Case studies of recycled concrete aggregate in India

Dr Sivakumar Kandasami
Deputy General Manager (Civil)
Buildings & Factories IC
L&T Construction, Chennai

RAEng Frontiers Champion: Webinar#7
Recycled Aggregate Concrete in South-East Asia
Tuesday 22 June 2021
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Tuesday 22 June 2021
Urban Transformation through Housing for All

1 crore and more

27th December, 2019

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Concrete: Sustainable Building Material

Make cities and human settlements inclusive, safe, resilient and sustainable

Over 90 per cent of COVID-19 cases are occurring in urban areas. The pandemic is hitting the most vulnerable the hardest, including the 1 billion residents of the world’s densely populated informal settlements and slums. Even before the new coronavirus, rapid urbanization meant that 4 billion people in the world’s cities faced worsening air pollution, inadequate infrastructure and services, and unplanned urban sprawl. Safe public transportation, reliable basic services and open public spaces are especially important now to ensure the health and livelihoods of urban dwellers. Successful examples of containing COVID-19 demonstrate the remarkable resilience and adaptability of urban communities in adjusting to new norms. Cities will emerge from the pandemic, but whether they are prepared for the next crisis will depend on how much they can advance data-driven inclusive and sustainable urban development.

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Concrete: Sustainable Building Material

Ensure sustainable consumption and production patterns

Consumption and production drive the global economy, but also wreak havoc on planetary health through the unsustainable use of natural resources. The global material footprint is increasing faster than population growth and economic output. Improvements in resource efficiency in some countries are offset by increases in material intensity in others. Fossil fuel subsidies remain a serious concern. An unacceptably high proportion of food is lost along the supply chain. And waste, including additional medical waste generated during the pandemic, is mounting. The pandemic offers an opportunity to develop recovery plans that will reverse current trends and shift our consumption and production patterns to a more sustainable course. A successful transition will mean improvements in resource efficiency, consideration of the entire life cycle of economic activities, and active engagement in multilateral environmental agreements.

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Governments of **Sweden** and **India**, with support from the World Economic Forum (WEF) launched the Leadership Group for Industry Transition (LeadIT) at the UN Secretary General’s Climate Action Summit in September 2019.

*To achieve reduction in emissions, greater public-private partnerships is envisaged.*

**LEADERSHIP GROUP FOR INDUSTRY TRANSITION**

**COURTESY: Stockholm Environment Institute**

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Components of Concrete

- **Portland Cement**
- **Aggregate** - sand, gravel, crushed rock
- **Water**
- **Admixtures** - when necessary

Reclaimed Concrete:
Aggregate washing plants in projects to separate aggregate fractions.

Current focus: Use of **fine and coarse RCA** in concrete applications.

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Aggregate Characteristics

IS383:2016

5 QUALITY OF AGGREGATE

5.1 General
Aggregate shall be naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof or **produced from other than natural sources**. They shall be hard, strong, dense, durable, clear and free from veins; and free from injurious amounts of disintegrated pieces, alkali, free lime, vegetable matter and other deleterious substances as well as adherent coating. As far as possible, scoriaceous, flaky and elongated pieces should be avoided.

Grading, Crushing value, Impact value, Abrasion value, etc.
Aggregate Characteristics

Crushed and screened to different sizes.

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Courtesy: METSO
Aggregate Characteristics

Normal production process of crushed aggregates
During production of CA, up to 30 percent (rock dependant) of the feed material is reduced to sizes < 4 mm and cannot be used as coarse aggregates.

Primary Jaw crusher Secondary Cone crusher Tertiary Impact crusher

Crushed stone sand particles
Vertical Shaft Impactor (VSI) crushed sand particles are cubical in shape. Only jaw or cone could result in flaky particles. No silt particles in crushed aggregates.

Other than natural sources
Manufactured Sand, Manufactured Coarse Aggregate
## Shortage of Aggregates

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<table>
<thead>
<tr>
<th>S.No.</th>
<th>District</th>
<th>Total No of Stockyards</th>
<th>Total No of Orders</th>
<th>Sold Quantity(Cu M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RANGA REDDY</td>
<td>1</td>
<td>5</td>
<td>60.00</td>
</tr>
<tr>
<td>2</td>
<td>MEDAK</td>
<td>1</td>
<td>13</td>
<td>75.00</td>
</tr>
<tr>
<td>3</td>
<td>KHAMMAM</td>
<td>1</td>
<td>40</td>
<td>120.00</td>
</tr>
<tr>
<td>4</td>
<td>BHADRADRI KOTHAGUDEM</td>
<td>1</td>
<td>6</td>
<td>60.00</td>
</tr>
<tr>
<td>5</td>
<td>JAGITHTAL</td>
<td>1</td>
<td>17</td>
<td>51.00</td>
</tr>
<tr>
<td>6</td>
<td>JAYASHANKAR BHUPALPALLY</td>
<td>17</td>
<td>1,610</td>
<td>26,857.00</td>
</tr>
<tr>
<td>7</td>
<td>MANCHERIAL</td>
<td>1</td>
<td>66</td>
<td>1,040.00</td>
</tr>
<tr>
<td>8</td>
<td>MEDCHAL</td>
<td>2</td>
<td>33</td>
<td>344.00</td>
</tr>
<tr>
<td>9</td>
<td>PEDDAPALLI</td>
<td>1</td>
<td>111</td>
<td>1,500.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>26</strong></td>
<td><strong>1,901</strong></td>
<td></td>
<td><strong>30,445.00</strong></td>
</tr>
</tbody>
</table>
No need to wait in long queues for sand anymore

Are you waiting for the sand?

Contact: 044-40990555, 9565222479, 9940498760 Email: support@msand.in
WhatsApp: 9384827276
No need to wait in long queues for sand anymore

Contact: 044-40905555, 956622479, 9940498760 Email: support@tsand.in
WhatsApp: 9384827276
Public entrance
Simply put, the public can choose and book the quarry that suits them.

Truck owner entry
Truck owners can simply register the details of their lorries at this site and select the quarry that suits them, as well as know the serial number and the day allotted for sand extraction and go to the quarry at the appropriate time to get the sand.

Interface
Details of the waiting time of the booked lorry, the serial number of the confirmed lorry, the date of sand extraction and the unbooked lorries can be found under a single screen.

Booking
They can book in the queue at the quarry to load the lorry with the appropriate details so that they can go to the quarry only on the day allotted to them and get the sand without having to wait on the road or in the quarry at other times.

Notice
The date on which the sand is allowed to be taken and other details will be sent to the email and mobile number.
Sources of C&D Waste

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Calls to reuse concrete from demolished nuclear sites

08 Jan, 2020 | by Catherine Kennedy

Concrete from decommissioned nuclear sites should be reused to fill in voids after reactors are demolished, an Aecom-led report concludes.

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GOA: C&D Waste from Refurbishment of Hotel Rooms

Table 7: Composition of the C&D waste from demolition of different type of structures

<table>
<thead>
<tr>
<th>TYPE OF CONSTRUCTION</th>
<th>AVERAGE MT/m²</th>
<th>LATERITE / MUD</th>
<th>CONCRETE</th>
<th>MORTAR</th>
<th>TILES AND BATHROOM FITTINGS</th>
<th>GYPSUM / PoP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangalore Tile Roofed</td>
<td>1.6</td>
<td>65%</td>
<td>3%</td>
<td>24%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>Concrete Roofed</td>
<td>2</td>
<td>52%</td>
<td>20%</td>
<td>21%</td>
<td>4%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Source: Based on anecdotal evidence collected from demolition contractors and debris transporters in Goa.

Table 8: Demolition waste volume and its composition (Taluka-wise, MT per day)

<table>
<thead>
<tr>
<th>TALUKA</th>
<th>MAJOR TOWN/CITY</th>
<th>LATERITE / BRICKS</th>
<th>MORTAR</th>
<th>CONCRETE</th>
<th>CERAMIC/ TILES</th>
<th>GYPSUM</th>
<th>TOTAL IN MT/DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bardez</td>
<td>Calangute, Candolim</td>
<td>37.7</td>
<td>14.3</td>
<td>7.8</td>
<td>3.2</td>
<td>2</td>
<td>65</td>
</tr>
<tr>
<td>Tivaudi</td>
<td>Panjim</td>
<td>43.5</td>
<td>16.5</td>
<td>9</td>
<td>3.8</td>
<td>2.3</td>
<td>75</td>
</tr>
<tr>
<td>Marmugao</td>
<td>Vasco</td>
<td>31.9</td>
<td>12.1</td>
<td>6.6</td>
<td>2.8</td>
<td>1.7</td>
<td>55</td>
</tr>
<tr>
<td>Salcete</td>
<td>Madga</td>
<td>31.9</td>
<td>12.1</td>
<td>6.6</td>
<td>2.8</td>
<td>1.7</td>
<td>55</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>145</td>
<td>55</td>
<td>30</td>
<td>12.5</td>
<td>7.5</td>
<td>250</td>
</tr>
<tr>
<td>% of Total</td>
<td></td>
<td>58</td>
<td>22</td>
<td>12</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ calculations.


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Circular Economy

- **A change in mindset**: Regenerate value out of waste i.e. concrete debris
- Most of the concrete debris end up as landfill.
- Create value out of waste: Use more recycled materials.
- **Structural Efficiency of Buildings**: Can we dismantle components and reuse? Can precast be the solution?
- Global movement towards Circular Economy
Concrete: Sustainable Building Material

INDIA: Agenda 2030 / Circular Economy

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Production of RA

C&D Waste

- Crushing
- Screening
- Washing

RA

- Coarse > 4.75 mm
- Fine < 4.75 mm

Recycled Aggregate can be a mixture of concrete, bricks, tiles etc.

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Production of RCA

- Crushing
- Screening
- Washing

CONCRETE debris

RCA

- Coarse > 4.75 mm
- Fine < 4.75 mm

Primary Aggregate can be replaced with processed fine/coarse RCA.

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C&D Waste Recycling Plant

Shastri Park C&D waste recycling facility, New Delhi: 0/3 mm, 3/10 mm, 10/20 mm and 20/60 mm

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Challenges for RCA Use

**Consistent quality:** placement, cost, quality

**Concrete Debris:** availability, grade

**Continuous supply required:** lack of vendors, impact on cycle times, concrete mix approvals

Can fine RCA (manufactured sand) be used in mixed sand?

RCA in prestressing applications?

Durability tests and limiting values need to be specifically framed.
Need for proper processing facility
Aggregate Water Absorption Capacity

✓ Minimize old mortar attached to aggregate
✓ IS 383:2016 Annex A:
  “A-3 C&D Waste: The concrete rubble has to be properly processed, including scrubbing to remove the unhydrated cement as much as possible.”

Proper processing in exclusive C&D waste recycling plants is preferred.

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Concrete Structures: Service Life

Design service life is the intended period for which the structure is to be used with anticipated maintenance but without major repair.

- Technical service life: until unacceptable deterioration.
- Functional service life: structure becomes obsolete due to change in requirements. eg. Tourism industry in Goa
- Economic service life: replacement becomes economically attractive.

RCA: Extent of Use in Concrete

Kattupalli shipyard and port: Can RCA be used?

<table>
<thead>
<tr>
<th>Grade</th>
<th>OPC</th>
<th>GGBS</th>
<th>Crushed Sand</th>
<th>12 mm</th>
<th>20 mm</th>
<th>water</th>
<th>Admixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>M30</td>
<td>190</td>
<td>190</td>
<td>880</td>
<td>547</td>
<td>528</td>
<td>165</td>
<td>4.67</td>
</tr>
</tbody>
</table>

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Tuesday 22 June 2021
RCA: Extent of Use in Concrete

**Mechanism of ggbs in concrete**

**ggbs**: high aluminate levels mean higher quantities of Friedel’s salt. (C₃A phase reacts with Cl⁻ ions.)

Higher the Cl⁻/OH⁻ ratio, higher the binding capacity.
Durability performance of sustainable structural concrete: Effect of coarse crushed concrete aggregate on rapid chloride migration and accelerated corrosion

Wayne Dodds, Christian Christodoulou, Chris Goodier, Simon Austin, David Dunne

AECOM

Aggressive Chloride Environment

- Coarse RCA has a detrimental effect on chloride migration.
- Could be overcome to a greater extent by using GGBS.
- 100% RCA and 50% ggbs outperformed Portland cement + natural aggregates.
- Up to 60% RCA + 50% ggbs could be adopted for compliance purpose.
- GGBS and coarse RCA are good for sustainability.

https://doi.org/10.1680/jcoma.17.00056
Case studies of recycled concrete aggregate in India
Tuesday 22 June 2021
Corrosion risk assessment of structural concrete with coarse crushed concrete aggregate

Wayne Dodds MEng (Hons)
Centre for Innovative and Collaborative Construction Engineering, School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough, UK
(Author: Dodds@ae.com)

Christian Christodoulou MEng (Hons), EngD
AECOM, Birmingham, UK

Simon Austin BSc (Hons), PhD
Centre for Innovative and Collaborative Construction Engineering, School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough, UK

David Dunne BEng (Hons), PhD
AECOM, Birmingham, UK
Table 8. Prediction of time to corrosion initiation (years)

<table>
<thead>
<tr>
<th>CCA content: %</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I</td>
<td>OPC</td>
<td>39</td>
<td>66</td>
<td>42</td>
</tr>
<tr>
<td>CEM II/B-V</td>
<td>30% fly ash</td>
<td>120+</td>
<td>120+</td>
<td>120+</td>
</tr>
<tr>
<td>CEM III/A</td>
<td>50% ggbs</td>
<td>120+</td>
<td>120+</td>
<td>120+</td>
</tr>
</tbody>
</table>

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*Tuesday 22 June 2021*
Aluminium Rebars: Durable Solution?

Durable Aluminium Reinforced Environmentally-friendly Concrete Construction – DARE2C

Harald Justnes, PhD
Chief Scientist
SINTEF Building and Infrastructure
Pb 4760 Sluppen, 7465 Trondheim, Norway
harald.justnes@sintef.no

Can withstand carbonation and chlorides
Cover depth can be reduced
No maintenance
Infinite service life


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RCA: Extent of Use in Concrete

BS 8500-2:2019 (First introduced in 2002)

RCA is now CCA i.e. coarse crushed concrete aggregate

CCA can be used up to M50 strength grade

Exposure class for all carbonation, XF1, DC-1

Source is known eg. Surplus precast units, reclaimed concrete, only physical properties need to be checked.

Chloride content BS1881-124

Sulfate content BS EN 1744-1
RCA: Extent of Use in Concrete
ACI SP326-39

High speed rail from Wuzhong to Yinchuan in China
M50 grade concrete processed, crushed and used to make precast concrete blocks.
RCA: Extent of Use in Concrete
ACI SP326-39

Fig. 5 Precast concrete blocks for highway bank protection revetment

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Successful Demonstration Project, Norway

School constructed using 37% RCA, Oslo

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Successful Demonstration Project, Norway

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RCA: India Project Experience

Project A: M15 Plain Concrete

IS 383: 2016

➢ Extent of Utilization in M15 Grade Plain Concrete

Coarse aggregates: 25% replacement of natural aggregate
Fine aggregates: 25% replacement of natural aggregate

Coarse Aggregate sourced from the Burari C&D Waste Recycling facility.
Approval was given for recycling only concrete waste generated at site.

IS383 Table 1 Note 1

“\textit{It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.}”
RCA: India Project Experience

Project A: M15 Plain Concrete Trials

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RCA: India Project Experience

Project B: M20 Concrete Grade Slab

- Use for construction of a Precast Factory
- Fine Aggregate sourced from a C&D Waste Recycling facility
- Feedstock of good quality
- Vetting and approval of RCA supply by SINTEF
- Replaced fine aggregate by 50% RCA
- Ongoing work and full results will be shared at a later date
- Own initiative of L&T
RCA: India Project Experience

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RCA: India Project Experience

Project B: M20 Concrete Grade Slab

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RCA: India Project Experience

Project B: M20 Concrete Grade Slab

M20 Grade: 50% RCA sand

M10 Grade: 100% RCA sand

Exceeds the 25% limit in Table 1 of IS383:2016

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RCA: India Project Experience

Project B: M20 Concrete Grade Slab

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Liverpool, UK: Building demolished and C&D Waste Recycled Onsite. Courtesy: Prof. Marios Soutsos, QUB.

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Onsite Recycling of C&D Waste: Regulations

Permission denied to operate a crusher for recycling concrete debris.

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ICJ Special Issues on C&D Waste

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London Olympics Aquatics Centre
- Sara Klomps, Zaha Hadid Architects

- 30% replacement with RCA
- Self-compacting concrete
- Fair finish possible
- Architectural concrete
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London Olympics Aquatics Centre

Picture Source: Hufton+Crow
Acknowledgement: Sara Klomps, ZHA
Concerns in sourcing RCA

- Consistent supply of RCA required in large quantities.
- Not too many qualified vendors.
- Use of RCA is L&T’s own initiative.
INDIA: How much of C&D Waste Generated?

Table 4: Estimates of quantity of C&D waste from various agencies

<table>
<thead>
<tr>
<th>NAME OF THE AGENCY</th>
<th>ESTIMATION YEAR</th>
<th>C&amp;D WASTE (MILLION MT /ANNUM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Environment &amp; Forest (MoEF&amp;CC)</td>
<td>2010</td>
<td>10-12</td>
</tr>
<tr>
<td>Technology Information, Forecasting and Assessment council (TIFAC)</td>
<td>2001</td>
<td>12-15</td>
</tr>
<tr>
<td>Central Pollution Control Board (CPCB)</td>
<td>2017</td>
<td>12</td>
</tr>
<tr>
<td>Building Material Promotion Council (BMTC)</td>
<td>2013</td>
<td>165-175</td>
</tr>
<tr>
<td>Centre for Science and Environment (CSE)*</td>
<td>2014</td>
<td>530</td>
</tr>
</tbody>
</table>


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Suggestions for Greater Uptake

Infrastructure Projects

• Asset owner should include RCA in the technical specification.
• Batching plant limitations i.e. additional storage facilities.
• Specify mandatory use for concrete grades up to M30.

IS 383:2016 Table 1 Extent of Utilization

• Plain Concrete
  ➢ 25% limit can be increased to 100%.
• Reinforced Concrete
  ➢ 20% limit for up to M25 concrete grade can be increased based on performance in concrete mix trials.
  ➢ Higher grades of concrete can also be allowed.

Example: BS8500-2 allows use of RCA up to M50 grade.
### Suggestions for Greater Uptake

#### Case studies of recycled concrete aggregate in India

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<table>
<thead>
<tr>
<th>SI No.</th>
<th>Type of Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Coarse aggregate:</td>
<td></td>
</tr>
<tr>
<td>a) Iron slag aggregate</td>
<td>50</td>
</tr>
<tr>
<td>b) Steel slag aggregate</td>
<td>25</td>
</tr>
<tr>
<td>c) Recycled concrete aggregate (RCA) (See Note 1)</td>
<td>25</td>
</tr>
<tr>
<td>d) Recycled aggregate (RA)</td>
<td>Nil</td>
</tr>
<tr>
<td>e) Bottom ash from Thermal Power Plants</td>
<td>Nil</td>
</tr>
</tbody>
</table>

| i) Fine aggregate: |
| a) Iron slag aggregate | 50 | 25 | 100 |
| b) Steel slag aggregate | 25 | Nil | 100 |
| c) Copper slag aggregate | 40 | 35 | 50 |
| d) Recycled concrete aggregate (RCA) (See Note 1) | 25 | 20 (Only up to M25 Grade) | 100 |

---

1. *See A-3 for brief information on recycled aggregates (RA) and recycled concrete aggregates (RCA).*

**NOTES**

1. It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.
2. In any given structure, only one type of manufactured coarse aggregate and one type of manufactured fine aggregate shall be used.
3. The increase in density of concrete due to use of copper slag and steel slag aggregates need to be taken into consideration in the design of structures.
4. While using manufactured aggregate as part replacement for natural aggregate, it should be ensured that the final grading meets the requirements specified in Table 7, Table 8 and Table 9.
Suggestions for Greater Uptake


Table 1: Percentage of incorporation of recycled C&D waste

To be decided based on concrete mix design trials at site and on the end application

Table 1: Limiting strength grade of reinforced concrete

To be decided based on concrete mix design trials at site

Table 1 Note 1

“*It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.*”

This requirement is applicable only for redevelopment of existing sites and not for greenfield projects.
Suggestions for Greater Uptake


Table 3: Current water absorption limit of 10%
To be decided based on concrete mix design trials at site

Table 7 and Table 9: Grading limits
Sieve analysis done with the desired combination proportions of natural and recycled aggregates.

Currently no link to cement content and SCMs
Percentage substitution should be linked to actual cement content

Acceptance criteria for processed RCA
To be decided based on concrete mix design trials at site
2019 CPWD DAR Volume 1
Recycled C&D waste products under the code nos.
- 7776 Concrete paver block of M30 grade
- 8658 Precast concrete block M10 grade

2019 CPWD DAR Volume 2
“New Technologies and Materials”
- 7776 Concrete paver block of M30 grade (60 mm thick)
- 8658 Precast concrete block M10 grade (100 mm and 200 mm thick)
Common Concrete Grades for RC Construction

HOUSING/RESIDENTIAL
M20, M25, M30

COMMERCIAL
M25, M30, M35, M40

SERVICE LIFE
50 years

MANDATORY REQUIREMENT
Strength criteria

Durability with RCA should not be an insurmountable problem.

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Concrete: Sustainable Building Material

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Larsen & Toubro is an Indian multinational engaged in technology, engineering, construction, manufacturing and financial services with over USD 21 billion in revenue. It operates in over 30 countries worldwide. A strong, customer-focused approach and the constant quest for top-class quality have enabled L&T to attain and sustain leadership in its major lines of business for eight decades.

2019 ACI Excellence in Concrete Construction Award

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