# PROPERTIES AND CHARACTERISTICS OF RCA

The properties of recycled concrete aggregate vary some from virgin aggregates, but typically not enough to undermine the benefits of their use.

Because recycled concrete aggregate (RCA) particles are comprised of reclaimed virgin aggregate and/or mortar, they tend to be more angular and rough than typical virgin aggregates, and their properties are slightly different. RCA typically has a higher absorption capacity, lower specific gravity, greater mass loss in tests such as L.A. abrasion and sodium and magnesium sulfate, and higher chloride content than virgin aggregates. Even still, RCA aggregates typically must meet the same requirements as virgin aggregates for the target application, even if the RCA is produced from a concrete pavement with a materials-related distress such as D-cracking or alkali-silica reactivity (ASR). Other concerns with RCA are precipitate potential and surface dust/contaminants, both of which might be considered during the design phase. More about these topics is available in ACPA's EB043P, "*Recycling Concrete Pavements*."

RCA must generally meet the same requirements as virgin aggregate for the target application. A summary and comparison of the some typical properties of virgin and recycled concrete aggregates is presented in Table 1. There are some clear differences in the physical, mechanical and chemical properties of typical virgin aggregate and RCA, mainly because of the inclusion of reclaimed mortar in the RCA. Most of these differences, however, require little (if any) consideration or procedural adjustment for use in typical applications.

## Physical Properties

### Particle Composition, Shape and Texture

RCA particles are comprised of reclaimed virgin aggregate, reclaimed mortar, or both. The relative proportions of these components vary with the original concrete mixture design, the properties of the virgin coarse aggregate particles, the bond between the virgin aggregate particles and the mortar, and the type and extent of crushing used in production. Particle composition also varies with particle size. Larger particles tend to contain greater proportions of reclaimed virgin aggregate while smaller particles often are mainly crushed mortar.

RCA particles tend to be highly angular and have rough surfaces (similar to crushed rock) although some crushing processes remove most of the mortar from smooth-surfaced virgin coarse aggregates, producing a coarse RCA that closely resembles the original virgin coarse aggregate in all respects.

### Gradation

With appropriate adjustments, concrete crushing plants can be set up to produce almost any desired gradation, although there often is an excess of fine RCA produced.

### Absorption Capacity

Absorption capacities of RCA are generally much higher than those of conventional aggregates. The primary factor affecting RCA absorption is the amount of reclaimed mortar that is present because the reclaimed mortar is usually more porous and absorbent and has a greater surface area than most types of virgin aggregate.

*Table 1. Comparisons of Some Typical Virgin Aggregate and RCA Properties (Snyder et al 1994)*

| Property | Virgin Aggregate | RCA |
|---|---|---|
| Shape and Texture | Well-rounded & smooth to angular & rough | Angular with rough surface |
| Absorption Capacity | 0.8% - 3.7% | 3.7% - 8.7% |
| Specific Gravity | 2.4 - 2.9 | 2.1 - 2.4 |
| L.A. Abrasion Mass Loss | 15% - 30% | 20% - 45% |
| Sodium Sulfate Soundess Mass Loss | 7% - 21% | 18% - 59% |
| Magnesium Sulfate Soundess Mass Loss | 4% - 7% | 1% - 9% |
| Chloride Content | 0 - 2 lb/yd$^3$ (0 - 1.2 kg/m$^3$) | 1 - 12 lb/yd$^3$ (0.6 - 7.1 kg/m$^3$) |

### Specific Gravity

Concrete mortar (comprised of sand, cement, water and air) generally has a much lower specific gravity than most virgin aggregate types. Therefore, the specific gravity of RCA mainly depends upon the relative proportions of reclaimed mortar and reclaimed virgin aggregate, and tends to decrease with particle size (generally increasing mortar content).

## Mechanical Properties

### Los Angeles Abrasion Mass Loss

The Los Angeles (L.A.) abrasion mass loss values typically are higher for RCA than for the virgin aggregates contained in the RCA. This is usually attributed to the presence of the softer cement mortar and the presence of particles that were only partially fractured during the crushing process (Snyder and Vandenbossche 1993).

L.A. abrasion test values for RCA usually are within specified limits so most states specify the same L.A. abrasion test result limits for both virgin aggregates and RCA. Specifications may waive L.A. abrasion testing for either RCA or virgin aggregate if the material has a good performance record.

### Freeze-Thaw Durability

Concrete pavements that have developed freeze-thaw durability cracking ("D-cracking") due to the use of frost-susceptible coarse aggregate in the concrete commonly have been recycled into unstabilized subbase layers and fill without any problems relating to the durability of the aggregate. Such pavements also have been successfully recycled into new concrete layers since at least the early 1980's.

## Chemical Properties

### Alkali-Silica Reactivity (ASR)

The potential for ASR in new concrete containing RCA is affected by the original alkali level of the old concrete, the remaining potential reactivity of the recycled aggregate, and the alkali content of new concrete (Stark 1996). The use of low-lime Class F fly ash and slag cement has greatly reduced ASR expansion in new concrete. Other mitigating techniques include limiting the content of RCA fines, reducing concrete permeability through a lower water content, using admixtures such as lithium nitrate, and reducing slab exposure to moisture. Research and construction projects have demonstrated that, with appropriate selection of cementitious materials, RCA containing reactive (and even highly reactive) aggregate can be used safely.

### Sulfate Soundness Mass Loss

The two most widely used tests are the sodium sulfate soundness test and the magnesium sulfate soundness test. RCA commonly fails the sodium sulfate soundness test while passing the magnesium sulfate soundness test with results that are better than those of the original aggregate (Snyder and Vandenbossche 1993). This contradiction between the two test methods suggests that either one or both of these tests may be inadequate for predicting the durability of recycled aggregates. As a result, these tests often are waived for recycled concrete products.

### Chloride Content

High chloride levels have been found in RCA produced from sources with long-term exposure to deicing chemicals. Significant amounts of chlorides often raise concerns about the potential for problems with concrete durability, set times and corrosion of embedded steel. No serious problems caused entirely by high chloride contents have been reported; however, some testing might be necessary when using RCA with high chloride levels in reinforced concrete pavements.

### Precipitate Potential

Crushing concrete reveals previously unexposed surfaces that usually contain some calcium hydroxide (a by-product of the cement hydration reaction), as well as some unhydrated or partially hydrated cement grains. Calcium hydroxide is highly soluble and is easily leached from the RCA particles in stockpiles and drainable subbase layers, resulting in highly alkaline runoff and effluent. The dissolved calcium hydroxide can combine with $CO_2$ to form calcium carbonate, which precipitates out of solution to form a heavy, creamy substance. Dust and other fine particles from the crushing, screening and handling operations also can settle on filter fabrics and in drain pipes, further exacerbating the problem. Over time, these materials can clog drain pipes and blind filter fabrics.

Suggestions for avoiding this problem include using only coarse, washed RCA in drainable subbase layers, using daylighted subbase drainage designs, or modifying the filter fabric design to ensure that it does not completely surround the edge drain pipe trench.

Precipitate and crusher fines do not pose a problem for concrete mixture and undrained subbase layer applications where the presence of partially hydrated cement grains can actually aid in stabilizing and strengthening the layer.

## Surface Dust and Contaminants

Small quantities of fine particles ("crusher dust") often remain on RCA particles after production. This dust may increase water demand and decrease aggregate-mortar bond quality in new concrete mixture applications and may migrate into drainage systems and filter fabric in drainable subbase layer applications. Aggregate washing, as is often performed in processing dirty virgin aggregates, is not universally required in either of these applications, but may be helpful or desirable in some cases.

Contaminants are usually a concern only for RCA that will be used in new concrete mixtures and not for unstabilized subbase and fill applications. For new concrete mixture applications, RCA contaminants generally should be limited to the same values required for virgin coarse aggregate.

### References


Snyder, M. B., Vandenbossche, J. M. Smith, K. D., Wade, M. 1994. Synthesis on Recycled Concrete Aggregate. Interim Report—Task A, DTFH61-93-C00133. Federal Highway Administration. Washington, D.C.

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