D waste diversion during. In addition, over 330,000 tons of soil and inert material was diverted from landfills by contractors and used as fill on local sites. The amount of material recycled was equivalent to filling a football stadium with 40-50 feet of material. Segregated materials included concrete, asphalt, brick and metals, with remaining C&D materials during excavation and demolition phases being mixed.

5. CONSTRUCTION

5.1. Steel

The salvage value of metals partially offsets the added labor costs for processing materials for recycling. Mixed salvaged steel in the Sacramento area can be sold for $12 - $15 per ton to salvage companies. Unprepared ferrous metal exceeding ¼ inch thickness has substantially more salvage value than light gauge scrap metal ($25 per ton).

5.2. Wood

Today's construction practices include the increased use of engineered wood products with high adhesive content, such as plywood, oriented strand board (OSB) and laminated lumber, including glue-laminated beams and wood I-beams. Wood waste processors may have concerns with this high adhesive content, and should be consulted during preparation of a waste management plan. Engineered wood products may account for up to 50% of wood C&D wastes on a new construction project. This high adhesive content has been a major challenge of C&D recyclers,

as it is not suitable for mulches and some other products. Engineered wood is often ground up and used as a daily landfill cover product, which is a waste.

"Clean" wood wastes from new construction are usually relatively uncontaminated and can be more easily used as feedstock for engineered lumber, than from the demolition process. Other uses for wood waste are pallet production, landscape mulch, wood pellets, animal bedding & compost mediums. Larger structural members (6x or larger) often have salvage value for salvage companies.

5.3. Glass

See section 4.5 under Demolition.

5.4. Packaging.

Packaging materials are plentiful during construction and protect materials, components and finishes during transportation and storage from dust and moisture. If segregation of packaging materials is possible, recyclers are usually easy to find that will accept these materials, often with reduced or even eliminated tipping fees. Care must be taken to avoid contamination of materials.

5.4.1. Cardboard. Corrugated cardboard has a well-developed end market in most communities. Boxes, packaging and protective covers can easily be flattened. Most recyclers will offer reduced tipping fees for clean cardboard. Some may even accept clean cardboard at no cost.

5.4.2. Plastic. While some mixed plastics may not be easily recycled, plastic packaging is now recycled into various useful materials and products including plastic lumber, composite lumber (plastic mixed with wood), injection molded materials, construction materials and home-use items.

5.5. Case Study 3 – Capitol Area East End Complex, Sacramento, CA

This recently completed complex encompasses five downtown city blocks in Sacramento. The contractors removed or relocated existing streets, buildings, parking and trees to make way for the new 1.5 million square foot state office complex, the largest in state history. DGS diverted 18,000 tons of C&D debris from landfills during demolition and construction, equaling over 91% of total C&D waste. Additionally, contractors diverted and used over 300,000 tons of excavated soil and rock as fill on local sites. In addition, contractors relocated an 8-unit art deco apartment to a nearby site and replanted 10 mature fan palms at Capitol Park.

Contractors on this complex reduced waste during the sub-grade construction by using spray-applied shotcrete in lieu of poured-in-place concrete for sub-grade walls, thus eliminating the need for 45 tons (worth $60,000) of plywood, and overexcavation for the formwork. The contractors also used reusable steel forms on a majority of the project's other concrete formwork, further reducing the need for plywood.

Contractors segregated asphalt paving C&D materials on-site during the demolition phase of the project, and steel during the construction phase. Otherwise, the contractors commingled C&D waste on-site and C&D recyclers removed mixed C&D waste to off-site materials separation and processing facilities. This resulted in savings of over $83,904 or 38% when compared to the high disposal method.

6. STRATEGIES

Contractors and owners can realize high levels of C&D waste diversion through careful planning throughout the project, establishment of C&D goals and inclusion of C&D waste recycling requirements in contracts. Early planning can often identify alternatives and methods of construction that can further reduce not only the quantities of materials disposed of, but also the quantity of materials initially purchased and installed in the project. Table 2 illustrates the integration of recommended C&D management tasks during typical project phases.

Table 2 Decision Points for C&D Waste Management During Project Phases[6]

PROJECT PHASE	C&D WASTE MANAGEMENT TASKS
Feasibility Study/Concept	Establish C&D Waste Diversion Goal • 50-75% goal recommended for most projects
Budget Development/ Programming	Preliminary economic evaluation of C&D management opportunities
Preliminary or Schematic design	Review potential building systems to consider: • Waste management potential • Modular design to reduce waste and labor
Value Engineering/Design Development	• Commission complete C&D Waste Management Economic Feasibility Study • Consider feasibility of salvaged materials use
Working drawings	Specify recyclable materials • Also materials with recycled content • Focus on design and details that reduce waste
Prepare Bid Package	Develop Integrated Waste Management Plan (IWMP) • Incorporate C&D specifications and diversion requirements into project manuals • Review C&D requirements in pre-bid meetings
Demolition	Require contractor to submit C&D plan including list of permitted C&D facilities prior to demolition • Contractor to assign project waste coordinator • Project waste coordinator to hold regular meetings with demolition contractors to track progress
Construction	Project waste coordinator coordinates C&D activities • Conducts progress meetings, solicits feedback • Continuously monitors C&D activities • Outreach and training to contractors and subcontractors
Building Close Out	Project waste coordinator summarizes and documents the results of C&D waste management efforts • Submits required contractual documentation, LEED documentation, etc.

[6] Modified from "The Capitol Area East End Office Complex: A Case for Construction and Demolition Waste Diversion"

7. LEED

The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) for New Construction (LEED-NC 2.1) as well as Commercial Interiors, (LEED-CI 2.1) Green Building Rating Systems™ encourage the recycling of C&D debris from construction activities. The USGBC grants credits for attaining C&D recycling rates of 50 & 75 % respectively within its materials and resources category. The USGBC grants additional innovation points for achieving a 90% or greater C&D recycling rate. The USGBC also encourages the use of recycled content materials by awarding up to two points for the procurement of building materials' with an accumulative total of 5-10% or more recycled content (by value). Furthermore, LEED-NC 2.1 awards points for the use of salvaged or reclaimed materials, supporting efforts towards selective deconstruction prior to, or instead of, mass demolition.

8. CONCLUSIONS

Through experience on these and other projects, DGS and its contractors are finding requirements for higher diversion rates achievable and beneficial. In fact, some contractors have even exceeded required diversion rate requirements and in doing so, realized economic benefits. Typically, reduced or eliminated tipping fees offset additional costs of waste management. Construction firms are also finding marketing benefits by achieving high diversion rates, receiving industry awards for such efforts. Recyclers in California are finding numerous markets for various types of C&D debris including asphalt, concrete, steel, aluminum, bricks, CMU, wood, glass, gypsum board, plastics, paper, paint, insulation, rigid foam, carpet and pad. This diverted C&D debris provides valuable raw material for manufacturers of recycled content products while strengthening the local, regional and national economies.

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