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Research Article

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Investigating The Effect of Aggregate Type on Some Physico Mechanical Properties of Interlock Paving Units

Samah A. Sanad*, M. L. Abd Ellatif, Maged E. El-fakharany

Raw Building Material and Processing Technology Research institute, Housing and building national research center (HBRC), Giza, Egypt.
*Email: samah.a.sanad@gmail.com

Abstract The current paper investigates the effect of change mineralogical and chemical composition of used aggregate on some average values of measured physico-mechanical characterization which control flooring application represented by paving interlock units with hexagonal prism shaped. The study was conducted on different produced paving interlocking unit containing three selected type of aggregate including dolomite, granite and basalt. The obtained result showed a significant effect on the tested physico-mechanical properties of paving interlocking mixes. These findings suggest that aggregate type have significantly affect the performance the durability and the duty conditions for the produced interlocking paving units.

Keywords Aggregate, Interlock, Paving unit, Flooring, Physico-mechanical properties

1. Introduction

One of the important aims for engineers and designers is choosing the right flooring and paving units for their projects. As it has significant effect on the aesthetic and durability of the project image. The construction industry in Egypt is in continues progress as old cities are growing and new ones are established. That increased the demand for building materials with low costs and good performance. There has been a move within the fabricating prepare of building and paving bricks towards more current strategies to overcome the limitations of antiquated brick-making techniques. This trend has driven to the advancement of two fundamental types of bricks: compacted bricks and interlocked bricks [1]. The development of interlocking mortar less brickwork has significantly increased productivity and effectiveness within the field leading to decrease the requirement for specialized building workers. Interlocked bricks are raised in place like regular bricks. The purpose of interlocking bricks is to create a beautiful impression with the continuous structure of masonry walls, while also allowing construction in rural areas without the need for labor training. In order to achieve the necessary strength, interlocking bricks do not require mortar to bind the individual brick products together. Therefore, mortar less masonry walls can save 35% in construction costs or 20 to 40% in labor costs [2]. Most of the blocks are good for the environment as they are made from recycled materials and sun dried, thus eliminating the use of ordinary bricks [3-4]. The traditional brick making process consists of mixing raw materials, shaping bricks, drying and firing until strength is achieved, consuming raw sources, energy and much money [5]. On the other hand, the high demand for fast work, lower energy and costs are among the factors that lead to changes in the masonry process [6], [7]. These changes also improve construction, performance and total cost. For this purpose, many new methods such as adhesive bonding, fiber-polymer, mortared masonry and interlocking mortar less masonry have been developed and used for fast and durable construction; prove that cost of interlocking blocks is less expensive than alternative units [8].

Durable interlocked paving units are very vital for prolong ate service life and so lower the costs for further repair. Due to the interaction of interlocked with external influences; the physical and mechanical properties of the concrete blocks can be threatened [9]. Interlocked paving units with good performance for the low cost housing projects needed a good durable concrete mix. This point will not happen without using locally economic materials and evaluating the components of the concrete mix. Several previous research investigations have yielded informative results about the use of local sources or wastes in the manufacturing of various forms of concrete specially interlocked paving blocks [10-16]. As discussed by [17] economic materials like local aggregate or soil can be added, as the ratio of cement to soil is generally between 1:6 and 1:10, depending on the quality of soil and cement; while for waste rice bran ash (RHA) cement blocks, the volume ratio of cement to rice bran is 1:4. Also, the specific mixture is 1:5:3 of cement: sand: gravel for interlocked concrete. Moreover, if designed correctly, interlocking blocks can offer an effective durable paving bricks, reducing environmental impact. I t should be noticed that paving unit interlock which the main subject of the research considered as a type or subclass of interlock bricks and applicable for paving purposes.

The aim of this study is to evaluate some physico-mechanical properties of concrete interlock paving unit produced from locally waste crushed aggregates of different sources such as granite, basalt and dolomite rocks instead of sparsely present gravel to minimize the used material costs and hence the manufactured concrete paving unit cost. The aim also extends to cover the most suitable duty composition for produced paving interlock unit according to Egyptian requirement.

2. Materials and methods

Materials

The used raw materials in the recent study which represented the main components of the produced interlock mixes involved (three types of coarse aggregate, sand and cement). As the variation of coarse aggregate and follow its effect is the main aim for recent study so, it can be described with some details as following:

The first used coarse aggregate is collected to be represented dolomite of Attaqa located in Suez Governate and characterized by its sedimentary origin due to replacement of limestone by a solution along fault planes, other fractures and/or along bedding planes where the dolomitization process took place during the deformation of the region (post-upper Eocene) [18]. The second used coarse aggregate type is igneous originated from crushed granite of G. Homrit El Gergab (Red Sea area) which belongs to younger granite of the studied area with interval of (575-600 Ma) during the pan African event [19]. The third used coarse aggregate is igneous originated crushed basalt represented Bahnsa area of Minia Governate and extruded geologically within Upper Oligocene age as reported by [20].

The aggregate samples were approximately maximum aggregate size and similar grading as all crushed aggregated passed through the 4-mesh sieve (4.75mm). The passed aggregate mixed with fine sand and ordinary Portland cement to prepare the different interlock paving concrete mixes.

Moreover, the used sand represented fine aggregate in the current study were collected carefully from Kafr Homied quarry about 55 km South Cairo in Giza Governate with a maximum size of 4.75 mm. Portland Cement Type II was used as binder for all interlock mixes in the current study (Portland Cement-CEMII-Rank42.5N, Suez Cement Company, Egypt) with 3.15 specific gravity that fulfils the requirements of Egyptian standard [21].

Mixing Process

The concrete mix design according to [22] is followed. The proportion by mass 1:1.8:2.3 (cement: sand: aggregate) of the concrete mix with W/C ratio was used 0.4. The representative samples then casted in Hexagonal prism to simulate the real interlock flooring units and to determine its compressive strength at ages of 28 days according to the Egyptian Code [22]. Finally, the different produced paving units were prepared with hexagonal prism shape as shown in figure 1.

Granite mix *Dolomite mix* *Basalt mix*

Figure 1: The produced hexagonal paving unit from different aggregate mixes.

Methods

Some methods and techniques were conducted to the studied coarse aggregate characterization involve (XRD-XRF) for mineralogical and chemical composition of studied aggregate respectively, while some others for investigate paving interlock units properties include (physico-mechanical- SEM) in the following some details about all of them. XRD is conducted for mineralogical analysis of the studied coarse aggregate by a X'Pert PRO PW3040/60 (PANalytical) diffractometer equipped with monochromatic Cu-Ka radiation source associated with X'Pert high score software works with a PDF-2 database. The chemical composition was determined by the X-ray fluorescence (XRF) model (phillips PW 1400 spectrometer, Holland). Scanning electron microscopy (SEM) was used to investigate coarse aggregate and cement paste reaction and follow the presence of micro cracks within produced different paving unit mixes by using SEM model Quanta 250 FEG (field emission gun) attached with accelerating voltage 30 K.V. FEI company (Netherlands). Moreover, the measured physico-mechanical criteria in the current study for the produced paving unit that include water absorption, compressive strength and abrasion resistance that based on Egyptian standard number [23] and also European standard [24] while the apparent porosity followed test method for [25] and bulk density followed test method for [26]. For more accuracy some of the studied physico-mechanical properties should be compared to duty property with its specification and limitation according to [25].

3. Results and discussion

Mineralogical and chemical composition of studied aggregate

Firstly, the studied coarse aggregate were investigated mineralogically by XRD as illustrated in pattern figure 2. As shown XRD detected the presence of different mineralogical composition which include carbonate minerals (Dolomite-Calcite) in dolomite aggregate, on the other hand quartz feldspars (albite and microcline) with subsiding of biotite in the case of granitic aggregate while, albite and augite minerals for basalt aggregate.

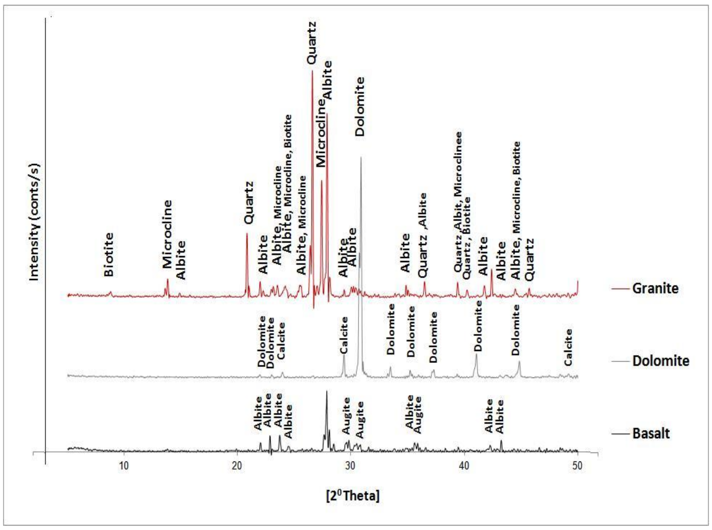


Figure 2: XRD pattern of used aggregate.

Table 1: The chemical composition of the studied coarse aggregate by XRF.

Component % / Sample name	SiO_2	MgO	Fe_2O_3	CaO	Al_2O_3	P_2O_5	Na_2O	MnO_2	CL^-	SO_3	TiO_2	K_2O	LOI
Dolomite	1.711	15.92	0.15	34.31	0.118	0.232	0.068	--	--	0.067	0.014	0.014	47.3
Granite	73.01	0.24	0.29	1.03	10.48	0.01	5.35	0.02	--	--	0.01	7.47	0.40
Basalt	43.18	3.82	17.90	12.70	13.50	0.53	2.27	0.21	0.10	0.11	3.43	0.65	1.49

Secondly, complete chemical analysis of the three studied coarse aggregate is listed in the above table 1. It is in a complete agreement with mineralogical composition reflected by dolomite coarse aggregate exhibited enrichment in CaO, MgO indicated presence of Dolomite – Calcite minerals. Granite coarse aggregate enriched in SiO2 – Al2O3 and K2O which indicated presence of quartz – alkali feldspars. Basalt coarse aggregate enriched in SiO2 – Fe2O3 and Al2O3, Na2O indicated presence of Albite and Augite.

The measured physico mechanical properties of different studied paving units.

All of the measured physico- mechanical properties average values were listed in table 2.

Table 2: Average of measured physico- mechanical properties for different studied paver mixes

Physico mechanical properties / Paver mixes	Bulk Density (g/cm^2)	Compressive Strength (N/mm^2)	Water absorption %	Apparent porosity %	Abrasion (mm)
Granite mix	2.88	30	5.62	16.52	20
Dolomite mix	2.86	25	6.42	18.36	22
Basalt mix	2.94	40.3	4.35	12.53	18

From the obtained results it can be showed that, the interlocking paving unit compressive strength and bulk density are important parameters through that, the performance of the interlocking paving unit can be predicted. The bulk density of all the studied paving interlock paving units ranged between 2.86 and 2.94 g/cm3, as illustrated in the figure 3. Interlock paving units of igneous aggregates (granite and basalt) showed the higher values if compared with dolomitic interlock paving units. That result can depend on their exact composition as igneous aggregates are made up of weightier mass minerals like feldspars and pyroxenes than the relatively lighter carbonate minerals of dolomite aggregate. On the other hand, granite interlock paving units showed a lower value than basalt interlock paving units however, that value is considered reasonable to good concrete mass with normal weight as discussed in [27]. The highest bulk density of the studied basalt interlock paving units due to basalt is made up of heavier mafic minerals rich in magnesium and iron as shown in XRF results, with little quartz than granite from the same origin. In addition to the geological formation of basalt due to rapid cooling resulting in fine grained rock with small crystals that pack more tightly increasing its density than coarser grained granite aggregate. That fact may help basaltic grains improve the strength of the concrete mix as founded by [28].

The compressive strength of granite, dolomite and basalt interlock paving units were compared since cement content and w/c ratio in the mixes design are the same. Interlock paving units of granite showed the middle value if compared with dolomitic interlock blocks and basalt interlock paving units of the highest strength value figure (3). The higher noticed compressive strength of basalt is due to the fact that basalt is denser and more durable and less water absorbing than other alternatives. That results show a robust super performance of the basalt concrete samples compared to the granite concrete that matched with the studies of [28-29]. Using highly compacted concrete mix will enhance the performance of interlocking paving units and its durability as mentioned by [9].

There is a direct relation between average bulk density with average compressive strength for all mixes as illustrated diagrammatically in figure 5. Based on [23] the produced paving mixes can be classified using their average compressive strength value as follow dolomite paving mixes hadn't achieved the requirement of normal duty property (less than 30 N/mm2.on the other hand granite paving mixes achieved the normal duty property

(30 N/mm2). Finally, for basalt paving mixes achieved the requirement of medium duty property by its average value (40 N/mm2) which means (≤35 N/mm2).

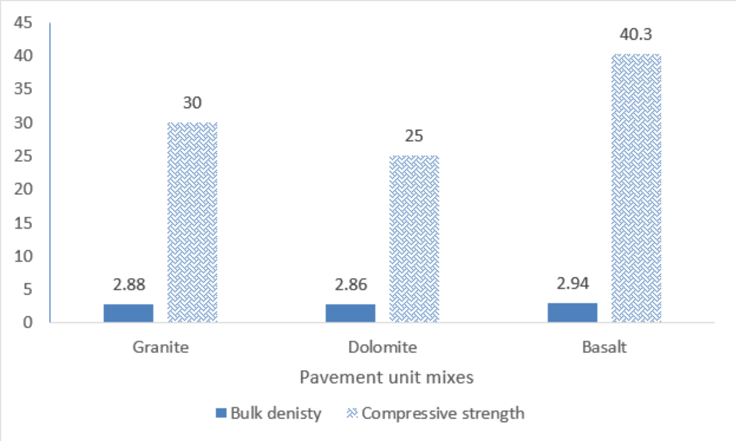


Figure 3: The direct relation between bulk density and compressive strength of all studied paving unit mixes

It is worth noting that the water absorption value figure 4 depends on many affecting factors such as cement type, the W/C ratio, use of admixtures also the proportion, type and size of aggregates. All the mentioned factors were fixed, while the only varying factor was type of aggregates. Water absorption results show a great effect of the aggregate type within the concrete. Paving units elaborated by igneous aggregates granite and basalt yield water absorption average values between 4.35 and 5.62% as illustrated in figure 4. Slightly increase of the water absorption value with blocks of basalt aggregate than granite where the higher water absorption value (6.42%) was recorded for the dolomitic interlock blocks. The decrease of water absorption in case of basaltic interlock signifies that the hardened concrete blocks is less porous to water specially when basalt replaced its carbonate alternate aggregate in a homogenous mix as mentioned by [30]. This relatively increase can be explained by its mineralogical composition, as dolomite aggregate rich in carbonate minerals of sedimentary origin that characterized by more water uptakes than other alternatives minerals of igneous origin. Moreover, granitic interlock with its specific mineralogical composition as presence of biotite mica in gave it the ability of water absorption than concrete with basaltic aggregate of the same rock origin [27], [31].

There is a direct relation between water absorption and the apparent porosity for all of the studied mixes as shown in figure 4. It can be noticed that the least water absorption mix was basalt mix with an average of water absorption measured 4.3% and consequently, 12.5% apparent porosity while dolomite mixes are the opposite case as it exhibited the highest average value for both water absorption and apparent porosity as it reported 6.1%,18.3 respectively.

Both of the basalt and granite paving mixes are within limit of B category according to [24] while dolomite paving mixes occurred within the suggestive border line ≤ 6

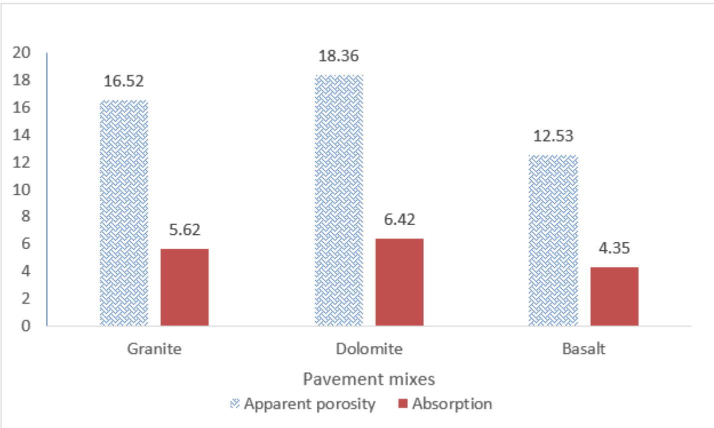


Figure 4: The direct relation between apparent porosity and the absorption of all studied paving mixes

Regardless of the studied aggregate figure 6 located in the (intensive zone) as it moves with narrow range (18-22 mm) which means higher wear by the wheel. It should be noticed that dolomite and granite mixes are more abrasive and consequently greater wear compared to basalt. According to the limitation of [24] all of the produced paving mixes occupied rank no. 3 as all less than 23 mm.

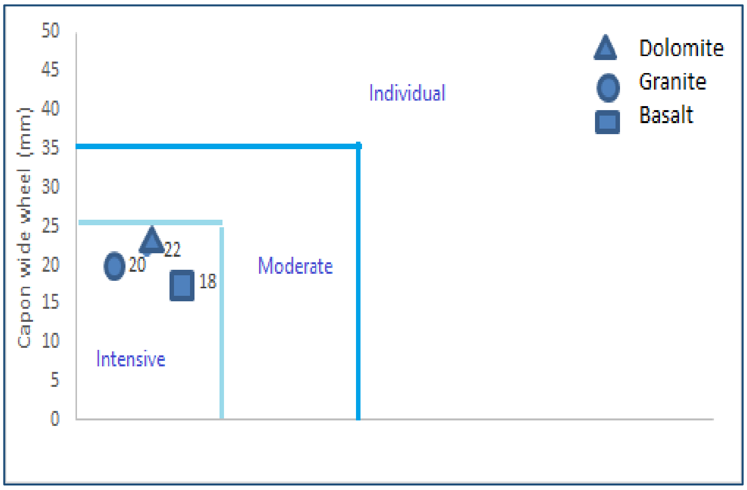
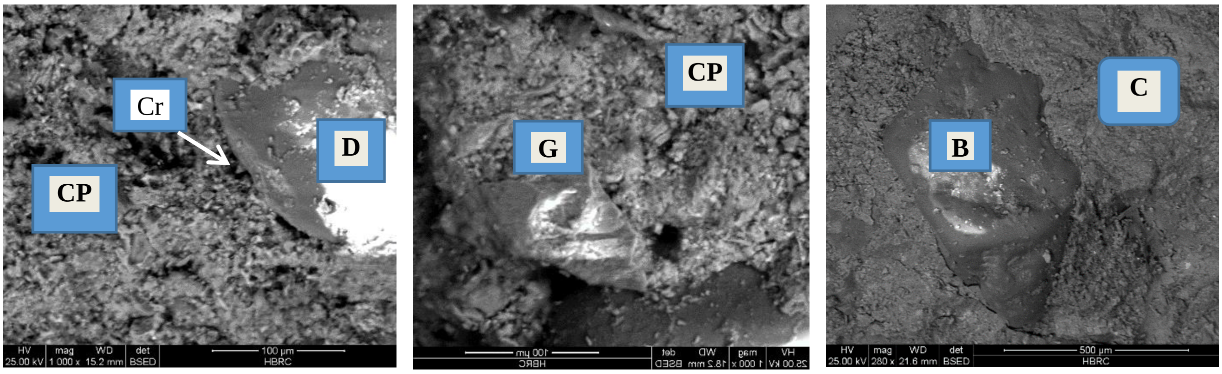


Figure 5: Plotting average abrasion value for different studied mixes by method of capon wide wheel

SEM micrographs (a, b and c) generally exhibited relation between the different used aggregate with cement paste among produced interlock concrete mixes. As shown dolomite aggregate interlock mixes figure (6a) appeared relatively more percentage of voids and pores than the other mixes, while the basalt interlock mixes is the least figure (6c). Consequently, dolomite interlock mix showed relative (less) compactness associated with forming clear micro cracks between dolomite aggregate and cement paste than granite and basalt interlock mixes. The SEM obtained results in a complete agreement with physico mechanical results as dolomite interlock mixes average value are the followed by granite interlock and finally basalt interlock which consider the most promising interlock mixes.



(a) Dolomite mix *(b) Granite mix* *(c) Basalt mix*

Figure 6: SEM micrographs of different produced paving unit

Cp: Cement paste, D: Dolomite aggregate, G: Granite aggregate, B: Basalt aggregate, Cr: microcrack

4. Conclusion and recommendation

According to all of the obtained results from recent study it can be concluded that:

The presence of a detectable effect for variation in mineralogical and chemical composition of used coarse aggregate on studied physico-mechanical properties.

Generally, basalt paving mixes represented the most promising physico-mechanical obtained results followed descending by granite mixes and dolomite paving mixes represented relatively the least.

The correlation between obtained physico-mechanical average values with documented limitations exhibited that all of studied mixes belong to intensive abraded zone or (rank No. 3). Both of the basalt and granite paving mixes are within limit of (B category) according to (EN1338-2003) while dolomite paving mixes occurred within the suggestive border line ≤ 6. Basalt paving mix achieved the requirement of medium duty property by its average value (40 N/mm2) which means (≤35 N/mm2).
All of the produced paving units are not recommended to use under conditions of heavy duty based on (ESS 4382-1/2004. Basalt paving mix preferable in medium zone while granite paving mix are restricted to apply in normal zone and dolomite mix didn't apply to any duty property.

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