

## FINE AGGREGATE USAGE IN CONCRETE AND MASONRY MORTAR BY LOCAL CONSTRUCTION INDUSTRIES

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**Abstract:** Fine aggregate is playing a vital role in both concrete and mortar. The main source of fine aggregate in the recent past is the river sand. The demand for natural river sand has increased as a result of the recent construction boom and the river sand price has escalated tremendously. Increased demand on river sand leads to over extracting and improper mining activities near the river beds causing harmful threats to the environment. This study was carried out based on the comprehensive questionnaire survey conducted among large and small scale contractors to determine the following necessities; whether the contractors are using or seeking manufactured sand as an alternative fine aggregate and issues regarding manufactured sand or whether they are trying any other alternatives for natural river sand. Based on the survey it is identified that majority of the surveyed contractors are using natural river sand and the usage of manufactured sand and offshore sand is very small. Most of the contractors are still reluctant to use these alternatives due to the lack of knowledge among the contractors.

**Keywords:** Fine aggregate; river sand; manufactured sand; offshore sand; concrete; mortar

### 1. Introduction

Cement, sand and metal are essential needs for any types of construction industry. Sand plays an important role in the mix design where it is the major material used for both mortar and concrete (Sankh et al., 2014). The demand for natural river sand has been increased in the developing countries due to the growth rate of construction industries. This concept leads to the increased consumption rate of natural sand. NCA (2003) states that most of the building structures are masonry and concrete made structures and where naturally occurring fine aggregate is mostly considered as the raw material for cement mortar for bonding bricks, plaster for surface finishing of walls, floor rendering or casting of columns or beams. In the study Kwan (2000) illustrates that more rounded and smooth river sand particles are considered to be a good solution for the increased workability of concrete and mortar and strength also be increased due to the low levels of silt and clay contents as it is subjected to years of washing. On the other hand due to the increased demand for fine aggregate, natural depletion occurs as an over exploitation of resources. Detrimental impacts on the environment arises because of river bank erosion, lowering of river beds, coastal erosion

and some health issues. As a solution to this issue, various alternatives such as manufactured sand, offshore sand and dune sand are explored and used in many parts of the world (Aswath, 2014). This research work has been carried out in order to have a comprehensive study on whether the small and large scale contractors are using any other alternatives for natural river sand or the demerits that they are expecting from the alternatives at their side. It is also necessary to study manufactured sand consuming trends, issues related to manufactured sand and river sand production and consumption. To gain the sufficient information related to above issues, questionnaire survey was carried out among large as well as small scale contractors around the country.

### 2. Literature Review

From the studies of (Samaranayake, 2005 & Dolage et al., 2013) it is observed that small developing countries like Sri Lanka, due to the lack of natural resources available, it is important to take much consideration on the fine aggregate usage by the construction industries since a rapid increase can be observed in the sand consumption after the year 2011. According to the literature (Sathsarasinghe, 2015) approximately 40% of natural river sand was consumed by Western

province areas specially where large scale construction works were carried out. Padmalal & Maya (2014) mentioned the statistics about the total annual demand of sand was estimated as 21 million cubic meters in Sri Lanka in 2018, where 95% of the demand is accounted by the main consumer 'construction industry'. In the past, the main source of fine aggregates was river sand which was extracted by mining river beds. Due to the increased sand demand drastically, sand suppliers had resorted to over exploitation and digging the river banks which caused serious impacts on environment. GSMB (2018) states that the government has imposed many restrictions on mining natural river sand which resulted in shortages and increased prices up to Rs.16, 000 per cube. As stated in (GSMB, 2018) a restriction of the maximum extraction quantity given by Geological Survey and Mines Bureau for a license is limited to 210 cubes per month, however Gavrilitea (2017) states that almost one third of the total sand demand in Sri Lanka is met from illegal sources.

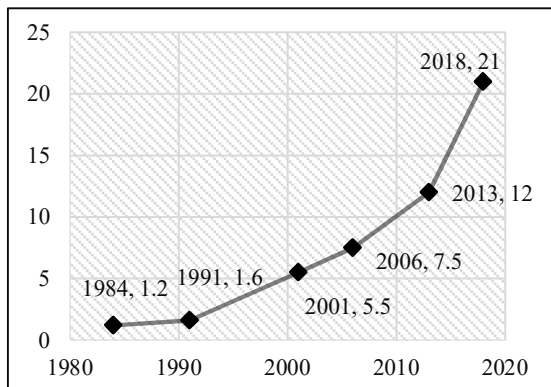


Figure 1: Approximate sand extraction in Sri Lanka (in million cubic meters) Source: Adapted from (Samaranayake, 2005 & Dolage et al., 2013)

Figure 1 shows a gradual increase in the extraction of river sand up to 2006 and a rapid increase is observed after 2006. This can be mainly due to rapid reconstruction of tsunami damaged infrastructure as well as new constructions such as air ports, harbour, express ways, high rise buildings, numerous real estate projects and ongoing development projects in various parts of Sri Lanka. This resulted in an increased demand for river sand mainly in

Western, Eastern, Central, Southern and Northern parts of Sri Lanka.

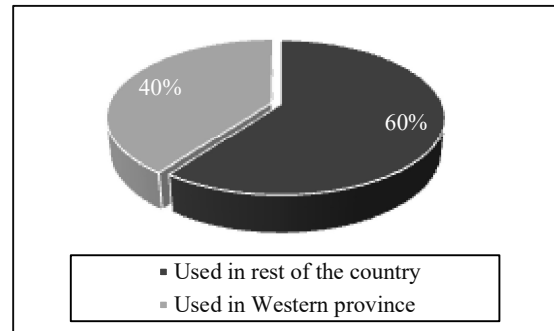


Figure 2: Sand consumption in Sri Lanka Source: Adapted from (Dolage et al., 2013)

Figure 2, it can be clearly observed that the consumption rate of fine aggregate is higher in Western province districts than other parts around the country where most of the high rise building construction are being carried out.

As a solution for this, different types of substitutes are available. For example Manguru et al. (2013) and Dias et al. (2008) suggested manufactured sand and offshore sand respectively which are some of the best substitutes that are used in some construction projects specially by large scale contractors. Padmalal & Maya (2014) showed the availability of river sand substitutes such as offshore sand, land based sand, dune sand and manufactured sand as 31.5 million m<sup>3</sup>, 9.6 million m<sup>3</sup>, 0.3 million m<sup>3</sup> and 9.96 million m<sup>3</sup> respectively in Sri Lanka which clearly shows that offshore sand and manufactured sand can fulfil the increased demand for natural river sand. River sand not only has demerits as mentioned above like eco-imbalance and non-cost effective material, but also there are some more problems encountered comparing with other substitutes. Some constructors achieved a lower strength of concrete with river sand than manufactured sand because of the exceedance of the silt content in river sand beyond 3% which gives harmful effects to the durability of concrete (MT, 2018). Study of (GP, 2019) emphasizes that there is a possibility of having 1-6% over sized materials like pebble stones and 1-2% of marine products such as sea shells and tree barks which may also reduce the workability of the concrete mix. Contractors who used manufactured sand as an

alternative to river sand were not worrying on the above limits as those harmful substances are absent in manufactured sand (GP, 2019). Other limitations are; there are no control limitations on the quality of sand since it is naturally occurring and the particle sizes cannot be controlled, however it is possible with manufactured sand which is undergoing several crushing stages (Manguru et al., 2013 & GP, 2019).

### 3. Methodology

This section describes the methodology used and the analysis carried out in order to achieve the project objectives. The data were gathered through face to face questionnaire survey. In order to represent the whole country, areas where large and small scale construction works have been carried out were selected. This survey was carried out in seven districts (Colombo, Gampaha, Kandy, Nuwara-Eliya, Galle, Batticaloa and Polonnaruwa) in five different provinces where the construction activities are being carried out. Survey was carried out targeting masons by directly visiting to their construction sites in different areas representing each districts. This study is based on the masons in Sri Lanka where a sample of hundred and five masons was used for this research. A comprehensive questionnaire was prepared for this survey which covers construction type (single storey house, hospital, high rise building, 2-3 storey building, etc.), company grade (ex: self-employed, C1, C2, CS1, etc.) and the details on the usage of different fine aggregate types by them.

### 4. Results

Survey was carried out among small scale self-employed contractors and large scale contractors representing C and CS levels construction companies in Sri Lanka. Total of 105 questionnaires were collected from the survey and Table 1 shows the number of responds received from each contractor types.

Table 1: Company grade and frequency of survey

Category	Contractor	No of surveys	Construction types
Small scale	Self-employed	68	Residential house, House Renovation
Large scale	Company C9-C1	14	Shopping complex,

			office building
	Company CS1	23	Hospital, High rise building

#### 4.1 Types of fine aggregates for construction works

River sand, manufactured sand and offshore sand were the common types of fine aggregates used in both concrete and masonry by small and large scale contractors observed during the survey. It was noticed that some masons used one type of fine aggregate for their whole structural and masonry works (i.e. river sand/manufactured sand alone for their whole construction activities at the site) while others used different types of fine aggregates for different construction works (e.g. river sand for foundation and structural works and manufactured sand for masonry works). Figure 3 shows the fine aggregate usage by small scale contractors in their construction activities.

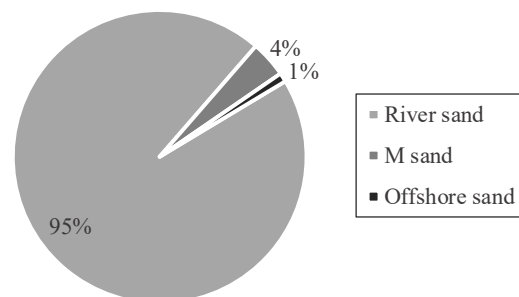


Figure 3: Fine aggregate usage by small scale contractors

According to Figure 3 most of the small scale contractors were using river sand as the main fine aggregate type where it contributes 95% of total. The contribution to other alternatives such as manufactured sand and offshore sand are very low because masons play the main role on consuming fine aggregate for the small-scale works such as house construction. Due to lack of knowledge on using other alternatives and none of civil engineers involvement in those construction activities make them not willing to use alternative sand types for the their construction works. In contrast, due to the involvement of civil engineering practices, from Figure 4 below, it can be observed that the

contribution to manufactured sand by large scale contractors is higher than small scale contractors.

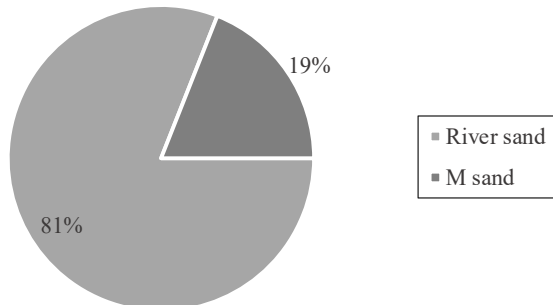


Figure 4: Fine aggregate usage by large scale contractors

It was observed that about 19% of large scale contractors used manufactured sand only as alternative to river sand. This trend is as result of involvement of civil engineers in the construction works and proper mix designs directly give the impact on the above contributions. Among both small and large scale contractors, it can be clearly identified that river sand is the main type of sand used for both concrete and masonry works while a small usage of manufactured sand. Offshore sand is rarely used in masonry and concrete works. Since out of 105 construction sites, 87 of them used river sand in concrete works and 16 of them used manufactured sand which can be further analysed as given in the sections below. Small scale constructions include house renovation and residential house works and Figure 5 illustrates the types of sand used for the above construction works. Among 68 small scale constructions, 39 construction sites were residential house construction where river sand is being used by 95%of the contractors and remaining 5% of contractors used M sand. Remaining 29 construction sites were house renovation works where 93% of them used river sand in their construction works. 7% of them consumed M sand and offshore sand equally.

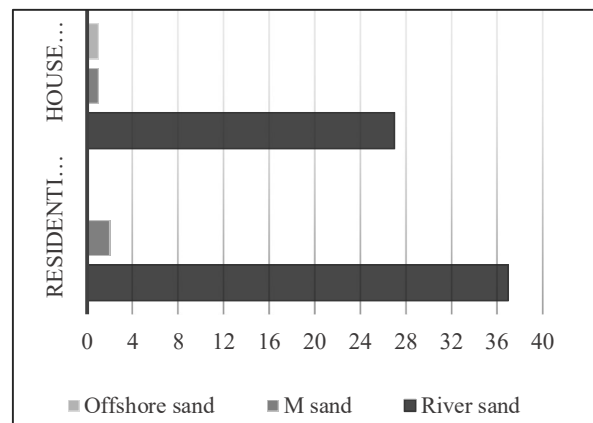


Figure 5: Sand types used in small scale

Activities like construction of shopping complex and office building were considered as medium scale projects and Figure 6 shows the usage of different sand types. Survey was carried out in 14 medium scale projects and from Figure 6, it can be easy identified that all the 10 shopping complexes and 4 office building construction sites used only river sand in their construction activities which describes none of them used other alternatives to river sand.

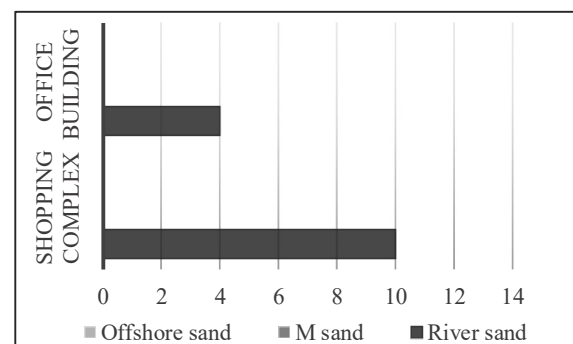


Figure 6: Sand types used in medium scale projects

Figure 7 shows the sand usage for large scale constructions such as construction of hotel and high-rise buildings. The usage of M sand is very high in large scale projects, i.e. specially around 67% of high-rise building projects used M sand and remaining 33% used river sand in their construction works. Out of hospital projects, 63% usage is by river sand and 37% by M sand. Therefore the involvement of civil engineers in construction activities and proper mix designs using other alternatives enhance their

willingness to use manufactured sand in the large scale construction works without any hindrance.

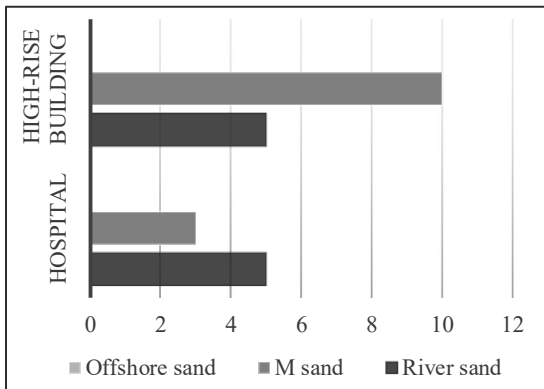


Figure 7: Sand types used in large scale projects

#### 4.2 Cost of river sand vs alternatives

Cost also plays an important part on selecting sand type for construction activities. Survey was carried out in the districts where the maximum and minimum cost spent on consuming one cube of river sand. Based on Figure 8 shows that most of the contractors spent more than Rs. 15,000 on one cube of river sand. Comparing with the cost spent on other alternatives such as M sand and offshore sand, cost of river sand is seemed to be high. Figure 8 shows the cost of river sand based on the districts surveyed which defines the influence of transportation cost.

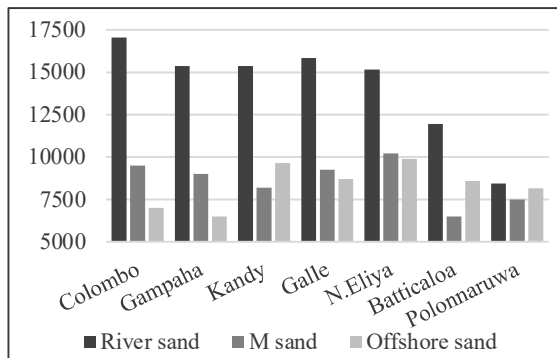


Figure 8: Average cost including transportation cost on different sand types (Rs.)

Most of the river sand mining activities are carried out in North Central province (i.e. Mahiyanganaya, Manampitiya, etc.) and transported to other districts which induces the cost for transportation and hence increases the overall cost. From the survey it was noticed that the construction sites in Western province spent around Rs.17, 500 on one cube of river sand which is the highest value spent compared

to other provinces. However, they spent around Rs. 9,500 on one cube of manufactured sand where the maximum value of Rs. 10,000 was spent on manufactured sand by central province contractors. As shown in Figure 8, it clearly shows that each parts around the country spent less amount on consuming manufactured sand than river sand which indicates a large deviation of cost for each sand types. Due to the increased mining activities, government imposed restrictions on mining river sand. This leads to the shortage of river sand supply and thus gives impact on river sand price. Each parts around the country spent lower amount on manufactured sand and offshore sand than river sand which can be considered as the good solutions as alternatives for river sand alternatives considering in terms of the cost for total construction.

#### 4.3 Experience on strength, workability and economy of fine aggregates

This section describes the experience of small and large scale masons on strength, workability and economy on different sand types used in their construction works.

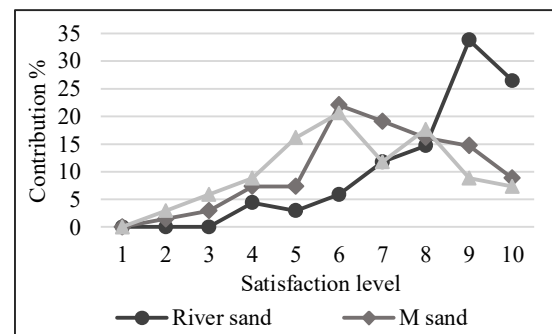


Figure 9: Experience on strength of sand types by contractors/masons in small scale construction sites

The satisfaction levels from masons on different sand types are plotted against the percentage of contribution by them for each satisfaction levels. Figure 9 shows the experience on strength of sand types used by small scale masons. According to Figure 9, small scale masons feel that the strength of concrete/mortar with M sand is lower than concrete/mortar produced with river sand. From Figure 9, it is noticed that most of them (around 50%) complies with medium satisfaction level on M sand with respect to strength. Similarly the satisfaction level on offshore sand seems to be lower than M sand

which is rarely used by small scale masons in construction activities. Considering workability of sand types used, most of small scale masons (around 60%) strongly satisfied with offshore sand which can be a better alternative to achieve good workability comparing with river sand. However they feel discomfort in using M sand in construction works. (see Figure 10).

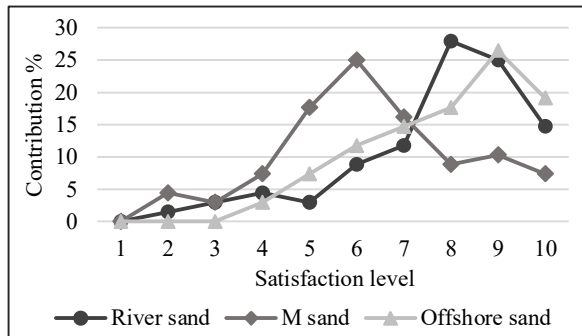


Figure 10: Experience on workability of sand types by contractors/masons in small scale construction sites

The satisfaction level when using offshore sand is much higher than M sand. The masons are not willing to use M sand for the works because of its low workability where a medium satisfaction level is observed from around 65% of masons worked in small scale construction works (see Figure 10). Around 55% of total small scale masons dissatisfied with the cost of river sand and very small percentage of them (around 10% only) satisfied with that. Considering other alternatives, more than 50% of them highly satisfied the cost of M sand and offshore sand and very less amount of them dissatisfied with the cost. These satisfaction level variations are well illustrated in Figure 11.

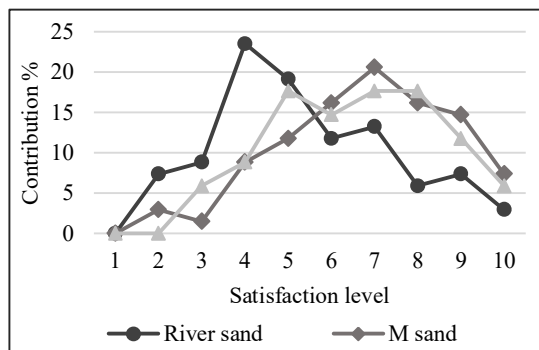


Figure 11: Experience on economy of sand types by contractors/masons in small scale construction sites

The above three graphs (Figure 9, 10 & 11) show the satisfaction levels of small scale masons on different sand types used in the construction works. Figure 12 shows the satisfaction on strength of sand types used by large scale masons.

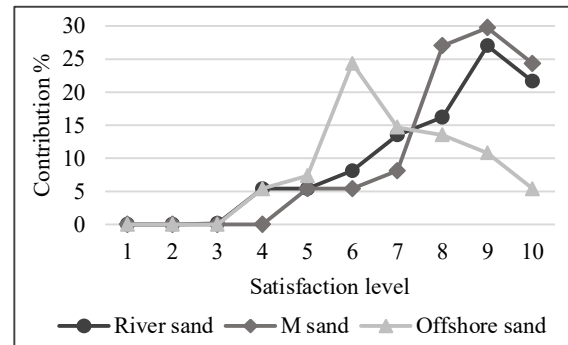


Figure 12: Experience on strength of sand types by contractors/masons in large scale construction sites

In contrast, here large scale masons felt that higher strength of concrete/mortar can be achieved when using M sand instead of river sand in the mixes. A higher satisfaction level with M sand (around 80%) can be observed, however most of them dissatisfied with the strength with offshore sand, but they strongly satisfied with the workability of mixes when using offshore sand (see Figure 13). Around 75% of large scale masons felt that more workable mix could be obtained when using offshore sand than other sand types. Better satisfaction level can be observed on workability with M sand by large scale masons where around 60% of them satisfied with that. This shows a considerable amount of large scale masons are now started using M sand in concrete and mortar which shows that they are willing to continue using M sand as an alternative to river sand.

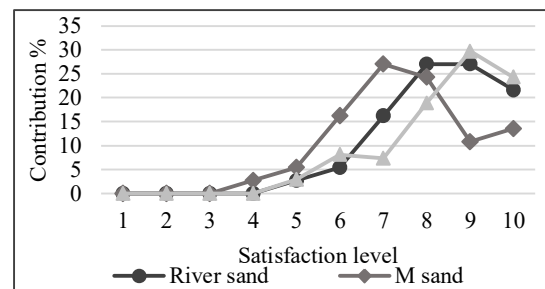


Figure 13: Experience on workability of sand types by contractors/masons in large scale construction sites

Similar to small scale masons, around 75% of total large scale masons were not satisfying with the cost of river sand but they highly satisfied with cost of M sand. According to Figure 14, it can be observed that around 60% of large scale contractors considered M sand as the cheapest material than other sand types and they are comfortable in using M sand in construction activities.

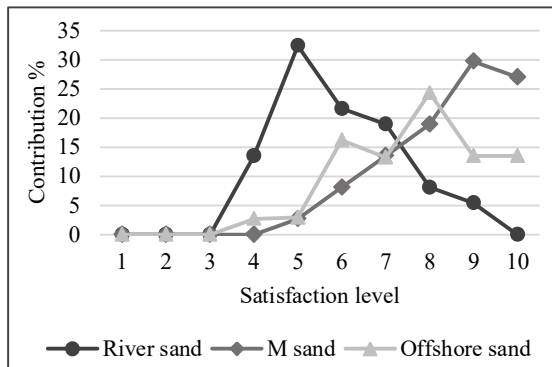


Figure 14: Experience on economy of sand types by contractors/masons in large scale construction sites

## 5. Discussion

Since the most common type of sand used in the construction industry is river sand. Masons feel comfortable on strength when using river sand. However, there were some construction sites where contractors used to conduct visual inspection tests to identify the suitability of river sand (uniform in colour) and do sieving works prior to plastering works to achieve the required size range. Some of them experienced with poor quality of river sand because of the mud particles which cause difficulties when using them in construction works. This may be due to improper river sand mining activities near river banks due to the increased demand. The contractors achieved a lower strength in the concrete and mortar mixes when using offshore sand comparing with river sand. They pointed out that the reason for the lower strength was because of the high salt and shell contents in offshore sand. So, offshore sand was washed at the construction sites for a continuous period and sieved before using in the construction works to enhance the sand with limited salt and shell content. When considering the usage of manufactured sand in construction works, more than 95% of them strongly satisfied with the strength because of the cubical and rough surface particles in manufactured sand which lead to produce good particle inter-

locking. On the other hand contractors were not satisfying with the cost of river sand. The reason for this is river sand is mined in particular areas and transported to other places which incurred the cost for transportation as an addition to the total cost for river sand. However around 95% of the contractors who used manufactured sand, satisfied with the cost. It was found that very low cost was spent on transporting manufactured sand from the quarries when comparing with river sand, because the source for the manufactured sand production (i.e. parent rocks) are abundant materials in each parts of the island. Consuming manufactured sand from quarries which are located nearby the construction sites, may not have an effect on the total cost for consumption. This also could be a reason for high satisfaction levels by masons on the economy when using manufactured sand.

During the survey it was noticed that none of the construction sites used admixtures for both concrete and masonry works which shows their capability of using river sand in both concrete and masonry works without using admixtures in the mixes. However some of them experienced few difficulties in obtaining a good workable river sand mix because of the high amount of debris and clay particles. But they were continuously using river sand because of the less experience on using other alternatives. From the survey it was found that, very less number of construction sites were using offshore sand in their masonry works, however they strongly satisfied with the workability of mix with offshore sand. This was because offshore sand also has particles similar to river sand. In contrast, when comparing the above two types of sand, manufactured sand got the lowest satisfaction level of workability (see Figure 10). However, M sand is considered as the best construction material because of its high strength and economy than other two types. The common issue identified by the contractors related to manufactured sand was early hardening because of the dust and low moisture. Therefore a continuous mixing (using human power) and a speedy work were done for the mixes at the work place after the preparation of both concrete and mortar until the application. Contractors found that it was very difficult to make a good bond between the bricks and mortar due to the high fine particles in manufactured sand as it acts as a barrier between mortar paste and brick. As a result, after the application of mortar due to high absorption of moisture, hair line cracks were observed in the joint surfaces. So manufactured sand is washed at the site

to control the dust and to enable moisture entrapped between the sand particles. It is also observed that none of them use admixtures when using manufactured sand to overcome the above issues and some construction sites use blended sand as 1:1, 3:2 and 2:1 river sand to manufactured sand as common mixing ratios without proper design calculations which defines the gap on proper mix design when using manufactured sand. Even though large scale constructions are managed by civil engineers and government/private consultants, there were no positive initiation to implement using manufactured sand as there were no proper engineered design methods available.

## 6. Conclusion

River sand is regularly used in the construction by large and small scale contractors and small consumption of manufactured sand and offshore sand also can be observed. Contractors who are using river sand, satisfy with strength and workability while strongly dissatisfy with cost. Using manufactured sand alone high strength concrete mixes were achieved comparing with river sand, but some issues were identified in masonry works. As a solution contractors are trying to blend manufactured sand with river sand to obtain a good bond, quality finishing and specially to overcome the cost. Contractors who use manufactured sand are not considering on the admixtures in mix design to overcome the issue with low workability. Lack of knowledge on using manufactured sand with appropriate admixtures makes reluctant on using them in construction industry. Therefore by applying the suitable admixtures with low cost fine aggregate, higher strength and workable concrete and mortar mixes can be obtained which can drastically reduce the overall cost for constructions.

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