

# ASSESSMENT OF THE USE OF INDUSTRIAL AND CONSTRUCTION BYPRODUCTS IN FULL-DEPTH RECLAMATION (FDR)

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## 1. INTRODUCTION

### Circular Economy

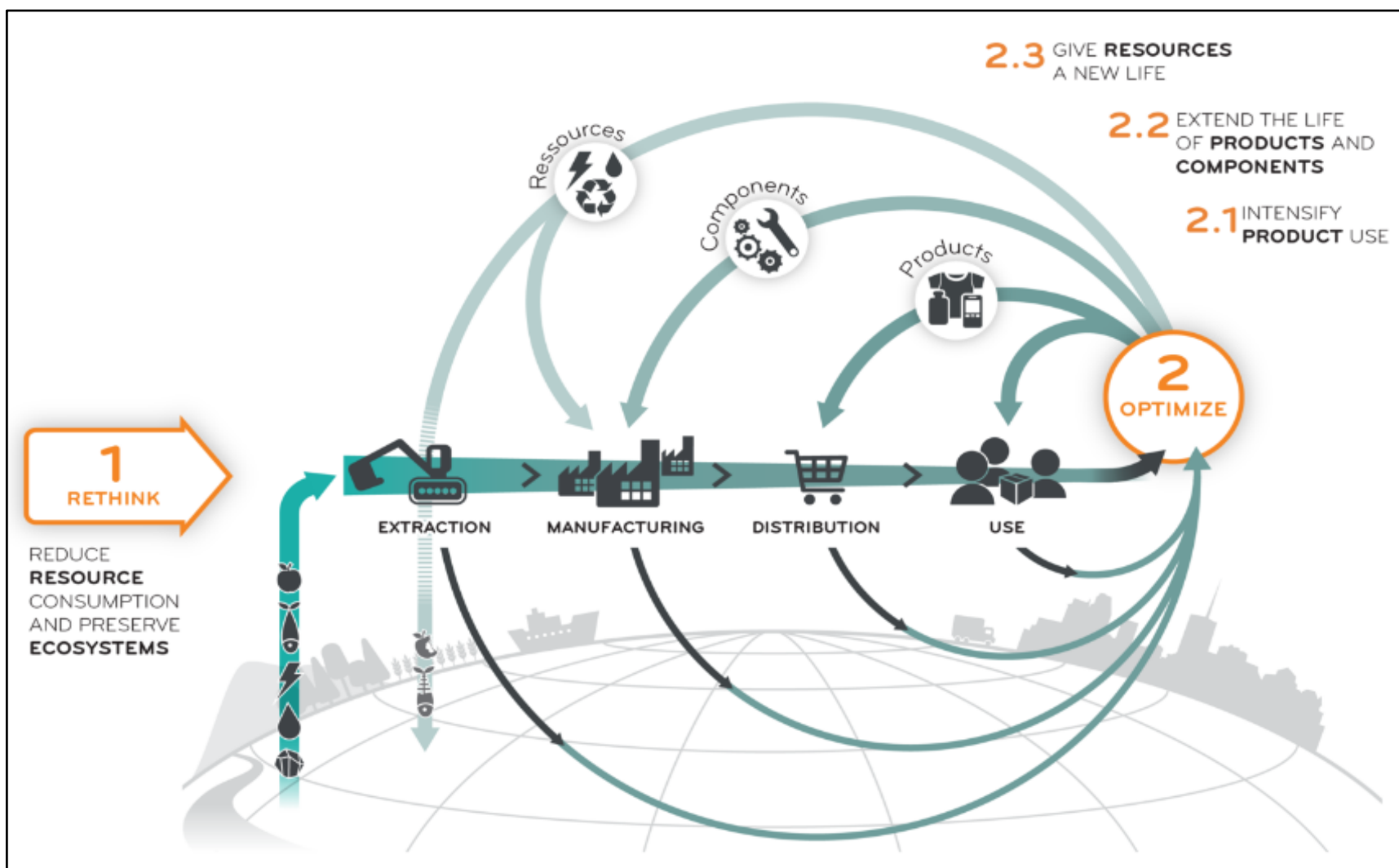


Figure 1. Circular economy key mechanisms [1]

The circularity index is :

-  3.5% in Quebec [2];
  -  6% in Canada [3]
  -  8.6% Worldwide [4] ;
  -  24.5% in the Netherlands [5];
- There is a **challenge** and **opportunity** to improve this indicator in Quebec.

### Full-Depth Reclamation (FDR)

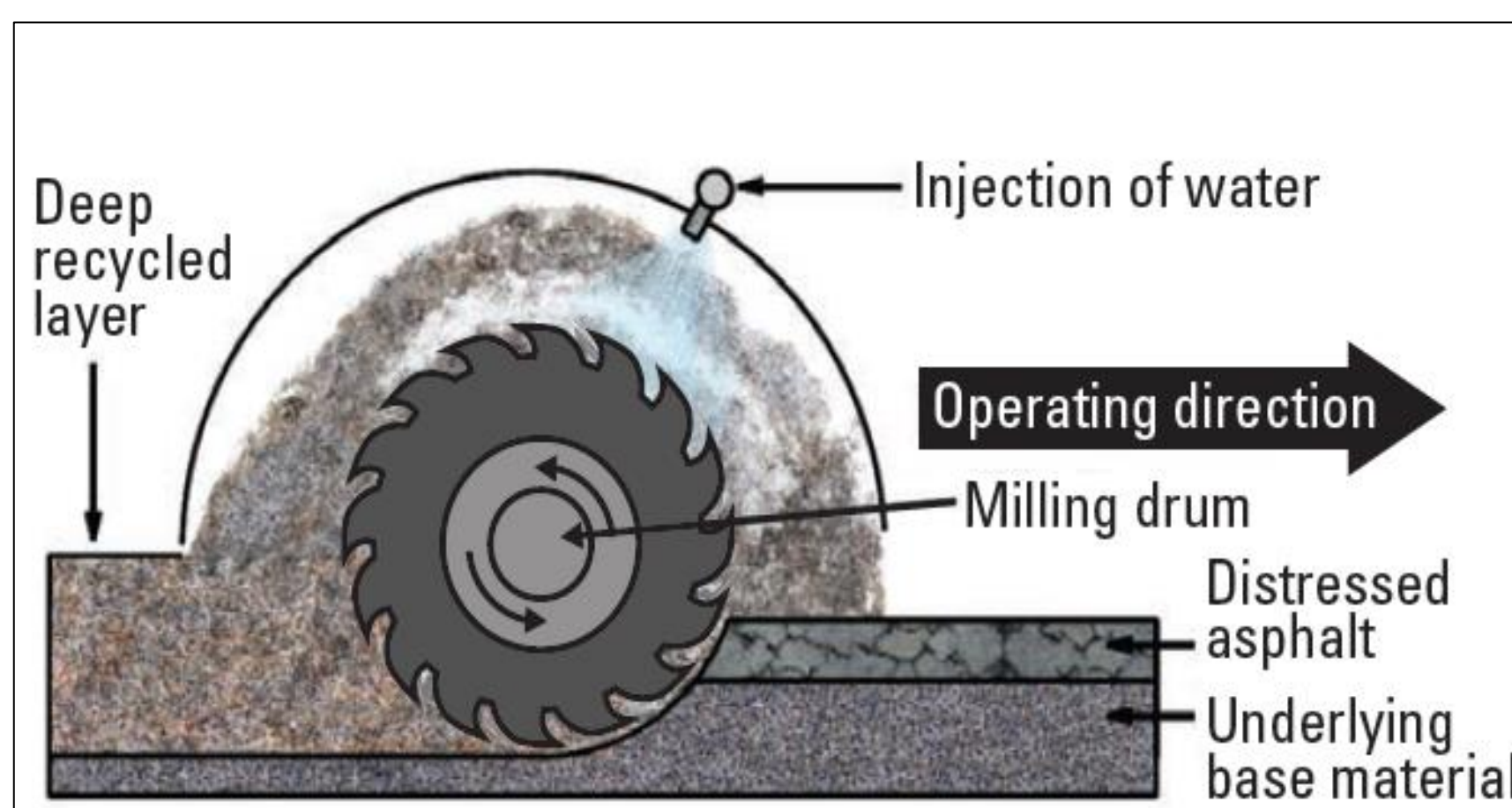






Figure 2. FDR crushing, pulverizing, and blending [7]

-  FDR is a pavement **rehabilitation technique**.  
When compared to a new HMA, the use of FDR has less [6]:
-  55.3% global warming potential;
-  49% demands of fossil fuel;
-  48.8% of total primary energy.

### Freeze-thaw cycle (FTC)

A FTC happens when air temperature decreases at the freeze water temperature, then rises enough for it to thaw again.



Figure 3. FTC effect on aggregates [8]

- 1 – Water accumulate in porous;
- 2 – Water freeze and expands, forcing cracks;
- 3 – Ice thaws, and water go;
- 4 – Repeated expansion and contraction cause further cracks until the aggregate split.

## 2. OBJECTIVES

Investigate the use of **virgin aggregate (VA)** **reclaimed asphalt pavement (RAP)**, **reclaimed concrete (RC)** and **steel slag (SS)** in mechanical stabilization of **full-depth reclamation (FDR)** under normal conditions (soaked and unsoaked) and soaked FTC.

## 3. EXPERIMENTAL PROGRAM

### Mix composition

- 60% VA \ 40% RAP: **VAIRAP** (Reference mix);
- 50% VA \ 35% RAP \ 15% SS: **VAIRAP\SS**;
- 45% VA \ 30% RAP \ 25% RC: **VAIRAP\RC**.

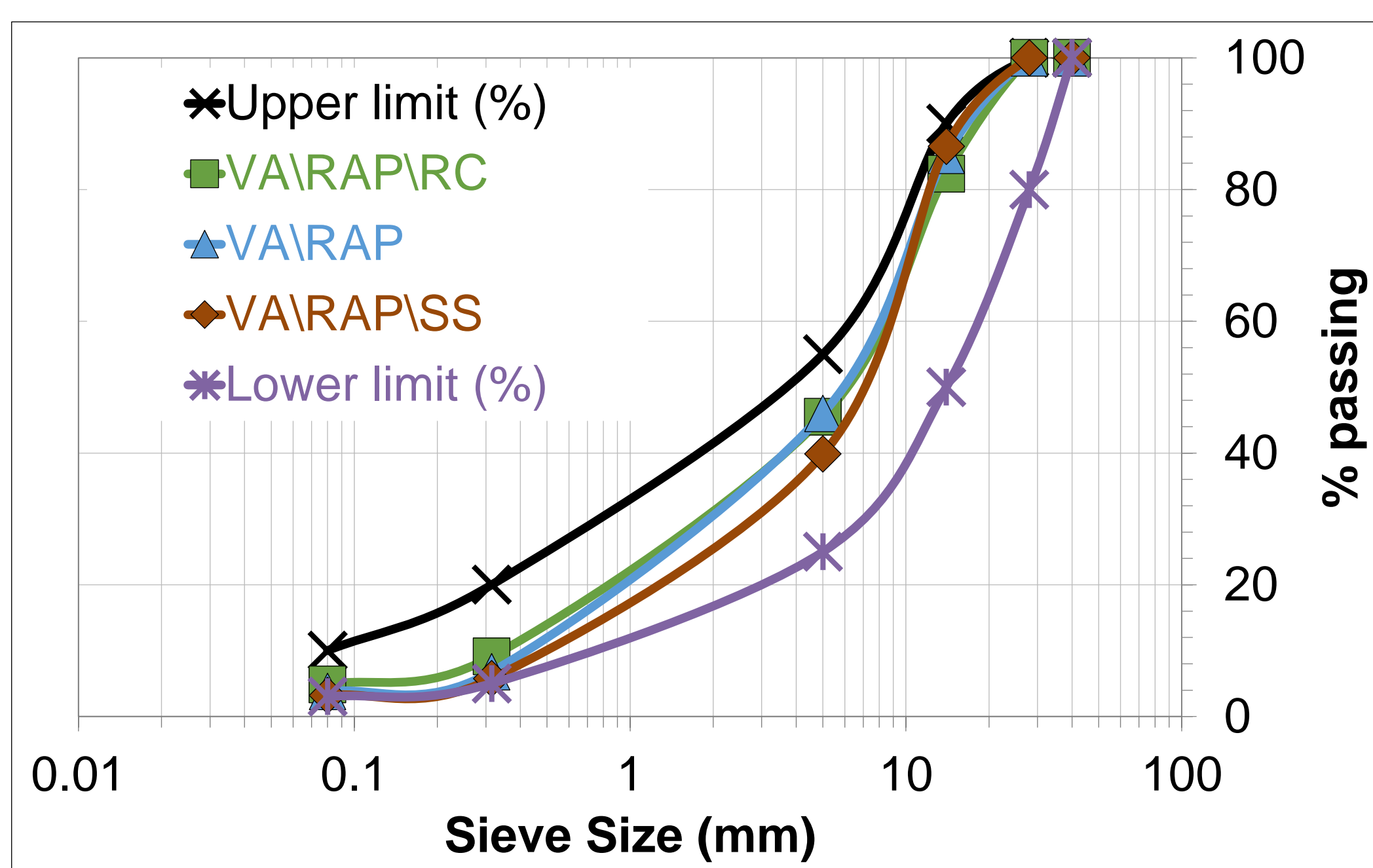


Figure 4. Granulometric distribution

### Testing

- Modified Proctor Compaction Test (ASTM D1557 – 12);
- Freezing and Thawing Compacted Samples (ASTM D560/D560M – 16);
- California Bearing Ratio (CBR) (ASTM D1883 – 21).

### Material granulometry

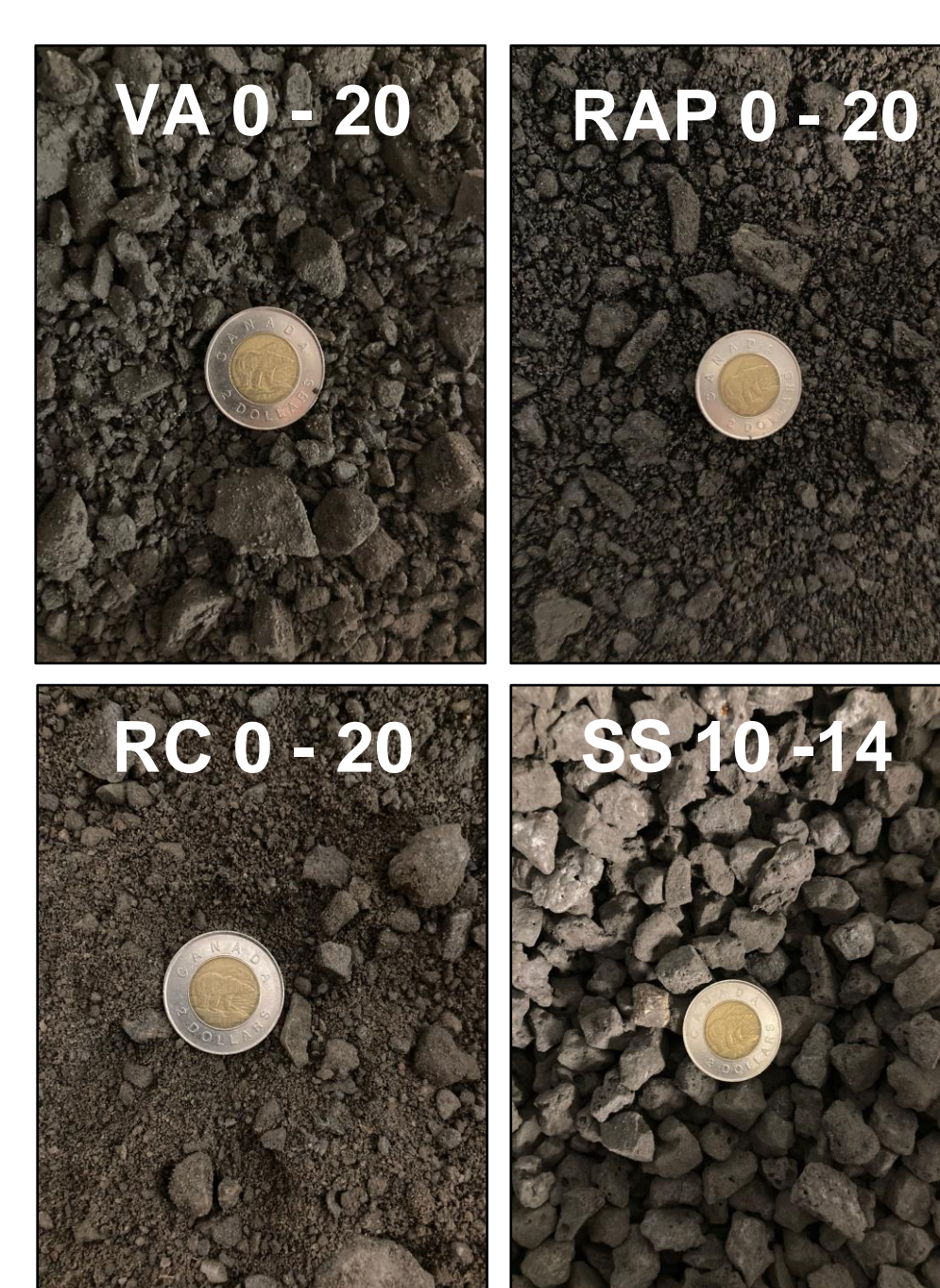


Figure 5. Materials



Figure 6. CBR Test

## REFERENCES

- [1] Institute EDDEC. (2018). Available at: <https://rrecq.ca/en/the-circular-economy/the-circular-economy-in-short/>. Accessed in: 30<sup>th</sup> August 2023
- [2] Recyo-Québec. (2022). Rapport sur l'indice de circularité de l'économie. Accessed in: 30<sup>th</sup> August 2023
- [3] Normandin, D. (2021). A first estimate of the Canadian circularity rate. Available at: <https://www.etsmtl.ca/en/news/2021/turning-point>. Accessed in: 2<sup>nd</sup> November 2023
- [4] Circle Economy. (2022). The circularity gap report. Available at: <https://www.circularity-gap.world/2022>. Accessed in: 30<sup>th</sup> August 2023
- [5] Circle Economy. (2020). The circularity gap report. The Netherlands. Available at: <https://www.circularity-gap.world/Netherlands>. Accessed in: 17<sup>th</sup> October 2023.
- [6] He, S., Salem, O., & Salman, B. (2021). Decision Support Framework for Project-Level Pavement Maintenance and Rehabilitation through Integrating Life Cycle Cost Analysis and Life Cycle Assessment. Journal of Transportation Engineering, Part B: Pavements, 147(1), 04020083. <https://doi.org/10.1061/jpeodx.0000239>
- [7] PCA. (2017). Guide to Full-Depth Reclamation (FDR) with Cement.
- [8] Brahney, Kristina. (2021). What is the freeze-thaw cycle & how does it affect my parking lot?. Accessed in: 10<sup>th</sup> April 2024. Available at: <https://www.fixasphalt.com/blog/what-is-the-freeze-thaw-cycle-how-does-it-affect-my-parking-lot>

## 4. EXPERIMENTAL RESULTS

### Proctor Test Results

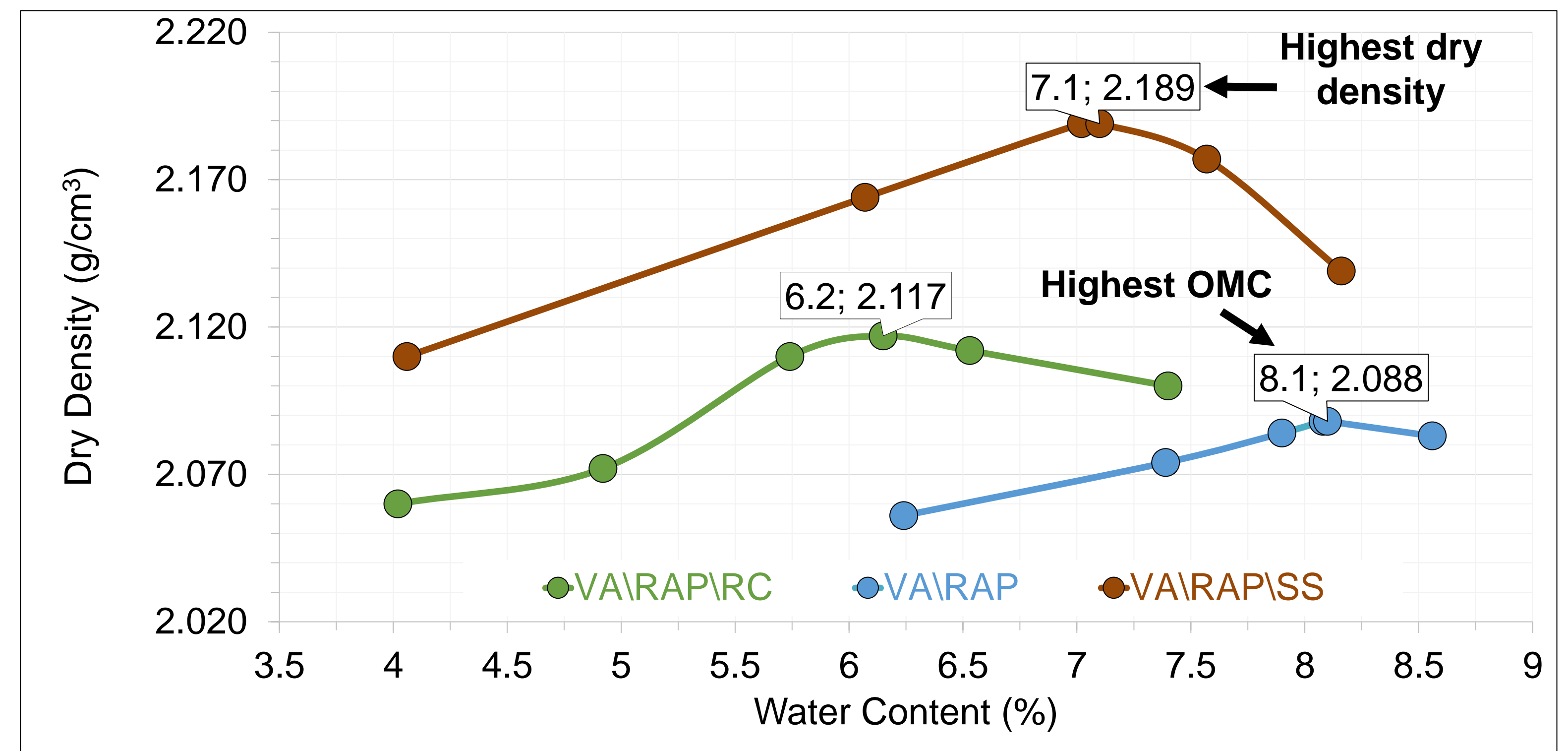


Figure 7. Compaction curves

- The **highest density** of the **VAIRAP\SS** mix might be related to the **highest SS density**;
- The **increase** in the **RAP** led to the **highest percentage** of optimum moisture content (OMC).

### CBR Test Results

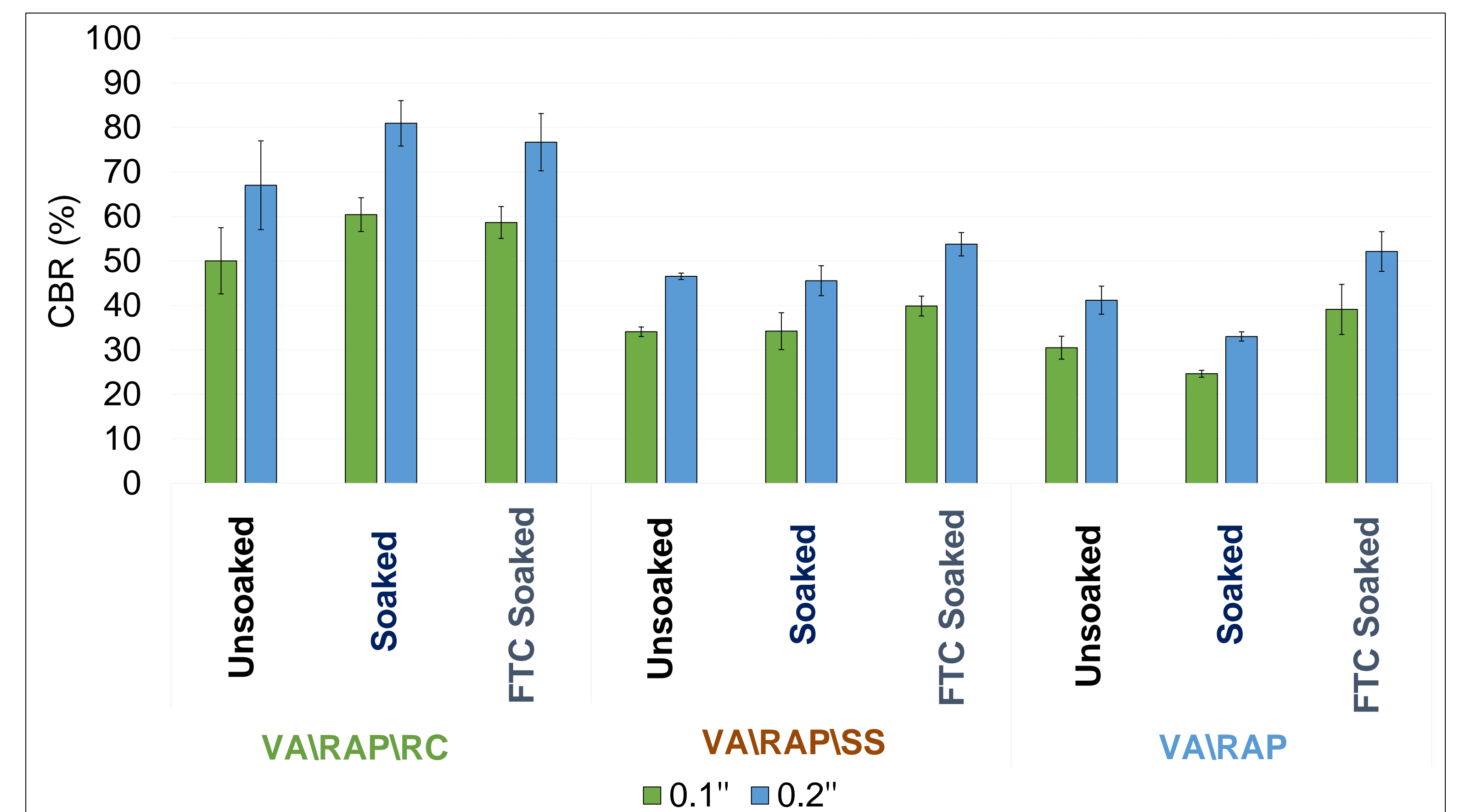


Figure 8. CBR Results under different conditions and penetration rates

- There was an **increase** in CBR results of **64%**, **145%** and **50%** in the **unsoaked**, **soaked** and **FTC soaked** condition, respectively, from the mix **VAIRAP (Ref)** to the mix **VAIRAP\RC**. Probably associate a **cementitious process**;
- From **VAIRAP (Ref)** to **VAIRAP\SS** this **increase** was **12%** and **39%** in the unsoaked and soaked, respectively. Presenting a **improvement** in CBR results due to de use of **SS**;
- From **unsoaked** to **soaked** and **FTC soaked** condition there was an average **increase** of **21%** and **16%**, respectively, in the **VAIRAP\RC** mix for both penetration rates, maybe associated with a **cementitious process** ;
- In the **VAIRAP\SS**, from **unsoaked** to **soaked** condition the results were the same in **0.1"** penetration rate. On the other hand, a **decrease** of **2.1%** in **0.2"** when compared both conditions. On the other hand, there was average **increase** of **16.2%** from the **unsoaked** to **FTC soaked** condition in both penetration rate;
- There was a **decrease** of **19%** in the results from **unsoaked** to **soaked** conditions in **VAIRAP** in both penetration rates. On the other hand, an average **increase** of **27.4%** from the **unsoaked** to **FTC soaked**. These results demands more investigation.

## 5. CONCLUSIONS

- The mixtures **VAIRAP\RC** and **VAIRAP\SS** have presented **better CBR results** than **VAIRAP (Reference mix)**;
- The **best performance** of all mixes tested is associated with **VAIRAP\RC** in **soaked** condition;
- The **CBR results** of the mix **VAIRAP\SS** was **increased** from the **unsoaked** to **soaked** **FTC** conditions;
- In **VAIRAP (Ref)** there was **increase** in the CBR results after **soaked** **FTC** that demands more investigation.