India Chapter of American Concrete Institute

INDIA CHAPTER OF ACI

American Concrete Institute
Advancing concrete knowledge

Durability of concrete produced with recycled aggregates, a contribution to safe and sustainable development

Salomon Levy
Prof. Nove de Julho University UNINOVE

Paulo Helene
President of Brazilian Concrete Institute IBRACON
Prof. University of São Paulo USP

IBRACON

UNINOVE
Universidade Nove de Julho

1

PURPOSE

- Evaluate the concrete durability produced by concrete recycled aggregates
- Smart balance between normal and recycled concretes for the same compression strength

2

2

METHOD

- Two properties, considered basic in predicting concrete durability, were selected to achieve the purpose:
  - ionic resistivity
  - chloride profile from 0-1, 1-2 and 2-3 cm deep.
- Using the innovative - Mix Design Nomogram (MDN)

3

3

MATERIALS

- Blended Portland Cement,
  - blast furnace slag = 35%
  - blaine fineness = 385 m²/kg
  - density = 2,990 kg/m³
  - cement compression strength = 49 MPa (7,105psi) at 28days, cylinder

4

4

MATERIALS (reference concrete)

- Fine aggregate: 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
- Coarse aggregate: Natural granite crushed gravel
  - density = 2,700 kg/m3
  - maximum size = 25 mm
  - fineness modulus = 7.0
  - water absorption = 0.8% (SDS)

5

5

MATERIALS *(recycled aggregate concrete)*

- Fine aggregate **(FRCA)**
  - density = 2,320 kg/m3
  - maximum size = 2.4 mm
  - fineness modulus = 2.5
  - water absorption = 10.3% (SDS) ASTM C270
- Coarse aggregate **(CRCA)**
  - density = 2,320 kg/m3
  - maximum size = 25 mm
  - fineness modulus = 6.6
  - water absorption = 5.6% (SDS) ASTM C270

6

6

Concrete mix proportion

- Three cement/dry aggregate ratios by mass 1:3.0 ; 1:4.5 and 1:6.0, were used to compose each concrete family.
- All mixtures = same fresh workability; slump test (70 mm $\pm$ 10 mm).
- **For each mixture => coarse and fine recycled aggregates replaced 20%, 50% and 100% of natural aggregates by mass. (21 mix proportions. 7 concrete families)**

7

7

Measured Properties

- Chloride profile down to a depth of 3 cm
- Ionic Resistivity, ASTM G57.
- Compressive strength, ASTM C 39.
- Also: cement content, water content, W/C ratio by mass, entrapped air content, workability, and fresh concrete density.

8

8

Building MDN

mix design nomogram

MDN was built to represent 7 families and 3 main properties

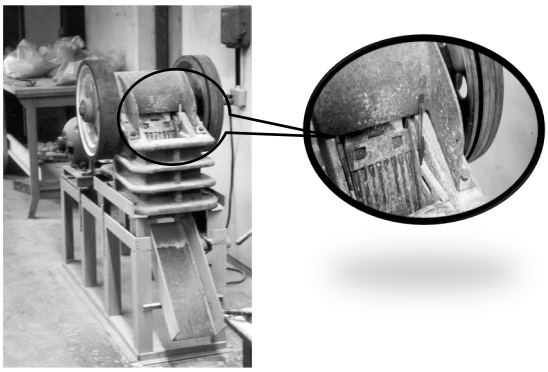
- Seven families:
  - 1 Reference concrete family,
  - 3 CRCA (20%, 50%, 100%) concrete family,
  - 3 FRCA (20%, 50%, 100%) concrete family.
- Three **main** properties
  - Ionic Resistivity
  - Chloride profile down to a depth of 3 cm
  - Compressive strength

9

9

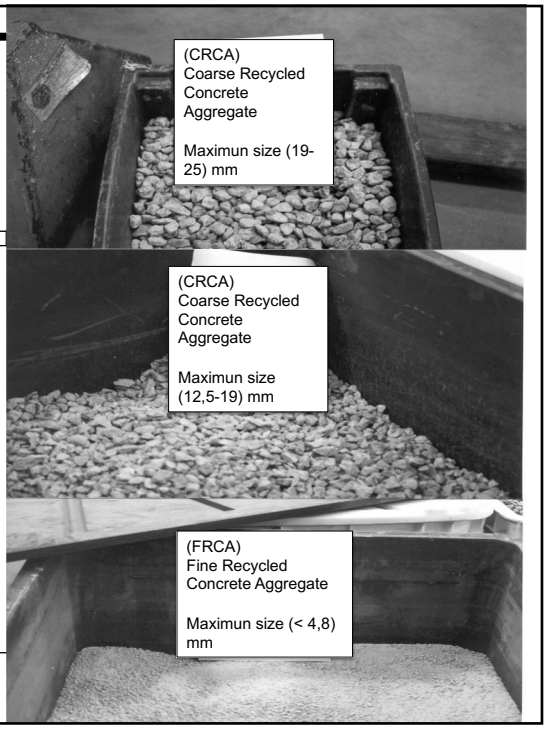
Method

- Preparation of recycled aggregates with jaw crusher



10

Aspects of recycled aggregates



11

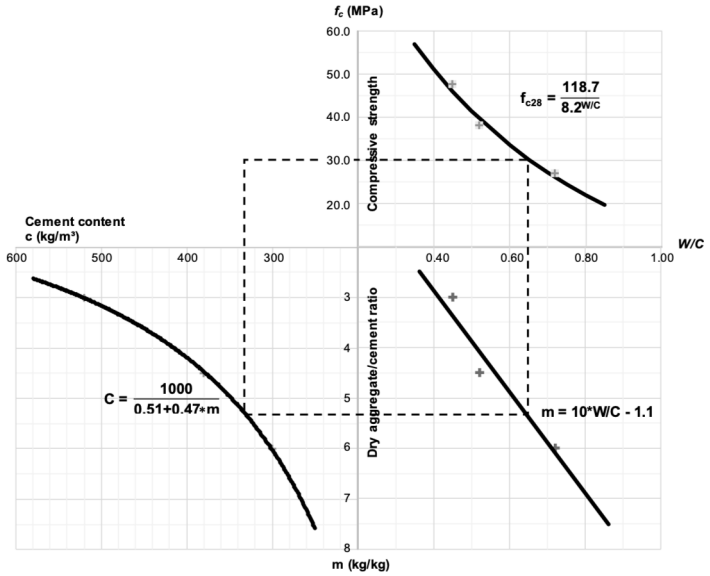
Building the Mix Design Nomogram for each concrete family

just an example !

12

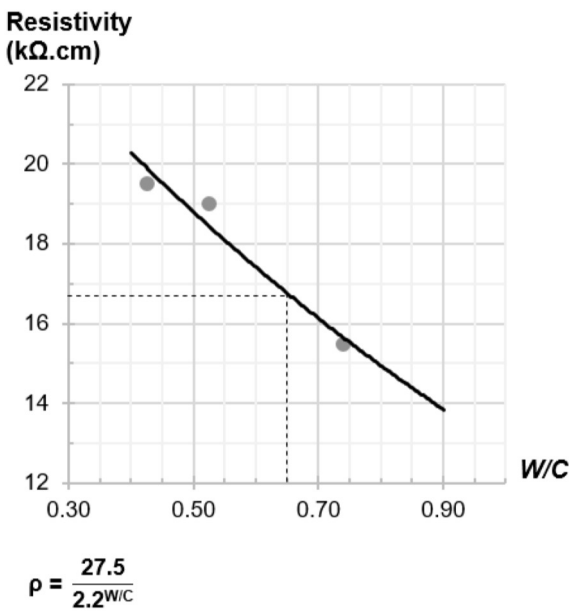
12

Fig. 1. Typical concrete mix design diagram as an example (MDN for concrete family 50-50% CRCA



13

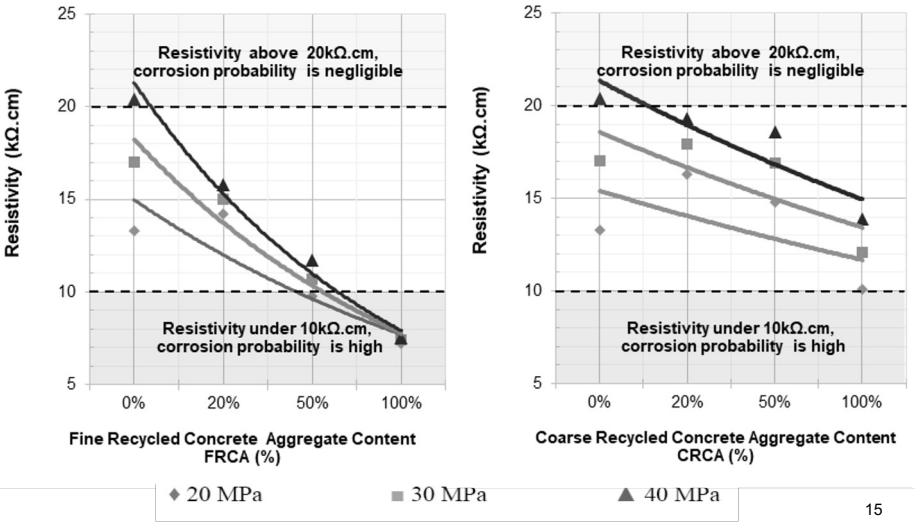
Fig. 2. Nomogram of resistivity for the 50%-50% Coarse Recycled Concrete Aggregate (CRCA) family. Example for concrete 30 MPa.



14

Resistivity

Fig. 3 Coarse Recycled Concrete Aggregate (CRCA) family.



15

15

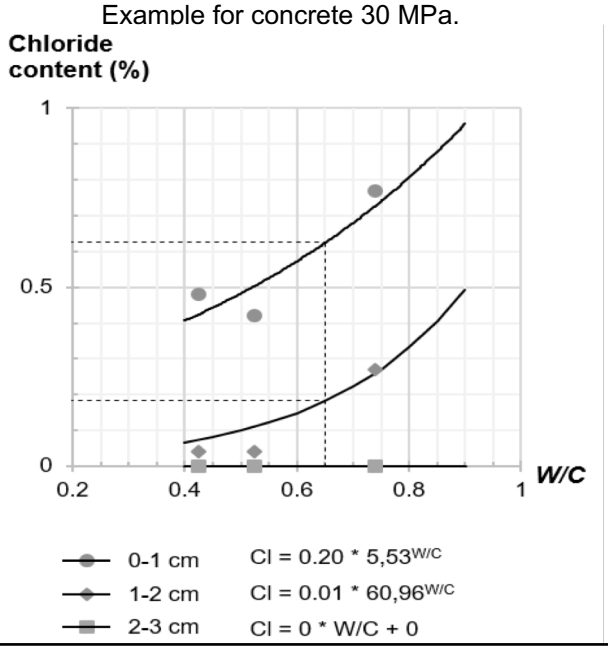
DISCUSSION

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

16

16

Fig. 4. Nomogram of chloride content at depth 0 to 3cm for the 50%-50% Coarse Recycled Concrete Aggregate (CRCA) family.
Example for concrete 30 MPa.

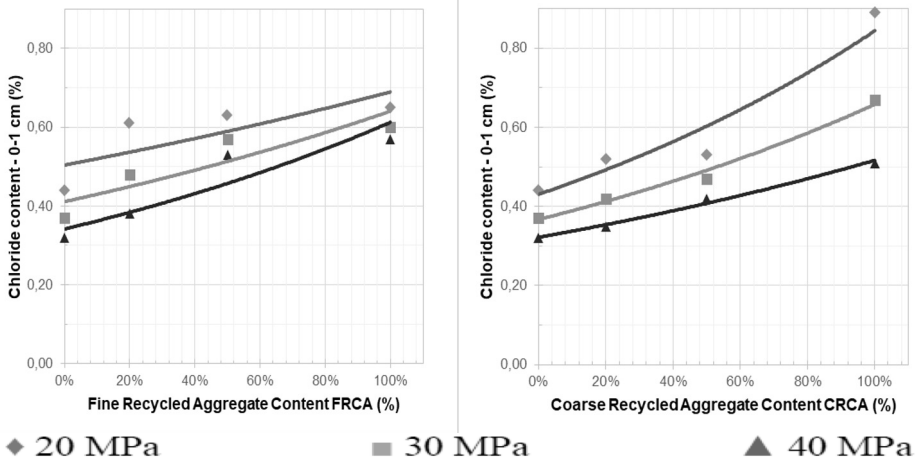


17

17

Chloride profile

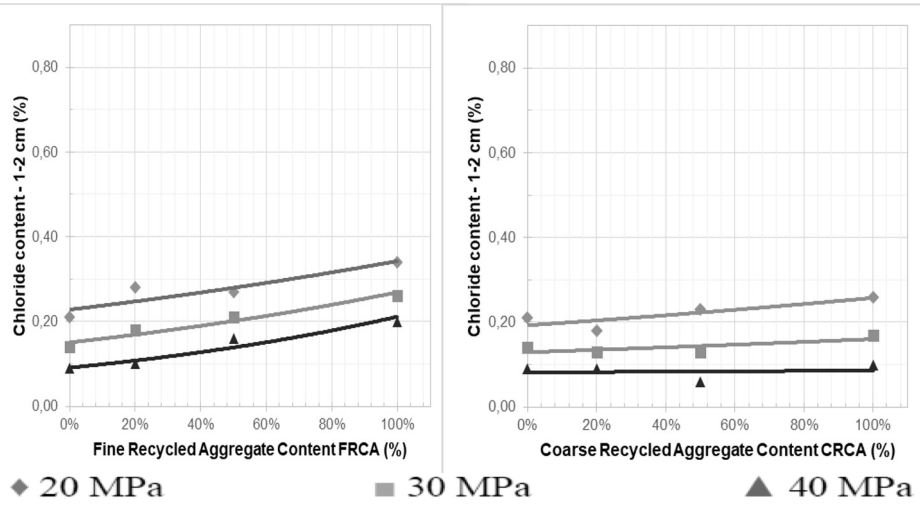
Fig. 5. Evolution of Chloride Content at a depth of 0 to 1 cm, with the amount of CRCA and FRCA to achieve 20, 30, and 40 MPa at 28 days old.



18

Chloride profile

Fig. 6. Evolution of Chloride Content at a depth of 1 to 2 cm, with the amount of FRCA and CRCA to achieve 20, 30, and 40 MPa at 28 days old.



19

DISCUSSION

- Comparing the limits given by international standards, with the values calculated in the mix design diagrams, none of the tested concretes meet the recommended conditions in the section nearest the surface, i.e. the range from 0 to 1 cm. At greater depths, in the 1 to 2 cm and 2 to 3 cm sections, the penetration of chlorides falls below recommended limits, meeting the requirements of all standards.

20

20

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.
- Results obtained in this research point towards an effective possibility of using fine recycled aggregates in the production of concrete.
  (As long as the maximum limit of 50% replacement is observed)

21

21

CONCLUSIONS

- The results obtained from this study show that, from the point of view of resistivity and chloride penetration, concretes made with recycled aggregates are viable in terms of durability and reinforcement protection.

22

22

ACKNOWLEDGEMENTS

☐ The authors would like to thank:

- Brazilian Concrete Institute – IBRACON
- Nove de Julho University – UNINOVE,

for making this research feasible.

Also congratulations to Prof. Raveindra Gettu and Kodur……. For this Honor Congress

23