Part A: Recycled concrete aggregate in road construction and recommendation for policy development

1. Introduction:

The construction and demolition sector is one of the biggest resource-consumers and waste-producers in our society, using up to 40% of the total raw materials extracted globally and generating about 35% of the world's waste.

Reduce, reuse and recycle approaches have become a priority option in modern waste management strategies. For example, the recycling rate of C&D waste was ranged from 10 to 90% in the EU in 2010, and the EU has set an average recycling rate target of 70% by 2020. Some of the EU countries such as Belgium, the Netherlands, Switzerland and Austria have already reached the target at 2013. The Netherlands reached 97% recycled rate of CDW at 2018. Recycling rate of C&D waste in Canada reached just 16%.

Aggregates (sand and gravel) are finite, non-renewable resources that are essential in the construction of infrastructure, building, etc, as well as for more specialized industrial uses such as sewage filtration, agriculture, erosion prevention, etc.

Manitoba is producing approximately 12 million tons of aggregates per year. However, by 2030 province of Manitoba will shortly, experience aggregate shortages of as local reserves are depleted.

Manitoba generates a significant amount of C&D waste and most of which are disposed of at landfills. This has created tremendous environmental problems.

Existing world experience showed that the application of construction waste recycling in pavement engineering was considered to be an energy-saving and environmentally-friendly technology, which was able to effectively reduce the exploitation of natural aggregates and solve the problem of disposal of construction waste.

Technology is currently under development to utilize recycled aggregate, obtained by crushing waste concrete, as a high-value-add material with applications such as aggregate for road construction and new concrete production.

2. Pressure Points

(a) Manitoba has very low waste diversion rate (~13%), with a range of recycling per capita between 0.025 to 0.11 metric tonnes per person annually
(b) Manitoba's greenhouse gas emissions: ~21 megatonnes. **Transportation account for 39%**, agriculture accounts for 31%, residential commercial fuel use 18%, landfills 5%, industrial processes 5%
(c) Manitoba will has deficit of local natural aggregate beyond 2030
(d) Manitoba has insufficient governmental regulations and lack of coordination in recycled materials utilization and C&D waste transport.
(e) Local industry such as construction and composites mostly import raw materials
(f) Majority of the materials collected from recycling programs are not processed locally in Manitoba, but are treated as a commodity that is exported to other provinces, the United States or China
(g) In 2018, China banned the import of 24 varieties of solid waste
(h) In 2018 Manitoba implemented a carbon tax that promotes and rewards efficient use of resources.

3. Recycled Aggregates

Recycled concrete and asphalt present an additional source of aggregate for the province of Manitoba. Asphalt and concrete waste comes from the demolition of roads, sidewalks, bridges and buildings. Other materials that can be incorporated into aggregate materials include crushed glass, asphalt shingles, brick, plastic, fly ash, and blast furnace slag.
The composition of the recycled aggregates depends on the type of original waste, the recycling plant production process and the size fraction obtained through the crushing process, and can differ depending on these three factors.

4. Recycled concrete aggregate

Recycling of C&D waste to produce recycled aggregates can be considered as a valuable option, not only for saving primary resources but also for minimizing landfilling impacts. Many studies have demonstrated that recycled concrete aggregates can be used as construction materials.

The most common recycling practice for CDW is the production of recycled concrete aggregates (RCA) that can replace natural aggregates (NA) in various applications.

The lack of RCA quality standards has led most of the countries to fulfil the requirements by investing in more low-grade applications; for instance, producing RCA for road base and filling materials in road construction.

A potential high-quality alternative to downcycling (low value application of recycled concrete aggregate is the use of RCA to replace natural aggregate in concrete.

The high-quality use of RCA in concrete is cited by various studies as an important contribution toward the closure of construction materials cycles, as it decreases the amount of residual CDW to be managed, increases the economic value of the recycled material and reduces the quantity of natural aggregate used.

4.1 Recycled concrete aggregate: quality concern

The quality of recycled concrete depends on type of structures, demolished method, the quality of original concrete and recycled technology that was used and these are vary from site to site and structure to structure. Therefore, this brings a wide variation in the quality of recycled aggregate.

The contents of C&DW must be properly analysed before the delivery to the recycling facility so that it is possible to find the most appropriate recycling process to enhance the output's quality. This will reduce processing time, produce higher quality RCA, increase the work rate and help to avoid excessive costs incurred by unnecessary recycling stages.

Factors such as technical, financial and environmental issues (i.e. plant capacity, transportation cost, amount of C&DW, hauling distances, scale of economy, price of natural aggregates, etc.) effects on the choice of the type of recycling plant.

The amount and the quality of adhered cement paste on the aggregate surface depend mainly on the grinding process, aggregate size, and strength of original concrete. The quantity of adhered paste increases with the decrease in size of aggregate. The recycled aggregates obtained from the concrete having lower strength have the higher quantity of adhered cement paste for the given size of aggregate.

Combinations of recycling process can produce a relatively of better quality of RCA, with least contaminants, without spending too much energy. The number of crushing stages undoubtedly reduces the adhered mortar content and irregularity of the aggregates and thus produces better quality of recycled coarse aggregate.

4.2 Greenhouse gas (GHG) life cycle approach

Sustainable resource management should evaluate the climate impacts of the decisions made.
User (municipalities etc) should assess the different options for aggregate production (extraction vs. recycle, etc.),

Total greenhouse gas emissions are calculated by summing the processing emissions and transportation emissions.

For the various source materials the processing emissions of sand and gravel has the lowest emissions, followed by recycled concrete. Recycled asphalt is more intensive, with quarried rock being the most emissions intensive aggregate to process due to the blasting process required.

Transportation emissions of the aggregate material depends of fuel types/fuel efficiency, travel distance and truck load capacity. Assuming the same trucks are used, transportation emissions of the aggregate material are generally the going to vary only by the distance travelled.

4.3 Infrastructure impact

The aggregate hauling operation would result in increased traffic volumes on the roads. Pavement structures are designed for specific traffic volumes and an increase in the traffic volume or truck size would result in the consumption of the pavement service life. This may result in premature failure of the pavement structure and required earlier rehabilitation interventions or reconstruction.

5. Performance based characterization of recycled concrete aggregate based material: Uof M research project (2016)

M. Ahmeduzzaman (2016) investigated the feasibility of using recycled concrete aggregate as base course material and effect of variation of fines on resilient modulus, permanent deformation and permeability tests.

The resilient modulus performance of recycled concrete aggregate has been found to be comparable to the performance of virgin unbound granular materials. The susceptibility of change in resilient modulus with increasing fines content has been found to be negligible within a range of 0-10% fines.

6. Recommendations:

Recommendations to improve the C&D waste management and recycling of aggregate in the WMR are included below:

- Establishment the Construction Waste Recycling Promotion Act /Recycled Aggregate Quality Standard for promoting the recycling of waste materials from construction, and development recommendation for more diversified and broadened facilitation of waste concrete. Instead of having a method where there is an option of using recycled materials in construction, there should be a mandated policy.
- For recycling of C&D waste, it is necessary to strengthen the policy aspects, particularly on the procurement policy of recycled materials to ensure sustainable resource management.
- Create accountability for waste diversion: Make specific actors (e.g producers, builders, facilities) more accountable for reducing and diverting CRD waste
- Align financial incentives : Use fees and charges to encourage waste reduction and diversion, such as through differential tipping fees or virgin materials levies
- Limit materials disposed, through waste disposal bans or transportation restrictions
- Improve CRD processes: Increase the resource efficiency of CRD activities, such as through building certification and deconstruction standards
- Increase the supply and demand of diverted materials, such as through public procurement and investment
- Increase the capacity and knowledge of the sector, such as through education programs and data collection
- For building owners and contractors, Province/Municipality should developed a wide range of resources including sample specifications for construction and demolition recycling
- Review and revise specifications;

- Establish a technical group, including representatives from local government infrastructure personnel, producers, engineers, manufacturers and agencies and to establish workable processes, guidelines, and specifications for local and provincial governments to improve the options for reusing recycled aggregates;
- Tender policies and construction techniques that encourage recycling;
- Co-purchasing recycled material for road construction by Winnipeg Metro Municipalities. WMR member municipalities could collaborate to co-purchased recycled material for road construction.
- A life-cycle assessment is required in future studies to identify all feasible utilization potentials for RCA and assess the most beneficial utilization options based on different circumstances and scenarios
- There is need for a qualitative survey on the stakeholders and professional's perspectives on the challenges of utilization of RCA and subsequent studies to recommend possible solutions to the challenges.

A cooperative approach between municipalities, producers and agencies to establish state of the art recycling processing and specifications in the WMR will enable greater efficiency of the resource and reduce the requirement of new material.