Sustainable Concrete Mix Design for Interlocking Concrete Block Pavers (ICBP)

H.A.C.K. Hettiarachchi[1] , W. K. Mampearachchi[2]

Abstract

Heavy usage of cement in modern construction industry has led to numerous environmental problems. The cement industry is one of the main industries which release carbon dioxide, a major greenhouse gas. Raw material extraction to manufacture cement is another major environmental impact. Heavy damage to the limestone deposits on earth when mining is causing major environmental pollution. (Mishra & Siddiqui, 2014) Reduction of cement usage in concrete industry is critical for a sustainable future. Particle packing optimization method can be successfully used to reduce the cement content while maintaining the quality of the concrete.

Selecting aggregate proportions to achieve required qualities of concrete is a challenging task. When a unit volume of concrete is considered, this volume consists of aggregates and cement paste. Aggregate form the skeleton of concrete and cement paste will be used fill the voids in between aggregates and coat the aggregate to ensure proper bonding. Packing of aggregate is a main factor for a high quality concrete. Optimization of aggregate is the process of determining the most suitable aggregate particle sizes and distribution to minimize the voids content of an aggregate mix. An optimized aggregate mix will have lesser amount of voids which needs to be filled with cement paste resulting low cement, high quality concrete.

Particle packing optimization is the process of selecting optimum aggregate proportions that result in minimum voids and maximum density thus requirement of cement and water can be minimized. Optimization of aggregates to achieve higher strengths with lower cement content has been studied for various applications over the past decade. Theoretical packing models such as Toufar, De Larrad, CPM, LPDM, power curve, Shilstone chart etc. were analyzed to determine the most suitable packing model. Though those studies were successful for more generalized applications there were limitations when applying the results for specialized applications such as zero slump concrete, pre cast concrete products, roller compacted concrete self-compacting concrete, high performance concrete etc. The main reason for such

limitations in generalized approach is the variation of the required properties of concrete in each application such as low water content requirement in zero slump concrete, roller compacted concrete and pre cast concrete, high water requirements in self-compacting concrete etc. The concept of particle packing is adopted to determine sustainable concrete mix for interlocking concrete block pavers (ICBP).

Typically the aggregates used for the concrete are 12mm coarse aggregates with manufactured sand and natural sand as fine aggregates. Fresh concrete is poured into the mold and both vibration and compaction is applied to cast the block. The mold is removed soon after the block is cast. Hence a low water cement ratio and high green strength needs to prevent edge falling and cracking of freshly cast ICBP. Present industrial practice seems to be far less economical due to the use of high amount of cement, wastage of aggregates, and high energy consumption of machines due to improper mix proportions.

The manufacturers use high amount of cement to achieve higher strengths. There are high variations in strength within the same batch of blocks. The main reasons for such variations is the lack of consistency in mixing, segregation of aggregates when pouring concrete mixture to the molds, lack of proper curing practices, not following a proper water/cement ratio as intuition is used to measure the adequate water content etc. Hence high strength variations within the same batch is visible.

This study proposes improved sustainable mix design using packing density method by optimization of parameters such as water cement ratio, coarse to fine aggregate ratio, quarry dust to natural sand ratio, cement content and compaction effort. The results of the study shows that the cement content can be reduced by 37% by optimizing the aggregate content used in the concrete mix.

Key words: Concrete mix design, Interlocking Concrete paving blocks, Sustainable concrete

---

1. Post Graduate Student, Transportation Engineering Division, Department of Civil Engineering, University of Moratuwa, c4chamod@gmail.com
2. Professor, Department of Civil Engineering, University of Moratuwa wk.mampearachchi@gmail.com 0112650567 (Ext: 2024)