[Granular Base] [Embankment or Fill] [Material Description]

RECLAIMED CONCRETE MATERIAL

User Guideline

Portland Cement Concrete

INTRODUCTION

Reclaimed concrete material (RCM) can be used as coarse and/or fine aggregate in Portland cement concrete (PCC) pavements However, concrete incorporating more than about 10 to 20 percent fine RCM aggregates can suffer a reduction in quality because of the high amount of water required to maintain adequate workability of the concrete mix

PERFORMANCE RECORD

RCM has been accepted by many jurisdictions and is covered by conventional aggregate specifications and by several highway agency specifications, including those in Colorado, Connecticut, Illinois, Indiana (special provisions), Iowa, Louisiana, Michigan, Montana, North Dakota, Oklahoma, and Wyoming [1] For large projects and/or projects where suitable quality aggregate is not readily available, site-processed RCM can be significantly cheaper than new aggregate hauled to the site

MATERIAL PROCESSING REQUIREMENTS

Material Handling

When RCM is collected from different sources or types of concrete, it should either be blended with other aggregates or separately processed and placed in separate stockpiles to ensure uniformity of RCM aggregate properties

Crushing and Screening

Crushing and screening is required to produce aggregate within the limits for concrete mix gradation

Quality Control

Levels of impurities such as sulfate and chloride ions, alkali-reactive aggregate and freeze-thaw expansion of large aggregate that can result in a breakdown of the concrete causing D-cracking in concrete pavements must be controlled to ensure that the finished concrete has consistent strength and durability [2,3] D-cracks are closely spaced cracks parallel to transverse and longitudinal joints that multiply outward to the center of the pavement panel These cracks typically start in the saturated aggregate at the base of the pavement and progress upward It has been recommended that the degree of contamination and potential reactivity of RCM aggregates should not exceed the limits permitted for virgin aggregates [4]

ENGINEERING PROPERTIES

Some of the engineering properties that are of particular interest when RCM is used in Portland cement concrete applications include gradation, particle shape, specific gravity, absorption, moisture content, durability, and permeability

Gradation Recycled concrete material should be crushed and screened to produce aggregate that satisfies the AASHTO M6[5] and M80[6] gradation requirements for PCC With appropriate adjustments, a plant can produce any desired gradation Crushed fine aggregates (minus 4 75 mm (No 4 sieve)) are generally not used or are blended with natural sand

Shape Processed RCM, being 100 percent crushed material, is highly angular in shape While this shape assists in increasing the strength of the mix, it can reduce its workability

Specific Gravity The specific gravity of processed coarse RCM aggregate ranges from 2 0 to 2 5, which is slightly lower than that of virgin aggregates This is primarily due to the adhesion of mortar to virgin aggregate particles The differences become more pronounced with decreasing particle size The specific gravity of processed RCM fines is in the range of 2 0 to 2 3 [7]

Absorption RCM aggregates can be expected to have higher absorption values than virgin aggregates High absorption is particularly noticeable in crushed fine material (minus 4 75 mm (No 4) sieve) from air-entrained concrete Absorption values for fine-grained RCM generally range from 4 to 8 percent (compared with 2 percent or less for fine virgin concrete aggregates) [7] If not accounted for in mix design, higher absorption values could adversely impact concrete workability

Moisture Content The in-situ stockpile moisture content for processed RCM is typically the same as that for conventional granular material

Durability Coarse-grained RCM typically exhibits good soundness characteristics and abrasion resistance Durability and soundness properties of processed RCM are similar to those of the virgin aggregates incorporated in the concrete and generally satisfy specification requirements for concrete aggregates [2]

Permeability Coarse-grained RCM is free draining (more permeable than conventional granular material due to lower fines content)

Some of the properties of concrete mixes containing RCM that are of interest include strength characteristics, workability, resistance to freeze-thaw, deleterious substances, alkali-aggregate reactivity, and corrosivity

Strength Characteristics In RCM mixes, compressive strength can be reduced up to 25 percent compared to mixes with conventional aggregates, with up to 30 percent improvement in the damping capacity, and higher amounts of drying shrinkage and creep [8] For a given compressive strength (at 28 days), both the static and dynamic moduli of elasticity for recycled-aggregate concrete are significantly lower (up to 40 percent) than those for concrete containing virgin aggregate [9 10] Concrete mixes incorporating coarse RCM aggregates generally can be expected to develop about 10 percent lower flexural strength at equal water/cement ratio and slump than conventional aggregates

Workability If fine RCM aggregates are used, concrete workability decreases (due to the high absorption and angularity of crushed RCM fines) and concrete flexural strength is reduced about

10 to 20 percent [11]

Resistance to Freeze-Thaw Concrete incorporating RCM aggregates has good resistance to freeze-thaw exposure provided a suitable air void system is present in the mortar phase of the concrete containing RCM aggregate

Deleterious Substances Chlorides may be present in RCM as a result of many years of deicing salt application on an old pavement High levels of chloride in the recycled aggregate can induce corrosion of reinforcing steel embedded in a new concrete However, the quantity of chloride typically found in old concrete pavement is below critical threshold values [12] A threshold value of 2 4 kg/m^3 (4 lbs/yd^3) is recommended by the American Concrete Pavement Association as a threshold to trigger the removal and replacement of concrete bridge decks due to corrosion potential [7 13]

Recycled concrete material may also contain coarse and/or fine aggregates that are susceptible to alkali-silica reaction [9,13]

DESIGN CONSIDERATIONS

Mix Design

Crushed RCM is considered a conventional coarse aggregate for Portland cement concrete mixtures by AASHTO M80 Coarse aggregates should conform to the grading requirements outlined in AASHTO M43[14] for the grading specified AASHTO M6 provides the physical properties and grading requirements for concrete fine aggregate [15]

Prior to use, trial batches should be prepared according to ACI 211 procedures[16] and necessary mix adjustments made to ensure that the specified requirements are attained

Special care is required when incorporating RCM fines to avoid dramatic reductions in concrete workability, strength, and finishability Blending RCM fines with natural sand at substitution rates of 10 to 20 percent has resulted in satisfactory performance Several trial mixes are often required to generate sufficient data to identify the optimum substitution rate

Due to their high absorption, prewetting of RCM aggregates is important Aggregates that are not saturated will absorb water from the concrete mix

In addition to satisfying the requirements of AASHTO M43 and M6, consideration must be given to sulfate and chloride contamination of RCM aggregates Chloride contamination is often due to the application of deicing salts (on pavements and sidewalks) High concentrations of chloride ions can result in corrosion of reinforcing steel ACI 201 2R, "Guide to Durable Concrete,"[17] provides guidance on the limits of such contaminants for various service conditions

Where sulfate attack is of concern, the potential for deterioration should be evaluated by the ASTM C452 sulfate expansion test [18] Sulfate-resistant cement such as Type II or V can be used, if necessary

Where alkali-silica reactivity is of concern, the potential for deterioration should be evaluated by the ASTM C289 test [19] Low-alkali Type II cement can be used if necessary

For reinforced concrete pavement construction or plain jointed pavements without load transfer dowels, it is important to ensure that the top size coarse aggregate is sufficiently large (typically 40 mm) to provide adequate interlock across joints and cracks

Structural Design

Conventional AASHTO rigid pavement thickness design procedures are appropriate for rigid pavements incorporating RCM

CONSTRUCTION PROCEDURES

The same equipment and procedures used for concrete containing conventional aggregate may be used to batch, mix, transport, place, and finish concrete containing processed RCM aggregates However, additional care and some minor changes are necessary to avoid potential problems

Material Handling and Storage

The same methods and equipment used to store or stockpile conventional aggregates are applicable for RCM

It is important to monitor the moisture content of RCM aggregates in stockpiles to permit determinations of the mix water requirements Sprinkling stockpiles to keep RCM aggregates saturated is an effective method of minimizing their potential to absorb moisture from the concrete mix

Mixing, Placing, and Compacting

The same methods and equipment can be used to mix, place, and compact RCM concrete mixes and conventional concrete mixes

Slipforming and finishing concrete made with RCM aggregates is improved by reducing or eliminating the RCM fines content in favor of natural sand

Quality Control

The same quality-control procedures for conventional Portland cement concrete pavement are required for Portland cement concrete incorporating RCM aggregates The slump, air content, and temperature of the plastic concrete should be monitored at the time of placement, and compressive strength cylinders cast for compressive strength determinations in accordance with the ASTM C39[20] procedure Flexural strength can be determined using flexural strength prisms (ASTM C78)[21] or by splitting tensile tests (ASTM C496)[22] on cylinders Due to the sensitivity of concrete pavement performance and durability to water-cement ratio, and the potential variability in RCM gradation, specific gravity, and absorption, particular attention should be given to these aggregate properties when using RCM in concrete pavement mixtures, and appropriate adjustments to the quantity of mixing water completed during concrete production

UNRESOLVED ISSUES

There is a need to obtain long-term performance and life-cycle cost data for concrete made with processed RCM aggregates to assess its durability, performance, and expected service life

Limits on chloride and sulfate contents of concrete materials are well established However, further investigation concerning the effect of other impurities that RCM may contain (other than chloride and sulfate) such as wood, asphalt, and earth on concrete performance is needed Also, there is a need for guidance regarding the monitoring and restriction of impurities in RCM

Further, there is a need to determine whether alkali-silica reactive or D-cracked concrete can be recycled as aggregate and to develop appropriate specifications for the use of such materials

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