Recycling Concrete and Masonry

Old concrete and masonry that have "reached the end of the road" can be recycled and used not only as aggregate for new concrete, but also for a number of other applications in construction. In the U.S. there are no longer any barriers to the use of recycled concrete as aggregate in new concrete. Since 1982 the ASTM definition of coarse aggregate has included crushed hydraulic cement concrete, and the definition of manufactured sand includes crushed concrete fines. Similarly, the U.S. Army Corps of Engineers and the Federal Highway Administration encourage the use of recycled concrete as aggregate in their specifications and guides.1

The technology of concrete recycling is well established in the U.S. Recycling of portland cement concrete, as well as asphaltic concrete, has been shown to be a cost-effective alternative for new road, street, and highway construction. As early as 1987, more than 1000 lane miles of portland cement concrete pavement had been recycled into new pavement.

Concrete recycling to produce structural grade concrete for non-pavement uses is technically feasible, with certain precautions. For example, it is generally accepted that when natural sand is used, up to 30% of natural crushed aggregate can be replaced with coarse recycled aggregate without significantly affecting any of the mechanical properties of the concrete.2

Advantages of Recycling

Environmental considerations. In this time of increasing attention to the environmental impact of construction and sustainable development, portland cement concrete has much to offer: (1) it is resource efficient—minimizing depletion of our natural resources; (2) it is inert—making it an ideal medium in which to recycle waste or industrial byproducts, such as fly ash; (3) it is energy efficient—in a cradle-to-grave study on the impact of energy expended in all phases of production, concrete was superior to wood and steel; (4) it is durable—continuing to gain strength with time; and finally (5) it is recyclable—fresh concrete is used on an as-needed basis (whatever is left over can be reused or reclaimed as aggregate), and old hardened concrete can be recycled and used as aggregate in new concrete or as fill and pavement base material.

Economic factors. Recycling concrete is an attractive option for governmental agencies and contractors alike. Most municipalities impose
tight environmental controls over opening of new aggregate sources. In many areas, zoning requirements and public rancor—"not in my backyard" sensibilities—limit the possibility or increase the cost of starting new quarries. For demolition contractors landfill space is scarce, especially in urban areas. Some landfills may not accept construction materials, and disposal of old concrete and masonry is costly. Also, dumping fees will most likely rise as construction debris increases and the number of accessible landfills decreases. Furthermore, the cost and transport distances of conventional aggregates could continue to increase as sources grow scarce. With recycled aggregates there is potential for cost savings in hauling. It is not unusual for contractors to haul conventional aggregates 50 to 70 miles on projects, and haul distances greater than 200 miles are not uncommon.

Applications for Recycled Concrete and Masonry

Recycled concrete is being used to produce aggregates for (1) many types of general bulk fills; (2) base or fill for drainage structures; (3) pavement subbases; (4) soil-cement pavement bases; (5) lean-concrete or econcrete bases; (6) bituminous concrete; and (7) new concrete for pavements, shoulders, median barriers, sidewalks, curbs and gutters, building and bridge foundations, and even structural grade concrete.

Crushed brick rubble may be used as an aggregate for lightweight concrete, and crushed masonry aggregate from various types of demolition debris can be used in the precast concrete industry, perhaps in concrete block. Common brick from demolition projects in the Chicago area is cleaned and palletized on-site and shipped to the South for use in expensive homes. Crushed masonry aggregate has been used for unbonded pavement bases, and in some regions of the U.S. it is a popular landscaping rock. Crushed concrete block and brick have been used experimentally as aggregate for grouting new concrete masonry walls.

Recycling Demolished Concrete

Terminology

To avoid confusion, the following terminology will be used in this publication:

Conventional concrete. Concrete manufactured from portland cement, water, and a combination of fine and coarse aggregate; the fine aggregate is usually natural sand, and the coarse aggregate is usually gravel or crushed stone. Also referred to as original concrete, old concrete, and demolished concrete.

Crushed concrete. Concrete made with ASTM C150 portland cements, ASTM C959 portland-pozzolan cements or portland blast-furnace slag cement, natural or manufactured sand, or a combination thereof, and coarse aggregates such as natural gravel, crushed gravel, crushed stone, air-cooled blast-furnace slag, or a combination thereof. Crushed concrete made with other materials is beyond the scope of this publication.

Original aggregates. Conventional fine and coarse aggregates from which original concrete is produced. The fine aggregate is usually natural or manufactured sand; the coarse aggregate is usually gravel or crushed stone. Original aggregates may also be referred to as virgin or conventional aggregates.

Original mortar. A hardened mixture of cement, water, and fine aggregate, 100% of which passes the 3/8-in. sieve, in the original concrete. Some original mortar is usually attached to particles of original aggregate in recycled concrete aggregates.

Recycled-aggregate concrete. Concrete manufactured from recycled aggregates or a combination of recycled and conventional aggregates such as sand, gravel, or crushed stone. Also referred to as new concrete.

Recycled concrete aggregates. Fine and coarse aggregates produced by crushing of original concrete. Also may be referred to as recycled aggregates. Fine recycled aggregate may also be referred to as crushed concrete fines.

Recycled concrete. Hardened concrete that has been processed for reuse, usually as aggregate.

Waste concrete. Concrete debris from demolished pavements and structures, leftover ready mixed concrete, rejected ready mixed concrete, and rejected precast or precast/prestressed concrete products.

Demolition of Old Concrete and Removal of Steel

Recycled concrete is simply old concrete that has been demolished and removed from pavements, bridges, foundations, or buildings
Three basic types of stone crushers. Note that impact crushers may be designed to operate vertically or horizontally.
and crushed into various sizes for reuse. Reinforcing steel and other embedded items, if any, must be removed, and care must be taken to prevent contamination by dirt or other wasted building materials, such as plaster or gypsum, or asphalt from pavements, which can be troublesome. It is advantageous if old concrete can be freed from foreign matter before demolition begins.

In the early days of recycling there was some concern regarding the removal of reinforcing steel bars and welded wire mesh from concrete. However, it has proven to be fairly easy to separate steel from original concrete through the ingenuity of demolition contractors and innovations in breaking, removal, crushing, and screening equipment.

Records of the history of an old concrete building, bridge, or pavement—such as those detailing quality and composition—are valuable documents, if available. Such records may indicate the strengths and mixture designs of the original concrete, and this information would be useful in determining the recycling potential of the concrete.

Production of Recycled Aggregates

Plants for production of recycled concrete aggregates are not much different from plants engaged in the production of conventional crushed stone aggregates. The National Stone Association (NSA) and its member companies recognize and accept the recycling of many construction waste materials, such as portland cement concrete, when it is cost effective. NSA believes recycling (1) conserves natural resources, (2) is good for the environment, (3) can be good business, and (4) is expected to grow.

Crushers. The two basic types of crushers are compression crushers and impact crushers. Most recycling plants have both primary and secondary crushers, however, some plants produce aggregates by primary crushing only. In plants with both levels of crushing, the primary crusher normally reduces the material down to about 3/4 in. The material then passes through two screens that separate the aggregate into sizes, greater than and less than 3/8 in. The larger material is fed to the secondary crusher where the maximum desired coarse aggregate size is set. In North America, 61% of recyclers use jaw crushers for primary crushing, and 43% use cone crushers for secondary crushing. Recyclers often prefer a jaw crusher because it can handle large pieces of concrete; a cone crusher, on the other hand, can handle fragments no bigger than 8 in.

Yield. The yield of coarse aggregate from a recycling operation depends on the type of concrete being recycled. Yield losses for "clean" concrete—plain concrete pavement, sidewalks, curbs and gutters—are negligible. Crushing operations typically yield about 75% coarse aggregate and 25% fine aggregate. However, a lower yield of recycled coarse aggregate should be expected when the gradation requirements call for a smaller top size.

Noise and dust. Crushing and screening operations in a recycling plant are always accompanied by noise, vibrations, and dust. Also, there are aesthetic concerns and the intrusion of trucking into areas where it may be undesirable. Consequently, when locating a recycling plant, environmental considerations and legal requirements must be carefully studied and necessary counter-measures taken. Nonetheless, concerns about noise and dust problems when crushing concrete in mobile plants in urban areas have been exaggerated.

Removing contaminants. Clean concrete cannot always be supplied by a demolition contractor. Concrete rubble often includes contaminants such as admixtures, asphalt, chlorides, cladding, soil and clay balls, glass, gypsum board, hardboard, iron, joint sealants, and crushed stone.
lightweight brick and concrete, paper, plaster, plastics, rubber, steel reinforcement, tile, vinyl, wood, and roofing materials of various kinds. Contaminants are mostly a concern when recycled aggregates are to be used in new concrete. Dust and fines that cling to the large coarse aggregate particles are of little consequence in recycled aggregate concrete, and washing is not required.

Contaminants usually are of no concern in base aggregate applications, except in cases where the recycled aggregate will be used in an unstabilized permeable base. In such instances, drain water may wash dust and fine material off the aggregate. This leachate can settle on filter fabric or drainpipes before reaching drainage outlets, clogging pipes, binding filter fabric, and ultimately causing system failure. However, washing the recycled aggregates can correct this problem.

**Soil and clay balls.** Soil and clay balls can be especially troublesome. Tests show that introduction of excessive clay into a concrete mixture increases water demand and reduces strength. Clay balls can cause popouts if located near a slab surface. Some recycling contractors use a 1-in. scalping screen ahead of the primary crusher to remove soil and clay balls from broken concrete. However, this step may not be necessary if care is taken by the loader operator to exclude soil or base material while removing old concrete in contact with the ground—foundations, floors, pavements, walks, curbs and gutters, etc.

**Limits.** In standard specifications for recycled aggregates, there should be maximum allowable limits on contaminants, such as asphalt, gypsum, organic substances (wood, textile fabric, paper, joint sealants, paints, etc.), soil, chlorides, and glass. Limits are suggested for various contaminants, usually by volume or weight percentage of the recycled aggregate: (1) asphalt—1% by volume; (2) gypsum—0.5% by weight of SO3; (3) organic substances—0.15% by weight; (4) soil—see limits in ASTM C 33, Specification for Concrete Aggregates; (5) chlorides—see limits in ACI 318, Building Code Requirements for Reinforced Concrete; and (6) glass—none should be tolerated, since conventional glass can cause alkali-silica reaction, as well as cracking and popouts in concrete.

**Characteristics of Recycled Aggregates**

**The crushing characteristics of hardened concrete are similar to those of natural rock and are not significantly affected by the grade or quality of the original concrete. Recycled aggregates produced from all but the poorest quality original concrete can be expected to pass the same tests required of conventional aggregates.**

**Gradation.** Reasonably well-graded coarse recycled aggregates can be produced with a jaw crusher. With proper crusher and screen selection, a plant can meet ASTM and American Association of State Highway and Transportation Officials (AASHTO) gradation specifications. With adjustments a crushing plant can produce any desired gradation. Accordingly, specifiers should call for the same gradation ranges for recycled concrete coarse aggregate as they would for conventional aggregates.

**Particle shape.** Recycled concrete aggregate is similar to crushed rock in particle shape. Demolished plain and reinforced concrete can be crushed in various types of crushers to provide recycled aggregate with an acceptable particle shape, but the type of crushing equipment influences the gradation and other characteristics of crushed concrete fines. Usually the fine material will be more angular, with a higher rate of absorption and a lower specific gravity—qualities not conducive to making workable concrete mixtures. Because of this, some researchers do not recommend the use of fine recycled aggregates for the production of new concrete. While many contractors use some recycled fines in their concrete mix designs—usually about 10% to 20% by weight of the total fine aggregate—others have used 100% recycled fine and coarse aggregates successfully.

**Texture.** When old concrete is crushed, some of the original aggregate particles split; jaw crushers produce a smaller proportion of split particles than impact crushers. Typically 30% to 60% by volume of old mortar will adhere to recycled coarse aggregate particles, depending on the aggregate size. More old mortar is attached to the smaller size fractions of coarse aggregate. From 20% to 65% by volume of old cement paste will
adhere to recycled fine aggregate particles, with the finer material containing the most old paste. As previously noted, crushed concrete fines tend to be somewhat coarser and more angular than desirable. But gradation of the recycled fines, and harshness and workability of the concrete made with them, can be improved by the addition of fine natural blending sand.

**Specific gravity.** Because of the large amount of old mortar and cement paste adhering to recycled aggregates, their specific gravity (relative density) will be 5% to 10% lower than that of the virgin aggregates in old concrete. Typical values of specific gravity of recycled aggregates range between 2.2 and 2.5 in the saturated surface dry condition.

**Absorption.** The water absorption of recycled concrete aggregates is much higher than that of the virgin aggregates in old concrete due to the large amounts of old mortar and cement paste attached to recycled aggregates. Absorption values typically range from 2% to 6% for coarse recycled aggregates. Absorption rates for crushed concrete fines range from 4% to 8%. Pre-soaking of recycled aggregates is sometimes recommended to help maintain uniformity of absorption during concrete production.

**Abrasion loss.** The abrasion resistance of aggregate is important in concrete pavements and floor slabs. It is measured by use of the Los Angeles (LA) abrasion test (ASTM C 131 or C 535). Recycled aggregates produced from all but pass these requirements. Typical abrasion losses for recycled aggregates range from 20% to 45%. The upper limit for pavement aggregates is 50%. A good service record—5 years or more—with a similar recycled aggregate concrete, under the same service and exposure conditions, will satisfy some specifications.

**Sulfate soundness.** Research on use of the sodium sulfate or magnesium sulfate test (ASTM C 88) for determining the soundness (resistance to weathering) of concrete made from recycled aggregates is misleading. U.S. results conflict with those from other countries. Accordingly, resistance to weathering of a recycled concrete aggregate usually is considered acceptable without running the sulfate soundness test if the recycled concrete was durable in its previous life.

**Alkali-silica reactivity (ASR).** An investigation was made into precautions needed to prevent expansive ASR when ASR-affected concrete is recycled as coarse aggregate in new concrete. It was determined that potential for ASR in new concrete was affected by old concrete's original alkali level and extent of expansion, and the remaining potential reactivity of the recycled aggregate. Also, the alkali content of new concrete had a significant effect on subsequent expansion due to ASR. The use of a low-lime ASTM Class F fly ash greatly reduced expansion due to ASR in new concrete. This research demonstrated that with appropriate selection of cementitious materials, even recycled concrete containing highly reactive aggregate can be used safely.

<table>
<thead>
<tr>
<th>Concrete ingredients</th>
<th>Minnesota DOT lb per cu yd</th>
<th>Wisconsin DOT lb per cu yd</th>
<th>Grand Forks Int'l Airport lb per cu yd</th>
<th>Wyoming DOT lb per cu yd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (Type I)</td>
<td>472</td>
<td>480</td>
<td>400</td>
<td>488</td>
</tr>
<tr>
<td>Fly ash (Type C)</td>
<td>83</td>
<td>110</td>
<td>130</td>
<td>133</td>
</tr>
<tr>
<td>Water</td>
<td>255</td>
<td>265</td>
<td>230</td>
<td>258</td>
</tr>
<tr>
<td>Recycled CA</td>
<td>1630</td>
<td>1815</td>
<td>1650</td>
<td>1349</td>
</tr>
<tr>
<td>Virgin CA</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>601</td>
</tr>
<tr>
<td>Recycled FA</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>253</td>
</tr>
<tr>
<td>Virgin FA</td>
<td>1200</td>
<td>1315</td>
<td>1260</td>
<td>882</td>
</tr>
<tr>
<td>Admixtures:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air entrained</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Water reducer</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

*Adapted from References 6 and 7.*
Characteristics of Fresh Recycled-Aggregate Concrete

Mixture design. The same principles used to design concrete mixtures with conventional aggregates—sand, gravel, or crushed stone—should be followed when using recycled aggregates. Trial mixtures are required to determine proper proportions and to check new concrete's quality. Table 1 shows a few typical concrete mix designs.

Because of the high absorption of recycled aggregates, some deviation in trial batch weights will likely be necessary. The concrete mix design engineer must be vigilant in determining the necessary quantity of mixing water when recycled aggregates are used, and especially when the mixture includes fine recycled aggregates.

Mixing water and workability. Because of the relatively high absorption of recycled aggregates as compared to conventional aggregates, more mixing water and a higher starting slump may be necessary. This is particularly true for aggregates that are dry before batching. Experience shows that recycled aggregates continue to absorb water after mixing in a batch plant. This can cause a loss of slump and workability after mixing is completed. To offset this, recycled aggregates—like structural lightweight aggregates—can be pre-wetted in stockpiles with a sprinkling system.

Water-cement ratio. At the initial design stage, it may be assumed that the water-cement ratio for required compressive strength will be the same for recycled concrete as it would be for conventional concrete, provided the recycled concrete contains recycled coarse aggregate and natural sand. A water-cement ratio adjustment will have to be made if a trial mix design shows that compressive strength is lower than initially assumed.

Cement content. The calculated cement content for recycled-aggregate concrete will be somewhat higher than the cement content for a comparable conventional concrete because of the higher free water requirements of recycled concrete mixtures. At least 5% extra cement would be required in mixtures using coarse recycled aggregates and virgin fines; at least 15% extra would be needed if both coarse and fine recycled aggregates were used. In any case, compressive strength may be increased by using a higher cement content and/or replacing some of the recycled aggregate with conventional aggregate.

Density and air content. New concrete will have a lower density because of the large amount of old mortar and cement paste adhering to recycled aggregates. The density of new concrete may be from 5% to 15% lower than that of control concretes made with conventional aggregates. The natural (entrapped) air content of recycled-aggregate concrete may be a little higher than that of corresponding concretes made with conventional aggregates. An air-entraining admixture is generally used in the mix design if freeze-thaw durability is required.

Fine-coarse aggregate ratio. For economy and cohesion of fresh concrete, a number of researchers have found that the optimum ratio of fine to coarse aggregate is about the same for recycled-aggregate concrete as for conventional concrete.

Table 2. Compressive strength of original concretes and recycled aggregate concretes for various water/cement and coarse/fine aggregate ratios.*

<table>
<thead>
<tr>
<th>Water/cement (w/c) ratio</th>
<th>Concrete compressive strength, lb per sq in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural coarse and fine aggregate (original concrete)</td>
</tr>
<tr>
<td>0.45</td>
<td>5440</td>
</tr>
<tr>
<td>0.55</td>
<td>4190</td>
</tr>
<tr>
<td>0.68</td>
<td>3190</td>
</tr>
</tbody>
</table>

*Adapted from Reference 2.
conventional concrete. Still other researchers have concluded that crushed concrete fines should not be used in producing new concrete because of problems in accurately determining their water absorption, free water content, and saturated surface dry density. While some concrete specifiers agree, others have found it beneficial to use 10% to 30% recycled fines as a weight percentage of the total fine aggregate in the mixture (Table 1). This is not to imply that 100% recycled fines cannot be used successfully in concrete. Highway pavements utilizing 100% recycled fine and coarse aggregate have performed well in Texas.

Other characteristics. There are other characteristics of fresh recycled-aggregate concrete too numerous to discuss in this brief publication, such as: batching, mixing, and transporting; placing, compacting, finishing, and curing; and plastic shrinkage cracking. For information on these, see References 2, 6, 7, and 9.

Characteristics of Hardened Recycled-Aggregate Concrete

Before reviewing the influences that recycled aggregates may have on the characteristics of hardened concrete, it would be appropriate to mention as a general principle that up to 30% of the conventional aggregate in concrete may be replaced by recycled aggregate without significantly affecting the mechanical properties of the new concrete. This may be the simplest, most economical, and least controversial way of getting wider use of recycled aggregates in new concrete.

Strength. Not only compressive strength, but also tensile, shear, fatigue, bond, and variability of strength are important mechanical properties of any hardened concrete, including recycled-aggregate concrete.

Compressive strength. The compressive strength of recycled-aggregate concrete can be equal to or higher than that of the original concrete if the recycled-aggregate concrete is made with the same or a lower water-cement ratio than the original concrete. More commonly, compressive strength of recycled-aggregate concrete will be 5% to 10% lower than that of a corresponding concrete made with conventional aggregates. Some minor strength loss will likely occur when crushed concrete fines are substituted for natural sand, because sand particles have greater strength (Table 2).

Coefficient of variation. The coefficient of variation for compressive strength of recycled-aggregate concrete was not much different from that of conventional concrete when recycled aggregate of uniform quality—usually from the same source—was used throughout production. This was confirmed by several different laboratory investigations. However, higher coefficients of variation can be expected if ready mix suppliers produce recycled-aggregate concrete with aggregates from a variety of sources—building rubble, pavements, curbs and gutters, etc. Large standard deviations and high coefficients of variation should be avoided because they make it more difficult and more expensive to meet the statistical compliance criteria in today's concrete codes and specifications. Namely, the higher the standard deviation, the higher the required average compressive strength of concrete used to select mixture proportions—and the higher the required cement content.

Tensile and flexural strength. Concrete's tensile and flexural strengths are important when designing structures and pavements. M. C. Won, a researcher at the Texas DOT, found that for the same water-cement ratio, replacing virgin fines (natural sand) with crushed concrete fines did not change tensile strength. But using recycled coarse aggregate, the flexural strength may be slightly lower than a similar mixture using conventional aggregates. On the other hand, using crushed concrete fines may reduce flexural strength by 10% to 20%.

Shear, bond, and fatigue strength. One researcher found that when new concrete was made with recycled aggregates from aged concrete pavements, fatigue characteristics of the new concrete were the same as for concrete made with virgin aggregates. Another researcher discovered that the bond strength between reinforcing steel and recycled-aggregate concrete was the same as that of conventional concrete under both static and fatigue loading when recycled coarse aggregate and natural sand were used. Shear strength appears to follow a similar pattern. Good flexural fatigue strength in recycled-aggregate concrete can be attributed to a superior bond between cement mortar and paste in new concrete and recycled-aggregate particles.

Modulus of elasticity. M. C. Won found that the use of both coarse and fine recycled aggregates significantly reduced the modulus of elasticity of new concrete. Values from 15% to 40% lower can be explained by the "mortar
Effect. Mortar has a lower modulus than virgin coarse aggregate, and since recycled-aggregate concrete has a higher volumetric proportion of mortar than conventional concrete, a lower modulus of elasticity should be expected.

Durability. Durability is the capacity of concrete to resist weathering action, chemical attack, abrasion, and other conditions of service. Some of the factors important to the durability of recycled-aggregate concrete are permeability, carbonation, freeze-thaw resistance, and sulfate resistance.

Permeability and carbonation. Permeability and carbonation appear to be somewhat higher for recycled-aggregate concrete when compared to conventional concrete at the same water-cement ratio. This may increase the risk of corrosion of reinforcing steel in recycled-aggregate concrete, but any risk can be offset by using a lower water-cement ratio, adequate curing, and an admixture—such as fly ash, ground slag, or silica fume.

Freeze-thaw durability (frost resistance). Recycled-aggregate concrete is resistant to freeze-thaw cycles. In fact, research has shown an increase in freeze-thaw resistance of recycled-aggregate concrete compared with concrete made with some conventional aggregates. Surprisingly, there is even evidence that repeated recycling of recycled-aggregate concrete further improves frost resistance.

Sulfate resistance. The resistance of recycled-aggregate concrete to sulfates (found in sea water) is about the same or slightly inferior to that of conventional concrete. Sulfate resistance generally improves with proper proportioning and the use of fly ash, ground slag, or silica fume.

Drying shrinkage and creep. The drying shrinkage and creep of recycled-aggregate concrete is higher by 40% to 80% than that of a corresponding conventional concrete. This is due to the large amount of old mortar and cement paste attached to recycled aggregates. Reinforced concrete elements constructed of recycled-aggregate concrete appear to be no more prone to shrinkage cracking than conventional concrete because high shrinkage and creep tend to cancel each other out. Comparative lower values of drying shrinkage are reported for new concretes using recycled coarse aggregate and natural sand; comparatively higher values exist when both fine and coarse aggregate are recycled.

Other characteristics. There are other characteristics of hardened recycled-aggregate concrete too numerous to discuss in this brief publication, such as admixtures in old concrete (chlorides, for example), plastic shrinkage cracking, abrasion resistance, and thermal coefficient of expansion. Readers may consult References 2, 6, 7, and 9 for information on these.

Recycling Demolished Masonry

In North America the recycling of demolished concrete has advanced far beyond that of demolished masonry. Concrete rubble from highways, streets, bridges, parking lots, walks, driveways, curbs, gutters, and other civil engineering works contains few materials other than steel and concrete. On the other hand, building demolition rubble contains many building materials—conventional, structural lightweight, and cellular concretes; brick; concrete masonry units (block); natural stone; portland cement mortar, plaster, stucco, and terrazzo; gypsum plaster; ceramic materials; roofing tiles and shingles; glass; wood; paper; plastic; asphalt; and metals. Some of these materials are contaminants in concrete. So the recycling of building rubble presents a much greater challenge, but it can and is being done all over the world.

Crushed Masonry Aggregate

Most of the present knowledge of recycling masonry rubble dates back to post-

Crushing train in action. With this cost-effective proprietary system, known as Paradigm, concrete pavement can be removed, crushed, and deposited back on the subgrade for use as new base material—all in one operation. The need for costly trucking and a recycling center is eliminated.
World War II experiences in Germany and the UK, and more recent recycling in the Netherlands. The term "masonry rubble" is collective for a variety of mineral building materials resulting from the demolition of buildings and structures. Masonry rubble may include conventional concrete and concrete block, clay brick, sand-lime brick, lightweight concrete and block of various types, and natural stone. Also, depending upon the geographical location of the demolition site, one might find portland cement mortar and plaster (stucco), and burnt clay products, such as roofing tile, in masonry rubble.

There is no question that crushed masonry rubble is a useful material; in Germany crushed brick aggregate is used in lightweight concrete for moderate weather exposures. However, there could be a risk of undesirable expansion if the crushed brick contains significant sulfate, which could come from the brick itself or from contamination by gypsum plaster. Results of a study by the U.S. Army Engineer Waterways Experiment Station noted that: "Inorganic, nonmetallic residues from demolition of buildings may be recycled for use as concrete aggregate if the sulfate content is controlled to prevent deleterious expansion due to sulfate reaction."

**A Bright Future**

Market researchers using 1998 statistics and phone surveys found over 1000 concrete recycling plants in operation in the United States producing more than 100 million tons of concrete aggregates per year. This survey, considered conservative, and other state-of-the-art reports point to a bright future for recycling of demolished concrete and masonry.

**Recycled Masonry Is Coming**

The National Concrete Masonry Association (NCMA) and others are looking into ways of recycling concrete masonry products. Rashwan and AbouRizk evaluated the technical, economical, and environmental viability of recycling concrete block and brick into grout for filling the cores in block walls. Berg and Neal investigated the viability of municipal solid waste bottom ash (MSWBA) as aggregate for concrete masonry units (CMU). Practical CMU mixtures were developed using a blend of MSWBA, sand, and fly ash; test results proved the units could meet ASTM C 90 load bearing requirements.

For more information on recycling of demolished masonry, see Part Two of Reference 2. The authors of this section, Drs. R. R. Schulz and Ch. F. Hendricks, drew heavily from experience and documentation from the post-war years in Germany and the Netherlands. While Schulz and Hendricks clearly noted that other parameters apply today, the earlier work remains interesting, and in some instances is still applicable with regard to recycling demolished masonry as aggregate in new concrete.
References


9. M. C. Won, Use of Crushed Concrete as Aggregate for Pavement Concrete, Research Section, Construction Division, Texas Department of Transportation, Austin, Texas, 1999.

10. Alan D. Buck, "Recycled Concrete as a Source of Aggregate," ACI Journal, American Concrete Institute, Detroit, May 1977, pages 212-219.


The Environmental Council of Concrete Organizations is a coalition dedicated to promoting the environmental benefits of concrete and its role in safe and sustainable construction.

ECCO members are companies, organizations, and individuals affiliated with the concrete industry. Together, they are committed to developing and disseminating information on the environmental benefits of concrete and concrete products.