THE EFFECTIVENESS OF USING RECYCLED CONCRETE IN CONSTRUCTION PROJECTS - MECHANICAL PROPERTIES INVESTIGATION

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Abstract- Green concrete has always been a revolutionary subject in the concrete industry history. In general, concrete is a friendly environmental material because of its narrow overall impact (per ton) on the environment. This paper introduces the “green” concrete as the using alternative and/or recycled waste materials (such as fly ash and recycled concrete aggregates) in the concrete production process in order to reduce environmental impact, energy spending, and natural resource use. This paper also covers the main aspects of using and choosing adequate materials for green concrete.

Index Terms- Concrete Properties, Construction Industry “Green” Concrete, Recycled Aggregate, SCMs, Wastes,

I. INTRODUCTION

The concept of Green concrete is to use eco-friendly materials in concrete production in order to maintain the system’ sustainability. Green concrete is distinguished by its availability and its cheap production cost, due to waste products used as partial substitutes for cement, dispense with waste disposal charges, lower energy consumption in production processes, and great durability. Using supplementary cementitious materials (SCMs), recycled aggregates and other industrial wastes could reduce the environmental impacts of concrete production [12].What makes Waste useful is its ability to produce other products or to be used as admixtures for cement, so in one way or another it contributes in less using of natural resources in a more efficiently way as well as protecting the environment from waste deposits. In addition, several inorganic residual materials can be utilized as green aggregates in concrete like concrete, stone dust, crushed and marble waste. Furthermore, the process of replacing cement with significant amounts of fly ash and micro silica in order to get improved green cements and binding materials, contributes in increasing the use of alternative fuels and raw materials with lower energy consumption. Many extensive researches have been conducted on the effectiveness of using industrial micro-fillers and by-products in concrete mixture. Using waste materials and adding (SCMs) or (Aas) improves the sustainability of concrete but it also could impact the concrete properties, such as workability, compressive strength, which are significant for concrete applications. On the other hand, unless concrete has been proved to be durable, concrete production using waste materials is not necessarily considered sustainable [12].This paper reviews several aspects related to the use of suitable recycled materials as substitutes for concrete aggregate, in order to make it applicable as a “Green Building” material. Also, the use of suitable substitutes for Portland cement, especially by-products of industrial processes, like fly ash, silica fume and ground granulated blast furnace slag [2].

II. GREEN CONCRETE PROPERTIES

The use of alternative aggregate (AAs) in concrete and replacement of conventional Portland cement with supplementary cementitious materials (SCMs) have been studied worldwide, and their impact on concrete properties. Most common (SCMs) include, but not limited to, furnace slag, fly ash, and silica fume[4,5,6].Other researchers have inspected some more alternative aggregate (AA)s like building rubbles[7],tire rubber[8],RCA[6], oyster shell[9],waste glass[10],and waste expended polystyrene reground material[11]. Most studies showed that percentage of replacement and type of raw material may enhance concrete properties or could negatively affect them, compared to that of conventional concrete. For example, [4] found that a higher percentage of fly ash that is used in the mix might reduce the compressive strength of concrete. [6] Concluded that 30% of RCA replacement might decrease concrete strengths [1].

III. MATERIAL/PRODUCT SELECTION CRITERIA

The main criteria influence selecting a certain material/product:

Resource Efficiency. Resource efficiency criterion basically involves the resource properties like recycled content whether it is renewable or natural, locally available or not, its ability of being salvaged/refurbished or remanufactured, reusable or recyclable, efficiency of resource used in the manufacturing process and durability [2].

Energy Efficiency. Energy efficiency refers to the energy used in concrete production. It is preferred to use the materials that consume the minimum energy amount during the concrete production process [2].
**Indoor Air Quality (IAQ).** Indoor air quality (IAQ) is carried by using materials of specific properties, such as: minimal chemical emission, low or non-toxic, moisture resistant [2]. Water Conservation. In order to reduce water consumption, there are certain selective materials are used as construction water at the time of construction, which help conserve water in landscaped areas or in building materials [2]. Affordability. Affordability is studied when the costs of the used building products/materials are feasible compared to other conventional materials, and should fall within the limited project’s budget [2].

**IV. RECYCLED CONCRETE AND MASONRY AS AGGREGATES**

Coarse recycled concrete and masonry (RCM) is mainly consists of graded aggregates produced from sorted-clean concrete and masonry waste especially that is manufactured for road subbase applications. That products being used may include little quantities of gravel, crushed rocks, bricks or other forms of stony and blended materials. However, crushed concrete fines can also refer to as recycled Fine aggregates. The grading, the shape of fines, also the excessive amounts of it may influence the bleeding rate workability, concrete ability to plastic cracking. Natural sand can be replaced by manufactured sand in a large amounts with almost not mentioned effect on based cement products [2].

Generally, Concrete is considered a distinctive building material because it can simply adjoin many recycled materials into the mix such as fly ash, which is a by-product industrial waste formed from the manufacturing of coal. One of the advantages of recycled materials is that it grants cost-savings for the customer. In addition, it is interesting to know that Concrete can also be recycled in another concrete mix, as a high quality aggregate [3].

Suitability of Green concrete in Structures

Some features may enhance suitability of green concrete such as [2]:

- Reducing dead weight of a structure and reducing crane load; by allow handling, lifting flexibility with lighter weight
- Better sound insulation and fire resistance than traditional granite rock
- Improved damping resistance of the building
- Speed of construction and short overall construction period.
- Reduction of CO2-emissions resulted from concrete industry by 30%.
- Increased use of waste products by 20% in the concrete industry
- Sustainable development and less environmental pollution
- Less maintenance and repairs needed for green concrete
- Good thermal resistance and fire resistance
- Better Compressive strength behavior than that of conventional concrete
- Almost an equal Flexural strength of green concrete to that of conventional concrete

**V. CASE STUDY**

Green Concrete is being used widely in the construction projects across Greater Vancouver, through rapid transit stations to residential developments. The following context focuses on the case studies objectives and results. The findings provide a review of the benefits, potential solutions to challenges and costs [14].

**VI. EXAMPLE PROJECTS**

- **York University Computer Science Building**
  The York University Computer Science Building was selected, in the Green Building Challenge 2000 held in Netherlands to represent Canada and is considered the first cold climate "green" building in the country. The building materials met the specifications of Green concrete and were precisely selected to achieve reduced construction waste and low embodied energy, for the majority of the building's concrete
elements. The concrete included 50% cement replacement by fly ash [14]. Quality of Fly Ash. Due to the higher calcium content in Type (C) fly ash together with the high Tri Calcium Silicate (C3A) content in the cement used, the resulting primary cementing action leads to higher early strength concrete.

Strength. The Green concrete mixes developed an impressive characteristics associated to the early strength. In many mixes, a one-day strength of 16 MPa was obtained. Specifically, the 28-day strength of 30 MPa was achieved in 7 days. Workability. The concrete placers found that the Green concrete mix is more workable and has better compaction than conventional concrete mixes, in spite of the lower water content in the wet mix. Setting Time. The Green concrete mix used in York University on average set faster than a typical all cement mix. The concrete was finished and cured successfully at -10°C under typical winter construction conditions.

Finishing. Due to certain adjustments that were involved in finishing technique such as, using a high pressure power washer to mist the air and keep the sheen on the surface, a delay in schedule was avoided. Appearance. A lighter and warmer coloured architectural concrete finish was obtained with fewer bug holes and honeycombing, resulting in a smoother and denser surface concrete.

**The Nicola Valley Institute of Technology (NVIT)/University Of The Cariboo**

The Nicola Valley Institute of Technology (NVIT)/University of the Cariboo (UCC) is the first post-secondary facility in Canada shared by both non-native and First Nations institutes. For all concrete components of the building, poured-in-place concrete with high volumes of fly ash was used [14]. Quality of Fly Ash. In order to provide sulfate resistance, Type (F) fly ash was used. Utilizing Fly ash is considered an advantage in the Thompson Nicola Region, where sulfate ions exist in the ground water and soil. Exactly Design Mix. The water/cement ratio was accurately designed to be the same as in common Portland cement mix, which is usually between 0.44 and 0.55, even though the design mix contained 50% fly ash cement replacement. The material-testing engineers designed concrete mixes to be adequate for their compressive strength requirements and intended exposure classification.

Curing. During construction process, (NVIT) has practised below-freezing temperatures. Temporary heating and hoarding were required to help incurring thinner elements resulting in an increase in fuel and labour costs. Obviously, large mass elements such as footings were not considered difficult, compared to thinner elements and pouring flatwork that are subjected to chilling as they are exposed at top and/or bottom during curing.

Finishing. Due to less bleed water rising to the surface, finishing becomes a challenge for the finishers. In addition, slow setting times prevented finishers from quickly accessing to the slab, leading to an increase in labour cost.

**The BCGas Coastal Facilities Operations Centre**

This massive reinforced concrete structure was established to achieve major environmental goals, including the use of recycled materials and green concrete. The BC Gas building represented the successful implementation of green concrete [14]. Design Mix. The concrete mix was designed for a 30MPa a strength, aiming to achieve a total reduction of 40% cement through the fly ash replacement. This amount was well above industry norms but within the reach of a market-driven type project, although arbitrary.

Finishing. Primarily, concrete was poured in the early morning as same as for conventional concrete. Generally, finishers are done by the end of the day when concrete sets up early, but when using fly ash concrete mix, the finishers stays on site until 2:00 a.m. the next morning. Later, it is poured in the end of the day and the finishing is being done the next morning. In the case of ambient temperatures fell below 100°C, the contractor prefers to reduce the fly ash percentage in the mix.

Workability. It means that fly ash concrete is found to be more workable than conventional mixes, and it was easier to place and fill forms. Economics. Costs of labour were lower because of the easiness of placing and the workability of the fly ash concrete mix. Furthermore, fly ash costs about half the price of cement and is readily available.

**RESULTS AND DISCUSSION**

Based on the collected data, the circumstances and weather conditions surrounding each of the four projects were differ from each other; the following comparison can be conducted:

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<th>Comparison between the four projects:</th>
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<td>The Liu Centre for the study of Global Issues, University of British Columbia (UBC)</td>
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<td>The Green concrete performance here was beyond expectations of the project team, on the level of strength and the ability of giving a high quality finish without a cost premium, this first time the use of Green Concrete at the first time has set a benchmark, with fully anticipating the bar to be raised by further advancements in the reduction of cement content.</td>
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<tr>
<td>York University Computer Science Building</td>
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<td>The used Green concrete grant a very excellent workability, offered a stronger finished concrete and did not interrupt the project schedule. In another project similar to York University, The contractors have decided to include at least 50% fly ash replacement for the concrete mix.</td>
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DISCUSSION

Since concrete is the most widely used material in construction sector and is considered one of the largest contributors to CO₂ emissions, as shown in Fig. 1, it was necessary to reduce the energy of production and minimize the use of natural resources, also using alternatives like crushed limestone and industrial by-products such as, fly ash and blast furnace slag.

Fig. 1: Average Embodied Energy in Buildings

The following Fig. 2 is a chart that shows the concrete strength in MPA of the conventional concrete.

Fig. 2: Ordinary Concrete and Regeneration Concrete Strength Curve

Table 1.

| The Nicola Valley Institute of Technology/University Of The Cariboo | A 40% fly ash replacement was used for the whole project, resulting in the reduction of approximately 180 tonnes of CO₂ emissions. Concrete was done in spite of the cold weather between late December and February that did not lend itself easily to larger replacement volumes of fly ash without increased costs and finishing delays. |
| The BC Gas Coastal Facilities Operations Centre | The Green concrete experience in this project was very positive. Although the original goal of 40% fly ash was not reached, large masses of cement were avoided while working with the Green concrete mixes. |

Fig. 3 shows strengths of recycled concrete, after adding waste materials such as fly ash and slags. It is obviously that recycled concrete has an improved concrete strength. Using waste/recycled material can reduce cement embodied energy, reduce CO₂ emissions and contribute to efficient utilizing of waste.

CONCLUSIONS

This review paper showed an increasingly general trend and enthusiasm toward using the manufactured and recycled materials/aggregates in the construction process. In general, there are some limitations to the production of recycled materials. This paper focused also on the benefits and barriers of the industry of the recycled materials/aggregates. Using concrete products like green concrete in future will reduce CO₂ emissions into the environment, therefore reducing environmental impact and it is economical to produce. Thus, green concrete is an excellent substitute of cement as it is cheaper, because it uses waste products, saving energy consumption in the production. Above all, green concrete has greater strength and higher durability when compared to conventional concrete.

REFERENCES

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