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USE OF RECYCLED AGGREGATES FROM CONSTRUCTION AND DEMOLITION (C&D) WASTE FOR BUILDING CONSTRUCTION IN DAR ES SALAAM, TANZANIA

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ABSTRACT

Dar es Salaam city faces the shortage of building materials even though more than 50% of the builing materials produced are produced for Dar es Salaam market (Kimambo, 1988). In Tanzania, the major building materials used in building construction are building blocks. Concrete blocks are gaining importance in developing countries (Kaosol, 2010). According to the survey conducted in Dar es Salaam, it is estimated that about 70% of building materials is concrete and building blocks, whereby blocks occupy about 30% for high rise buildings and 70% for single storey buildings. The source of aggregate comes from quarry sites more than 120 km afar. Transportation of aggregates from far distant increases the cost of materials, energy consumption, traffic and environmental degradation. Since, Tanzania is one of the poor countries; it is very expensive to get building materials from far distance. Authors suggest that recycling of concrete rubble can be an alternative source of aggregates. In Tanzania, recycling of building material from construction and demolition rubble does not exist. About 20% of rubble is reused for backfilling of pothole, foundation and the rest is thrown away. The experience from developed countries shows that concrete rubble has great recycling potential; producing aggregates for stabilization of sub-base in road construction etc. These applications are lower applications (downcycling). The ongoing research project is investigating the possibility to recycle concrete rubble to generate load bearing concrete blocks for building construction.

Keywords: Reuse, Recycling, C&D waste, building materials, concrete block

I. INTRODUCTION

The demand for construction materials increases daily all over the world. The construction industry accounts directly and indirectly for nearly 40% of the material flow entering the world economy (Roodman and Lenssen, 1995) and in developing countries for around 50% of the total energy consumption (Levin, 1997; Bonini and Hanna, 1997). Tanzania faces the same pattern.

Tanzania is a developing country with a tremendous need for housing especially in urban areas such as in the capital city, Dar es Salaam. The Dar es Salaam city is oldest and rapid growing city in Tanzania. Its population is estimated to be 3.5 million (in 2010) compared to 2.5 million in 2002 (NSB 2002), i.e. 39% increase for 8 years. This shows that the demand of accommodation is increasing. This puts pressure on the availability of building materials to meet the growing demand of the shelters (i.e. buildings). The major building materials used in residential and small industrial buildings in Tanzania are concrete and sandcrete blocks (Egmond, 2000). According to the survey conducted in Dar es Salaam, the buildings construction can be classified into two groups namely single storey and multi-storey buildings. The construction of these buildings differs from materials used, equipments, skilled people required. For example, in constructing single storey building, building blocks (i.e. concrete blocks) are used as load bearing material; columns systems applied for multi-storey buildings as load bearing materials while the sandcrete blocks used as infill materials. So every type of building construction system consumes a substantial amount of building blocks. The study done by Kaosol,

(2010) indicates that the concrete blocks are gaining importance in developing countries. It is estimated that about 70% of building materials is concrete and building blocks, whereby building blocks occupy about 30% for high rise buildings and 70% for single storey buildings in Tanzania. The demand for blocks is expected to increase even more as the population and demand for shelter are increasing. This will result in a deficit of building materials in future. In order to support building construction to be sustainable, innovative production of building materials by recycling concrete rubble into load bearing building materials is essential especially in Tanzania

The raw materials for making concrete blocks are a hydraulic binders, water and aggregates (Jackson and Dhir, 1988, GTZ, 1991). The aggregate is an economical filler material with good resistance to volume changes which take place within the concrete after mixing, and it improves the durability of the concrete (Jackson and Dhir, 1988). The common aggregates used in Tanzania are those derived from natural source (quarry sites). Out of 30 formal constructed buildings and 11 building blocks manufacturers visited and interviewed, non of them using the recycled aggregates from concrete rubble instead all are extracted from quarry site. As we know the aggregates are non-renewable mineral materials; according to high growth of building construction the supply of aggregate near future might be limited and results conflict among users (Mufuruki et al, 2007; Sabai et al, 2009).

This paper focuses the aggregates material for building blocks production from crushed masonry rubble (i.e. concrete rubble) of construction and demolition buildings in Tanzania. The demand for aggregates in Tanzania in 1997 was about 60 millions tonnes (Woodbridge, 1997), equivalent to 2 tonnes per year per capita. It is estimated that the demand for aggregates such as that used in the building blocks in Tanzania might almost triple from the estimated 87.4 million tonnes in 2009 to 219 million tonnes in 2050 (PRB, 2009, WBCSD, 2009). The share of locally available raw materials used to producing building materials in Tanzania is about 47% of the required amount (NCC, 1992); the rest is imported which puts quite some strain on the country’s economic situation. Dar es Salaam city consumes more than 50% of all building materials produced in the country, but the capital still face shortages of building materials (Kimambo, 1988). An increased use of local resources and a disproportionate future demand for the availability of local building materials will result in a depletion of the natural resources due to the expansion of the construction industry in Tanzania. To ensure the sustainable building construction in future, the alternative source of aggregates is inevitable. This recycling the concrete rubble from demolished and constructed building is under investigation in the on-going research.

The construction of these buildings differs from materials used, equipments, skilled people required. For example, in constructing single storey building, building blocks (i.e. concrete blocks) are used as load bearing material; columns systems applied for multi-storey buildings as load bearing materials while the sandcrete blocks used as infill materials. So every type of building construction system consumes a substantial amount of building blocks. The demand for blocks is expected to increase even more as the population and demand for shelter are increasing. This will result in a deficit of building materials in future. In order to support building construction to be sustainable, innovative production of building materials by recycling concrete rubble into load bearing building materials is essential especially in Tanzania

II. BUILDING CONSTRUCTION AND DEMOLITION IN TANZANIA

2.1. Building Construction Condition in Dar es Salaam City

The on-going projects up to January 2010 which includes buildings, civil works, electrical and mechanical works that costs amount of more than ten (10) Tanzania millions shillings (about USD 7000) was 2219 (data from Contractors Registration Board (CRB). Out of these projects, building construction occupies 1227 (55% of total registered construction projects). While in Dar es Salaam city contains 544 buildings (44% of all buildings in Tanzania). This reveals that building construction is higher and is growing faster in Dar es Salaam. This shows that the generation of waste from building construction and demolition is expected to be higher (see Figure 1 below).

Figure 1. a) &b) buildings under construction; c) many of high rise buildings are under construction
(*taken at Ilala, 2010)*

Dar es Salaam city comprises three municipalities namely: Temeke, Ilala and Kinondoni. The Municipal Engineers from Temeke, Ilala and Kinondoni municipalities revealed that the available building permits records were 1806 from 2008 and 2010 as shown in Table 1 below. From the Table 1, the single story buildings are 83%, 55% and 34% on other hand multi-storey were 17% 45% and 66% in Temeke, Ilala and Kinondoni municipalities respectively. It indicates that in Temeke and Ilala municipalities more single storey buildings are under construction, while in Kinondoni municipality the multi-storey buildings are higher.

Table 1 Building permits classification in Dar es Salaam, Tanzania.

Type of the buildings	**Temeke Municipal Sept. 2008 - May 2010**		**Ilala Municipal Nov. 2008-May 2010**		**Kinondoni Jan-May 2010**	
	Bldg permits issued	%	Bldg permits issued	%	Bldg permits issued	%
Single storey buildings	741	83	306	55	120	34
Multi-storey buildings	157	17	246	45	236	66
Total	**898**	**100**	**552**	**100**	**356**	**100**

From Table 1 above, by sorting and analyzing the use/function of the buildings in terms of residential, commercial, Institution, residential together with commercial and residential together with institutional buildings; it found that residential buildings are many compared to others as shown in Figure 2 below. This indicates that most of the residential buildings constructed are multi-storey building in Kinondoni municipality, while in Temeke and Ilala most of the buildings are single storey buildings. The reason for this is attributed by economic capability of people because in Kinondoni most of people are constructing multi-storey building for residential. It occupies 84% of residential buildings while Temeke is 85 % and Ilala is 58%. The Temeke Municipal Engineer supported this by saying that “most of people residing in Temeke are poor compared to other municipalities”. Also Kinondoni is highly populated (i.e. 1.1 million people in 2002 census) while Temeke was 0.78 millon people(NBS 2002). The land scarcity problem due to high population in Kinondoni may influence the multi-storey buildings construction. The land scarcity problem caused people to encroach even to live in the borrow pits at the quarry sites like Kunduchi quarry sites in Kinondoni municipalities. The land problem not only affects the space to live but also reduces potentials areas for building material source. The problem of building materials in future is giving bad signal, and therefore scientists have to work out to find more alternative sources for obtaining the building materials for future use. Being aware on this problem, authors join other scientists all over the world to investigating the possibility to recycle concrete rubble as an alternative source for production of aggregates that can be used to manufacture the load bearing concrete blocks for building construction.

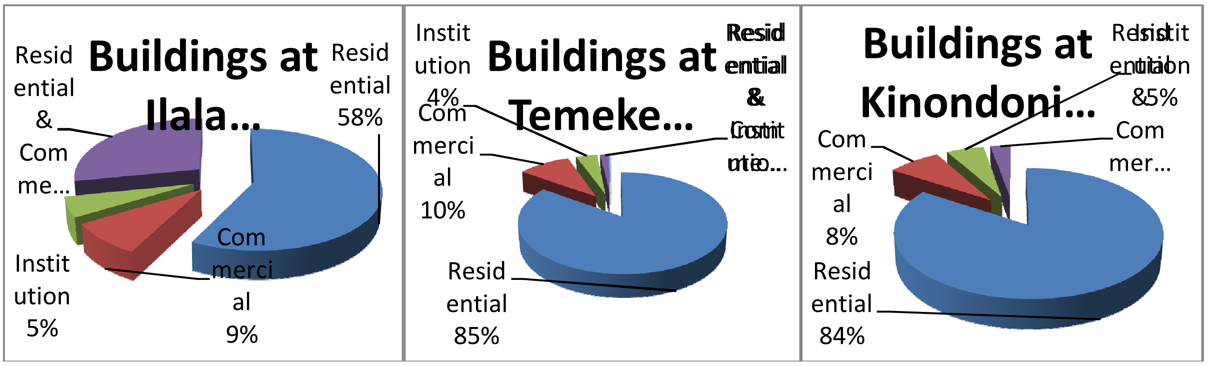

Figure 2 show the functions of the buildings constructed in Dar es Salaam city
[*in Temeke Residential and Institution reads 0% because it was only 1 building permit out of 898 permits issued*]

According to Dar es Salaam city council, informal settlement occupies 70% of the total build up area. Data from informal settlements are difficult to obtain even though they are also generating construction and demolition waste. It is indicated that there are buildings are under construction within the city which are not registered and regulated by respective authority.

2.2. Building Demolition Condition in Dar es Salaam City

Most of the permits issued in Ilala Municipalilty especially city center and outskirt areas like Jangwani, Kariakoo, Kisutu, Ilala, Buguruni are involving permits for demolition activities. The reason stated by Municipal Engineer was land scarcity. The number of demolition permits issued from July 2009 to May 2010 by Ilala municipal council were 23; Temeke was 1 while Kinondoni no specific data. But this figures do not reflect the actual situation of building demolition because there were thousands of buildings that actually demolished at Kipawa areas (near the Mwalimu Julius Nyerere International Air Port) which were situated in Ilala municipality and others located at Temeke municipality situated near the Dar es salaam Port (*known as kurasini Shimo la Udongo*) were demolished. The reason stated was, that buildings were demolished following *government order* after building owners were being compensated. Therefore, there was no need to procure demolition permits. Thus there are a lot of buildings demolitions which are conducted in various areas in Dar es Salaam without requesting permission from responsible authorities (i.e. Municipalities). At Temeke, there were also 8 blocks of 3 storey buildings demolished as shown in the Figure 3 below. Unfortunately regarding those demolition activities, there is no record information in the Temeke Municipality while the event occurred almost 4 km from Temeke municipality headquarter. When asked, why the demolition of the buildings like that can be demolished without information to the municipality, the answer was that, "*most of demolition activities are done during weekend nights, and the same time, all rubble are removed from the site; so it is difficult to be controlled by the Municipality*". There are poor records on building demolition activities while there is no data on amount of C&D waste generated in Dar es Salaam.

Figure 3. Rubble generated from building demolition in Dar es salaam, Tanzania
(taken at Changómbe, Temeke in 2010)

Also, information from National Construction Council (according to an interview Dr. Fundi) it found that in the period of 10 years (1996-2006) there were 840 high rises (7+ storey) buildings were constructed in Dar es Salaam. The construction of those buildings involved demolition of existing buildings. Experience learnt from Tanzania National Housing Corporation (NHC) is that there are 46 buildings in Dar es Salaam which are demolished and new ones are under construction instead. Also according to 30 buildings sites visited and interviewed, 20 (66%) out of them were accompanied with demolition of old buildings. This indicates that there are many buildings that are demolished and new ones are constructed in Dar es Salaam city which end up to generate a lot of C&D waste (e.g. concrete rubble). Besides of construction, renovation and demolition activities, there are other sources of C&D waste generation, these include: natural disasters like earthquakes (*e.g. in Italy (2009), Haiti (2010), Chile (2010)*), avalanches and tornadoes; man-made causes like war and bombing and structural failures (Chan *et al*, 2000) which may happen in Tanzania as well (e.g. US embassy bombing in 1998 in Dar es Salaam, Tanzania). This reveals that the generation of C&D waste is rather extensive even though there are no records on amount of C&D waste generated. These C&D waste have great recycling potential (Hansen, 1992; EU Commission, 2000; Masood *et al*, 2002; Poon *et al*, 2009). And therefore the reuse and recycling/upcycling of these material resources from C&D activities back to building redevelopment instead of disposing or throwing them away required.

III. REUSE AND RECYCLE OF CONSTRUCTION AND DEMOLITION WASTE IN TANZANIA

In Tanzania, the metal e.g. iron and plastic wastes are locally reused and recycled but the masonry/concrete rubble there is no formal reuse or recycling in Tanzania. All reusing and recycling of this material waste is informal because the recent enacted Environmental Management Act (URT, 2004); the C&D waste addressed as solid waste and its treatment suggested is disposal. The current reuse and recycling of C&D waste (i.e. concrete rubble) is described below

3.1. Reuse of Concrete/masonry rubble in Tanzania

The Masonry rubble is reused for backfilling or hardcore in building construction. Also in road maintenance for filling potholes (see Figure 4) including landscaping in general. According to Eng.

Mwankusye (from NHC), the C&D waste i.e. concrete rubble is used for non-structural applications because its quality is not well understood. It is regarded as unfit for new building construction because the by-product is assumed to be weak. Buildings owned and operated by National Housing Corporation (NHC) when demolished, it is estimated that about 20% of masonry rubble is reused as hardcore material in new reconstructed building(s) and the remaining (about 80%) is thrown away. At the same time, information from central dumping sites (at Pugu Kinyamwezi) it is rare to find the concrete/masonry rubble dumped in to dumping site. According to Dump attendants the drivers dump it on the rough roads, stabilize soil at the area with swamp in nature and other uses as explained above. These kind of use the C&D waste is the same as other countries like The Netherlands, Germany, (EU Commision 2000;Hendriks and Pietersen, 2000), USA (USA PW Technical Bulletin, 2004), Thailand (Kofoworola *et al.*, 2009), Japanese and Singapore as well. At least other countries are crushing them before use but in Tanzania applied rubble as it is. This ends to make disturbance to road users especially for small cars (see Plate 3 below). All in all these applications are low application known as *downcycling*.

The blocks recovered have been used for light weight structures i.e. temporal toilets (both super structure and pit lining), fence the construction site. Others have been used for construction of the septic tanks and soakaway pit in many houses low income people. This application is dangerous for users because the quality of blocks is not known whether can withstand stresses from both horizontal and vertical. Therefore, the structures built with materials in which their quality is not known is dangerous and not recommended for safeguarding users like and other ecosystem downstream.

Figure 4. The reuse of concrete rubble for filling pothole in Dar es Salaam
(taken Ukonga and Mwenge, 20010

3.2. Recycling of concrete/masonry rubble in Tanzania

The common aggregates used in Tanzania are those derived from natural source (quarry sites). Out of 30 formal constructed buildings and 11 building blocks manufacturers visited and interviewed, non of them using the recycled aggregates from concrete rubble instead all are extracted from source. As we know the aggregates are non-renewable mineral materials; according to high growth of building construction (Table 1 above) the supply of aggregate near future might be limited and results conflict among users (Mufuruki *et al*, 2007; Sabai *et al*, 2009). To ensure sustainability of building construction in future, the alternative sources of aggregates have to be investigated in Tanzania to aid the existing one.

There is one group of young people that situated at Jangwani, Ilala Municipality which collects and crushes the concrete rubble from demolished building structures mixes with flesh stones from source (they call it *shamba*). This is good step towards the recycling of the by-products generated from the construction and demolition structures in Tanzania. The rubble and stones have been mixed in order to to ensure the quality of resultants aggregates. The quality of aggregate is neither tested in the laboratory nor monitored but assumed is good. The crushing of masonry rubble has been practiced in most of developed countries like The Netherlands, UK, USA etc. Most of the crushed aggregates have been used for sub-base material in road construction and some has been used as aggregates for fresh concrete and non-structural paving blocks (Hendriks and Pietersen (2000), MacDonough *et al* (2002), Poon *et al*, (2002), Poon *et al*, (2006)). In the Netherlands, crushing concrete waste into aggregates has became the common practice for many years due to a shortage of natural aggregates and a lack of available landfill space (Kirby and Gaimster, 2008).

Since the aim of the research project is to explore the extent to which the crushed aggregates from concrete rubble can produce load bearing blocks; the conventional production method of concrete block have been adopted. The processes and conditions for production of concrete block from recyclable materials will be the same as those produced from conventional production method except fine and coarse aggregates have been derived from crushed aggregates. Then block products will be tested in the laboratory. The compressive strength and other quality parameters will be tested and documented. The outcome of this experiment will be presented in a different paper; it is beyond of the scope of this paper.

The recommended nominal compressive strength of the concrete blocks in Tanzania ranging from 3.5 – 21 N/mm^2 (TZS 283:2002(E)). From the literature, the recommended minimum compressive strength is 7 N/mm^2 (Jackson and Dhir, 1988). The recycling/upcycling of the crushed aggregates from concrete rubble to generate the load bearing blocks, the focus is to meet the minimum compressive strength of 7 N/mm^2. For the time being the standards and specifications for the recycled materials do not exist. So the existing production methods, procedures and specifications will be adopted.

IV. THE PRODUCTION OF CONCRETE BLOCKS FROM CONCRETE/MASONRY RUBBLE IN TANZANIA

Concrete blocks have been opted and presented in this paper because the concrete waste (as C&D waste) apparently makes up the largest portion about 40% of solid waste stream (Dolan *et al*, 1999; Macozoma, 2002) in the world also in Tanzania where the C&D waste generation in urban areas such as Dar es Salaam continues to increase. Concrete blocks are the major building system used Tanzania whilst it is gaining importance in the majority of developing countries (Kaosol, 2010). Concrete block masonry has the advantage that it offers little waste and any broken or unused block can be recycled or saved for future projects rather than being disposed of (USA PW Technical Bulletin, 2004).

The aggregates required for concrete block production are fine (passed 5 mm sieve) and course aggregates (i.e. retained on 5 mm sieve and pass in 75 mm sieve) *http://www.tpub.com/content/engineering/14070/css/14070_287.htm*. Coarse aggregates in this paper defined as those aggregates which are used in production of concrete blocks. The recommended particle size for blocks production is ranging from 5 mm to 13 mm (Jackson and Dhir, 1988; GTZ, 1991).

4.1. Aggregates sampling and sample reduction

To get aggregates from recovered concrete/masonry rubbles, stratifies random sampling was used to sample the samples of rubble from the construction and demolition building as well as from the single and multi-storey buildings in Dar es Salaam city. Samples from natural source also sampled. Due to economic constraints, to get the representative samples: ten (10) samples of concrete rubble were collected from generation points and then crushed into aggregates. These samples include three (3) from multi-storey and 3 samples single storey demolished buildings; 2 samples from building construction (i.e. multi- and single storey building). Two (2) samples of coarse and fine aggregates from natural source also sampled for control purposes.

After crushing the heap of rubble, the 50 kg sample were sampled by quartering method according to recommended standard methods of aggregates sampling and test methods (TZS 58 (part1-3);1980) in order to get the representative sample. Then the 50 kg samples were sent to University of Dar es Salaam (*the building material laboratory*) for testing and analysis. The particle size distribution of the all-in aggregates was done by following the standard methods of the TZS 58 (Part1- 3):1980 & BS 812 (part 1-3):1975. To get the appropriate minimum mass of the sample for sample grading, the 15 kg was applied as recommended in Table 2 below. Since the crushing process was manually, the 37.5 (40) mm nominal size of material was applied. Therefore, 15 kg mass of each sample was determined by sample divider method to get the representative sample except for fine aggregates (sand), the 2 kg sample was used.

Table 2 the recommended an appropriate minimum mass of sample for the laboratory testing

Source: TZS 58 (Part 3): 1980

Nominal size of material (mm)	Minimum mass of sample (kg)
63	50
50	35
40	15
28	5
20	2
14	1
10	0.5
5	02
3	0.2
Less than 3	0.1

4.2. Grading crushed aggregates derived from construction and demolition waste

After sampling the representative samples, the grading by sieving analysis was done. The square hole perforated plate sieve of 300 mm diameter conforming to TSZ and having aperture size of 37.5, 28, 20, 14, 10, 5 mm and wire cloth sieves of 200 mm diameters and aperture sizes of 2.36, 1.70, 1.18, 0.600, 0.425, 0.300, 0.212, 0.150 and 0.075 mm were applied (TZS 58(Part 3):1980. The results of particle size distribution (sieving analysis) are presented in the Figure 5 below. Almost the curves of all samples (all-in aggregates) behave the same except for the fine aggregate sample from source. By calculating fineness modulus (FM) of each analyzed sample (see equation 1 below), the results were 5.6, 5.1, 6.0 for demolished multi-storey buildings (DM1, DM2, DM3) and 6.6 for constructed multi-storey building (CM) respectively. For single storey buildings FM were 5.3, 4.0, 5.8 for demolished buildings (DS1, DS2, DS3) and 4.6 for constructed building (CS) respectively. The FM of aggregates derived from natural source were 6.3 for coarse aggregates (NCA) and 2.0 for fine aggregate (NFA) respectively. According to Schoner *at al.*, (1987), the grading curves following curves A,B,C are recommended for structural concrete. For particles with maximum size of 37.5 mm the recommended fineness modulus of A was 6.4, B = 5.2 and C = 4.3 respectively; whereby A-B graded as *'Good'* while B-C as *'Fair'* (Schoner *at al.*, (1987).

Therefore, based on this fact, all recovered aggregated from construction and demolition buildings can produce the structural building material element because all most all curves fall within Good and Fair grade. Furthermore, the building material i.e. building blocks will be produced. The on-going research project will produce the building blocks from these recovered materials and presented in a separate paper. Therefore, the grading of the aggregates is important. According to Roberts *et al.*, (1996), the aggregates gradation helps to determine almost every important property characteristics of the concrete product made from that particular aggregates including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance and resistance to moisture damage.

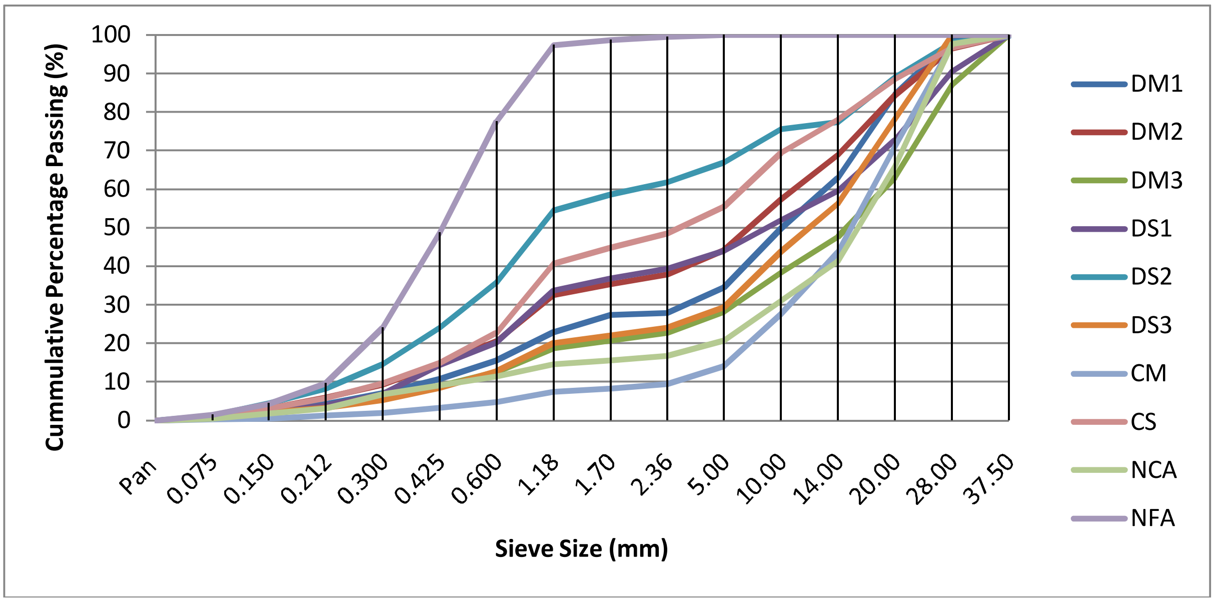

Figure 5 Particle size distribution (sieving analysis) results

Fineness Modulus is described in ASTM C 125 and is a single number used to describe a gradation curve. It is defined as:

$$F.M. = \frac{\sum(\text{cumulative percentage retained on specified sieves})}{100}$$

(Source: ASTM C 125) ……….eq. 1

where: FM = fineness modulus

specified sieves = 0.150 mm, 0.30 mm, 0.60 mm, 1.18 mm, 2.36 mm, 4.75 mm, 9.5 mm, 19.0 mm, 37.5 mm, and larger increasing in the size ratio of 2:1.

The larger the fineness modulus, the more coarse the aggregate

V. BARRIERS IN REUSING AND RECYCLE AGGREGATES IN TANZANIA

Acceptability of recycled material is hampered due to a poor image associated with recycling activity, and lack of confidence in using the product made from recycled materials (Rao *at al*, 2007). According to interview conducted in construction sector stakeholders e.g. contractors, consultants, regulatory bodies, building block manufacturer, C&D waste recyclers include:

- Acceptability of recycled materials by the building owners (clients)
- Lack of skilled people
- Lack of appropriate equipments
- Lack of appropriate technology
- Small quantity of construction and demolition waste generated compared to the demand of the materials
- Lack of awareness
- Lack of government support e.g. no policy in place directing the disposal of high potential recyclable materials like concrete rubble

- Bureaucracy
- No specific codes and standards for the recycled product(s)

VI. CONCLUSIONS AND RECOMMENDATIONS

There is building material scarcity problem in Dar es Salaam besides the demand is increasing. The rapid growing of the building construction and demolition activities generate more C&D waste i.e. concrete/masonry rubble. The low applications of C&D waste reveal that the waste material has the value in the local market. The recycling/upcycling of concrete/masonry rubble into valuable building is needed. By grading the crushed aggregates showed that the aggregates can be used for production of structural concrete element. The ongoing research is investigating the opportunity to recycle/upcyle the crushed aggregate from construction and demolition buildings to produce the load bearing blocks for building construction for sustainable construction and natural resource conservation.

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