Durability of Concrete Mixed with Fine Recycled Aggregates

Salomon Levy
Prof. Nove de Julho University UNINOVE
President of IBRACON Committee on Sustainability
Paulo Helene
President of Brazilian Concrete Institute IBRACON
Prof. University of São Paulo USP

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PURPOSE

- This work aims to analyze the influence of two types of fine recycled aggregates (one from recycled concrete, the other from recycled masonry) on four significance properties of concrete:
  - water absorption,
  - pore volume,
  - carbonation depth,
  - resistivity.

  Related with durability of concrete.

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MATERIALS

- Blended Portland Cement,
  - blast furnace slag = 35%
  - blaine fineness = 385 m²/kg
  - density = 2,990 kg/m³
  - fc_{28} = 49 MPa (7,105psi)
- Coarse aggregate
  - Natural granite crushed gravel
    - density = 2,700 kg/m3
    - maximum size = 25 mm
    - fineness modulus = 7.0
    - water absorption = 0.8% (SDS)

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MATERIALS

- Fine aggregate *(reference concrete):*
  - natural washed quartz river sand
    - density = 2,650 kg/m³
    - maximum particle size = 4,8 mm
    - fineness modulus = 2.6
    - water absorption = 1.8% (SDS) ASTM C270

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MATERIALS

- Fine aggregate:
  - recycled concrete aggregate **(FRCA)**
    - density = 2,320 kg/m3
    - maximum size = 2.4 mm
    - fineness modulus = 2.5
    - water absorption = 10.3% (SDS) ASTM C270
  - recycled masonry aggregate **(FRMA)**
    - 76% of clay brick, 24% of lime mortar
    - density = 1,890 kg/m3
    - maximum particle size = 2.4 mm
    - fineness modulus = 2.5
    - water absorption = 13.0% (SDS). ASTM C270

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Concrete mix proportion

- Three cement/dry aggregate ratios by mass 1:3 ; 1:4.5 and 1:6, were used to compose each concrete family.
- All mixtures = Same fresh workability slump test (70 mm $\pm$ 10 mm).
- For each mixture => Recycled aggregates replace 0%, 20%, 50% and 100% of natural fine aggregates by mass. (21 mix proportions. 7 concrete families)

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Properties measured

- Measured properties:
  - Compressive strength, ASTM C 39.
  - Water absorption (SDS), ASTM C270.
  - Total pore volume, ASTM C 642.
  - Accelerated carbonation, RILEM CPC- 18 method.
  - Resistivity, ASTM G57.
  - Also: cement content, water content, W/C ratio by mass, entrapped air content, workability, and fresh concrete density.

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CONSTRUCTING THE MDN

mix design nomogram

35 MDN were constructed to study 7 families and 4 mainly properties

- The seven families:
  - 1 Reference concrete family,
  - 3 FRCA (20%, 50%, 100%) concrete family,
  - 3 FRMA (20%, 50%, 100%) concrete family.
- The four properties
  - Water Absorption
  - Total Pore Volume
  - Carbonation Depth
  - Resistivity

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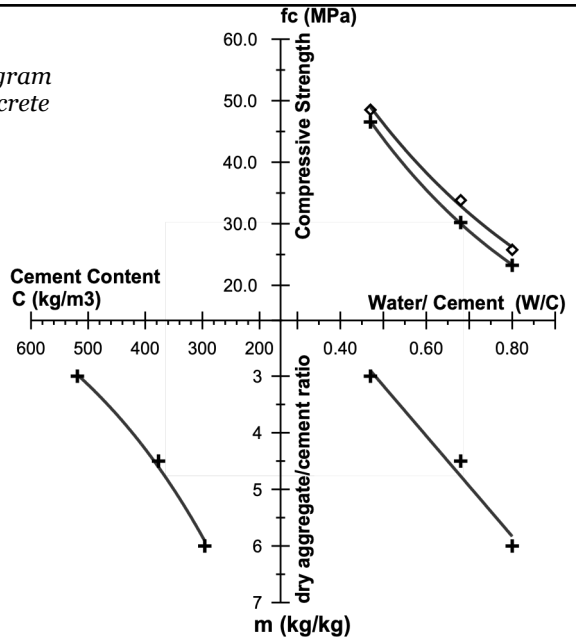
Figure 1.
MDN Mix Design Nomogram
100% Fine Recycled Concrete Aggregate



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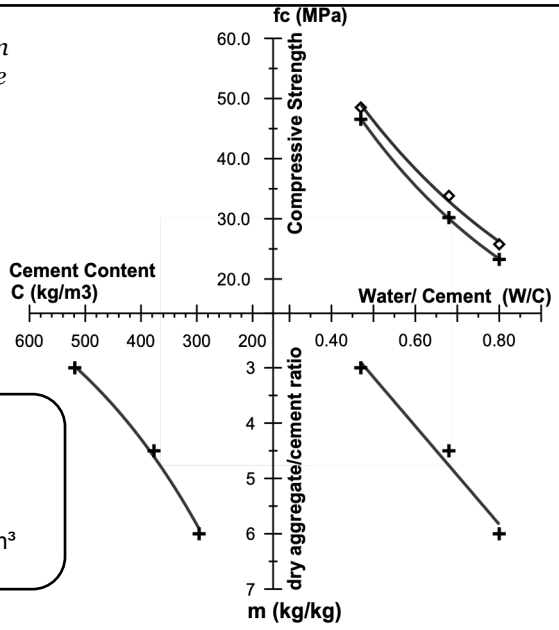
MDN Mix Design Nomogram
100% Fine Recycled Concrete Aggregate



→ for $f_{ck,28}$ = 30 MPa

W/C = 0.68
m = 4.75
C = 366 kg / m³

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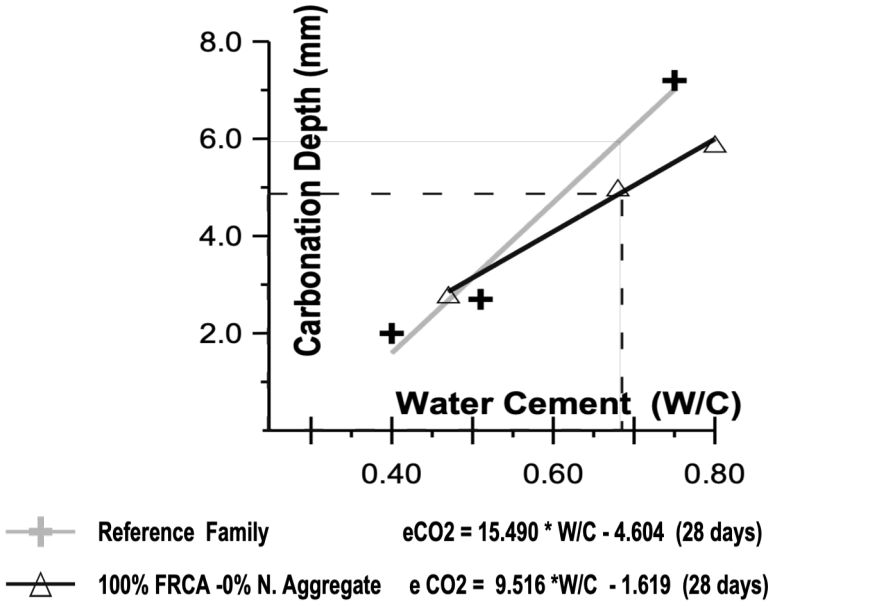

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Figure 2 MDN for Carbonation Depth

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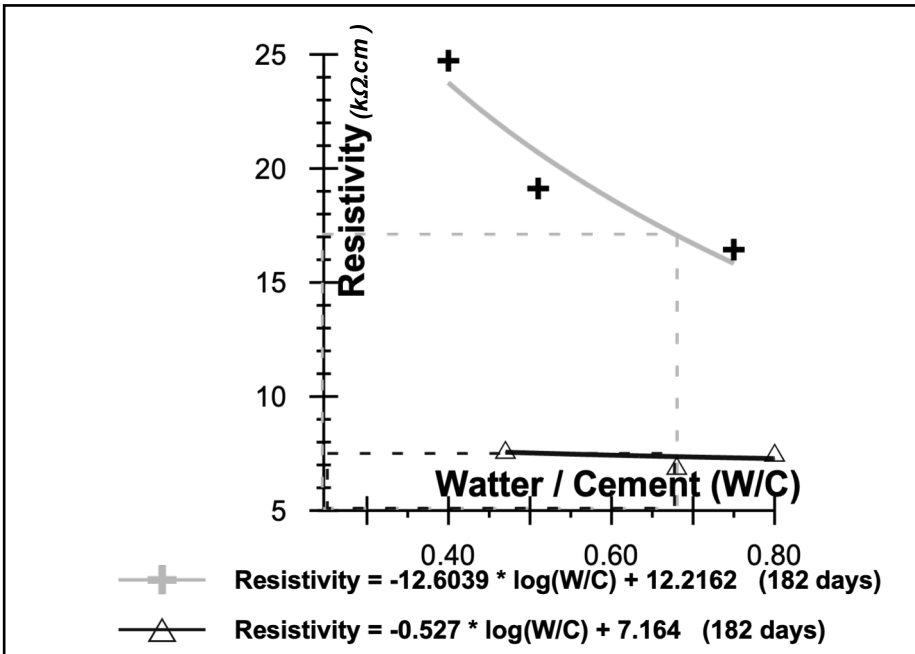

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Figure 2 MDN for Resistivity

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DISCUSSION

- Water absorption (and total pore volume) increased when the natural aggregates were replaced by recycled aggregates. (absorption of fine recycled aggregates was 6 to 10 times higher).
- An optimal value of carbonation depth was reached when, 50% of natural aggregates were replaced by FRMA. When natural aggregates were replaced by FRCA, no significant alterations.

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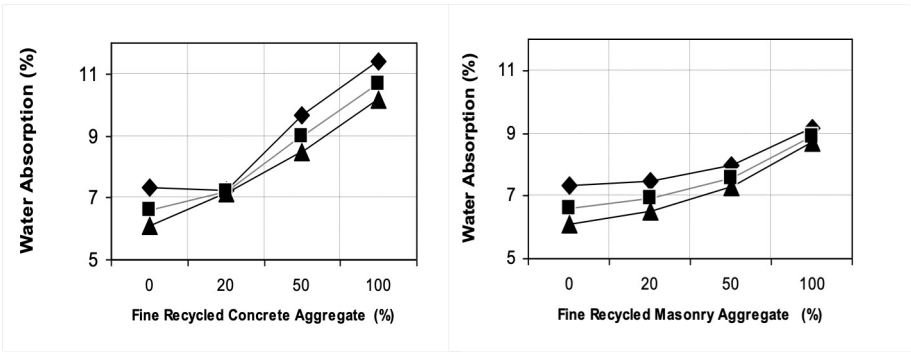

Legend ♦ 20 MPa ■ 30 MPa ▲ 40 MPa

Figure 3: Evolution of water absorption.

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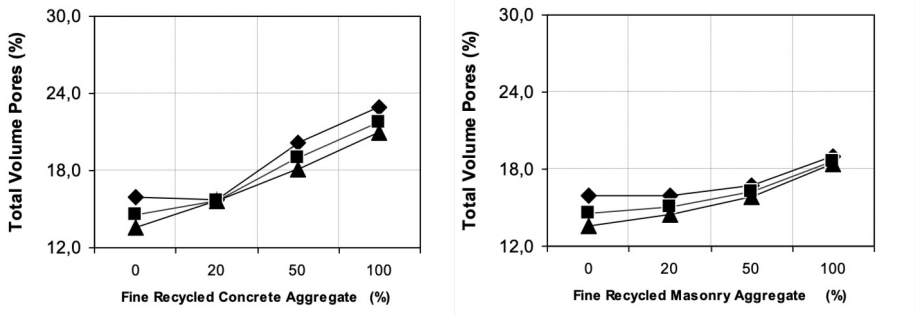

Legend ♦ 20 MPa ■ 30 MPa ▲ 40 MPa

Figure 4 Evolution of the total pore volume

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DISCUSSION

- When using FRCA or FRMA , carbonation depth still lower compared to reference concrete families.
  (Fine recycled aggregate use higher cement content to achieve same compressive strength).

- (Higher alkaline reserve acts to protect concrete surface against carbonation mechanisms. (Clifton, 1993)).

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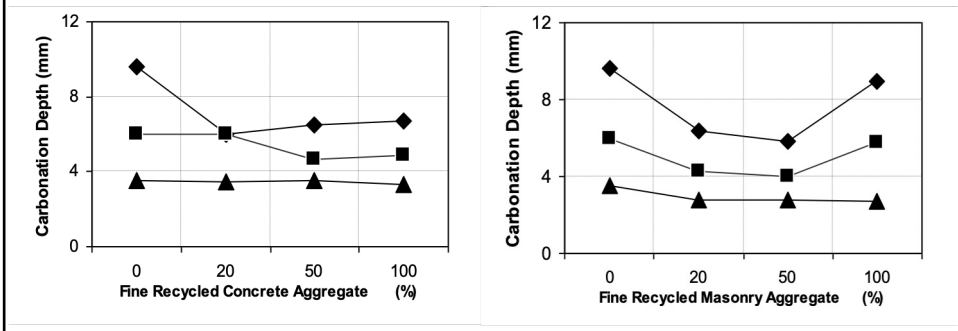

Legend ♦ 20 MPa ■ 30 MPa ▲ 40 MPa

Figure 5 Evolution of the carbonation depth.

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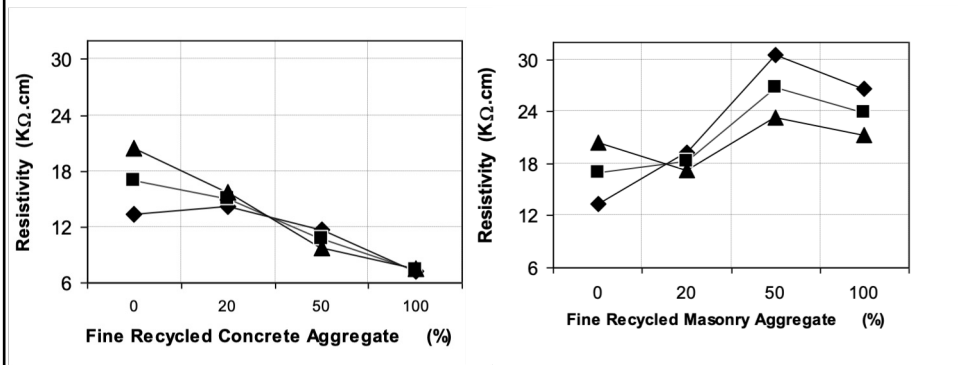

Legend ♦ 20 MPa ■ 30 MPa ▲ 40 MPa

Figure 6 Evolution of resistivity.

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DISCUSSION

- Comparing data results with CEB (Euro-International Committee du Béton) criteria (bulletin CEB 192), corrosion probability could be considered high only when FRCA replaced 100% of natural aggregates .
  (In all the other mixtures corrosion probability was low or negligible)

CONCLUSIONS

- From the properties studied in this work, it was possible to observe and compare the behavior of concrete families and not only of isolated mixtures.

CONCLUSIONS

- Concrete made with recycled aggregates (20%; 50% and 100% replacement) from old masonry or from old concrete had same fresh workability and achieved same compressive strength at 28-day as concrete made with natural aggregates in the range from 20MPa to 40MPa.

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CONCLUSIONS

- Carbonation depth always decreased when replacement was 20% or 50%.
- For FRMA aggregates, an optimum value was reached when the replacement was 50%.
- Water absorption and total pore volume, always increased with replacement of recycled aggregates, but carbonation and resistivity no.

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CONCLUSIONS

- This research show that the replacement of natural aggregates by recycled ones can be technically useful when durability properties is the focus.

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CONCLUSIONS

- Results obtained in this work point towards an effective possibility of using fine recycled aggregates in the production of concrete.
  (As long as the maximum substitution limits of 50% are observed)

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