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Recycling of Demolition Debris as Sub-base and Base Course in Road Pavements in Palestine

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Abstract

The amount of the destroyed building debris resulting from the Israeli aggression war on the Gaza Strip in December 2008 weighs approximately more than one million tons. This rubble spreads in several regions of the Gaza Strip in the form of accumulated piles causing an environmental disaster. For this reason , the rubble must be cleared away. This does not mean to throw it into the sea; building debris can be considered as a good source of construction materials that can be used alternatively for natural aggregate crushed rocks. Accordingly, this research shows how to use the mounds of rubble in road construction. After conducting relevant tests on the crushed debris generated by UN-crusher, results showed that this crushed material can be used successfully in the road pavement as subbase and base course. This means that the use of building debris in road constructions meets the technical, economic and environmental conditions based on the international, regional and local specifications and standards.

Keywords

Construction and Demolition debris , Crushed material , recycled aggregate, subbase and base course

1. Introduction

During the recent Israeli aggression war on the Gaza Strip between 18 December 2008 and 27 January 2009, thousends of buildings and hundreds kilometers of roads in addition to other structures of agriculture, telecommunication, electricity … etc. were damaged or destroyed (see Appendix). Preliminary estimates indicated that the amount of debris resulted from this aggressive attack weighs between (1,250,000 – 1,500,000) tons (Ministry of Housing, 2009). This rubble spreads in several regions of the Gaza Strip in the form of accumulated piles causing an environmental disaster. It can also form a real danger for people living in the region and especially for children who playing near the debris piles. Furthermore, the rubble of the demolished buildings is a fertile place for rodents and stray animals. Therefore the local government in the Gaza Strip has decided to clear the debris away. The removal does not mean here to throw the debris into the sea. The building debris can be considered as a good source of construction materials that can be used alternatively for natural aggregate crushed rocks. Several studies have been conducted on the recycling of debris and its usage in aggregate production for cement concrete and road pavements (Ahmed, 1993, Chan et al., 2001, FHWA 2004, Kelly, 2003, Klee, 2009). In the Gaza Strip there were also some attempts to study general properties of building debris as aggregates in cement concrete mixtures and in road pavements (Almassri, 2008, Rustom et al., 2007, Zuhud, 2008). In this research, it will be shown for the first time in the Gaza Strip how to use the demolished building debris as subbase and base course in the road pavements. This also means that the reuse of building debris in road constructions must meet economic technical and environmental conditions based on international, regional or local specifications and standards. *It will here be proved how to reuse the building debris in road pavements according to technical condition*. In other words, in order to achieve this main goal, it is required to investigate the suitability of the crushed debris generated by the available crusher in the Gaza Strip. Regarding the environmental conditions, an environmental assessment conducted by the United Nations Environment Program has shown that the building debris generated in the Gaza Strip can be reused decidedly (UNEP, 2009).

2. Research Methodology

In order to fulfill the purpose of this research, the following methodology has been followed:

1. Studying the engineering properties of crushed debris by taking samples from the crushing station and conducting all the required laboratory testing according to the international Specifications.
2. Studying and analyzing the engineering properties of base course and subbase layers made of recycled demolition debris.

3. Engineering Properties of Crushed Debris

In order to study the engineering properties of the crushed debris, it is necessary to conduct the following required laboratory tests : sieve analysis (AASHTO-T 27), specific gravity and absorption for fine and coarse aggregates (AASHTO-T 84), Atterberg limit tests (AASHTO-T89, AASHTO-T 90), Los Angeles abrasion test (AASHTO-T 96), soundness test (AASHTO -T 104), Proctor compaction test (AASHTO- T 180), California bearing ratio (AASHTO- T 193), Impact test (British standards 882). All tests are carried out in the Material and Soil Laboratory of the Islamic University of Gaza. The engineering properties of crushed debris are summarized in Table (1). The result of the sieve analysis is also given in Figure (1).

From Table (1), the crushed material has a maximum Los Angles value of (40%). Accordingly, its resistance to mechanical load (traffic) is acceptable. The structural layer coefficient according to the AASHTO at (CBR ≈ 176%) and at (degree of compaction of 100%) is larger than 0.14/in. This indicates that the crushed material has great value of bearing capacity against the heavy traffic load, because according to specifications of several road agencies or countries the minimum CBR is equal 80 for base course and 30 for subbase. The crushed material is also non-plastic and its liquid limit value is equal 17% (not greater than 25%). The results of the absorption test reveal that the samples have higher absorption value (approximately 5.0%) compared to AASHTO specifications (not greater than 3%). This is because the crushed material samples include more impurities; plasters, tiles and blocks which increase the absorption capacity. Considering the relatively dry climate in Palestine and particularly in the Gaza Strip the achieved absorption value can be considered as normal. Additionally, the value of soundness (11.4%) indicates that the sample is high durable and can resist bad weather conditions of freezing and thawing. According to AASHTO, the max. limit for soundness is 18%.

Based on the above discussed test results given in Table (1), it can be said that the properties of crushed building debris are mostly very close to the conventional materials for subbase and base course layers according AASHTO specification.

Table (1): Engineering properties of crushed building debris.

Technical Properties		**Test Results**
Los Angeles Abrasion		40%
CBR (100% compaction)		176%
Liquid Limit		17%
Plasticity Index		NP
Specific gravity (SSD) coarse		2.35 g/cm^3
Specific gravity (SSD) fine		2.52 g/cm^3
Specific gravity (OD) coarse		2.23 g/cm^3
Specific gravity (OD) fine		2.42 g/cm^3
Proctor	OMC	9.5%
	MDD (g/cm^3)	2.088 g/cm^3
Absorption % Coarse aggregate		5.33%
Absorption % Fine aggregate		4.38%
Soundness test		11.1%
Soil Classification		A-1-a

Regarding the conducted sieve analysis test, the examined samples of crushed building debris were sieved and the results have been compared with the standard values adopted by different agencies and countries. Most specifications of subbase and base materials of the following agencies and countries (AASHTO, ASTM, UK (Croney et al. 1998), Germany (ZTV SoB-StB, 2007), Palestine (PSI, 2004) state that aggregate to be used in subbase and base course must be almost equal to or smaller than 50 mm, so all larger particles are removed and returned to be crushed once more. Figure (1) shows the gradation curve (0/50 mm) of the crushed building debris. Accordingly, the crushed material can be considered as a Gap / well graded gravel (classification = A-1-a).

Figures (2 – 6) illustrate examples for the comparisons between gradation of the crushed building debris and required gradation for unbound base course according to AASHTO (type A) (Croney et al. 1998), German ZTV (type 0/56) (ZTV SoB-StB, 2007), and Palestinian PSI (PSI, 2004), and for unbound subbase according to UK Standard and ASTM (Croney et al. 1998). The comparisons show that the gradation curve of the crushed material sample lies mostly between the two standard limits of all presented specifications. It lies close to the lower standard limit which represents the coarse limit.

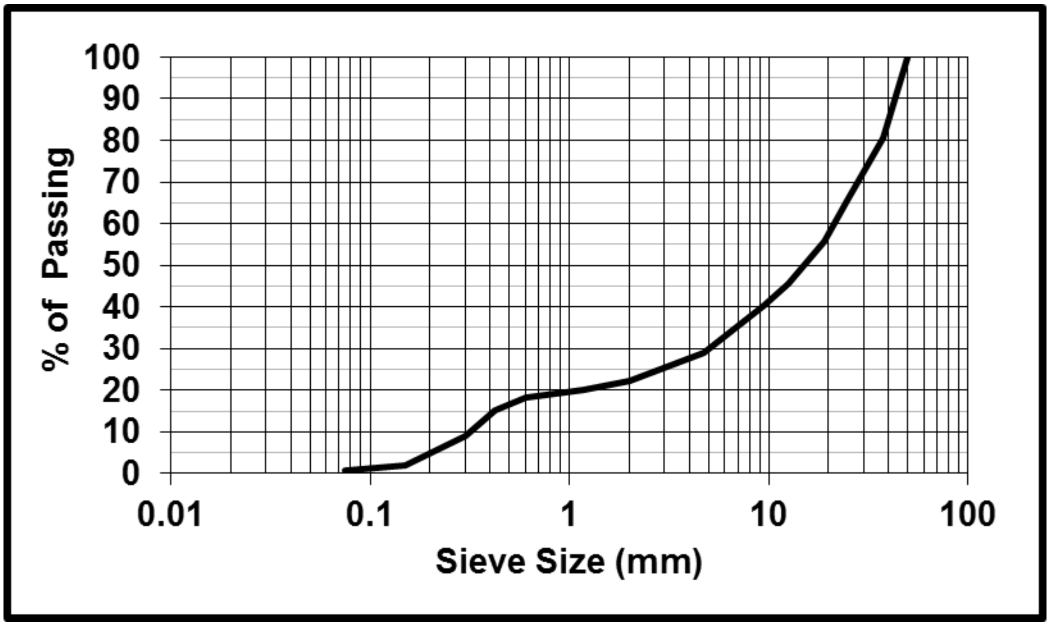

Figure 1: Gradation curve of crushed building debris.

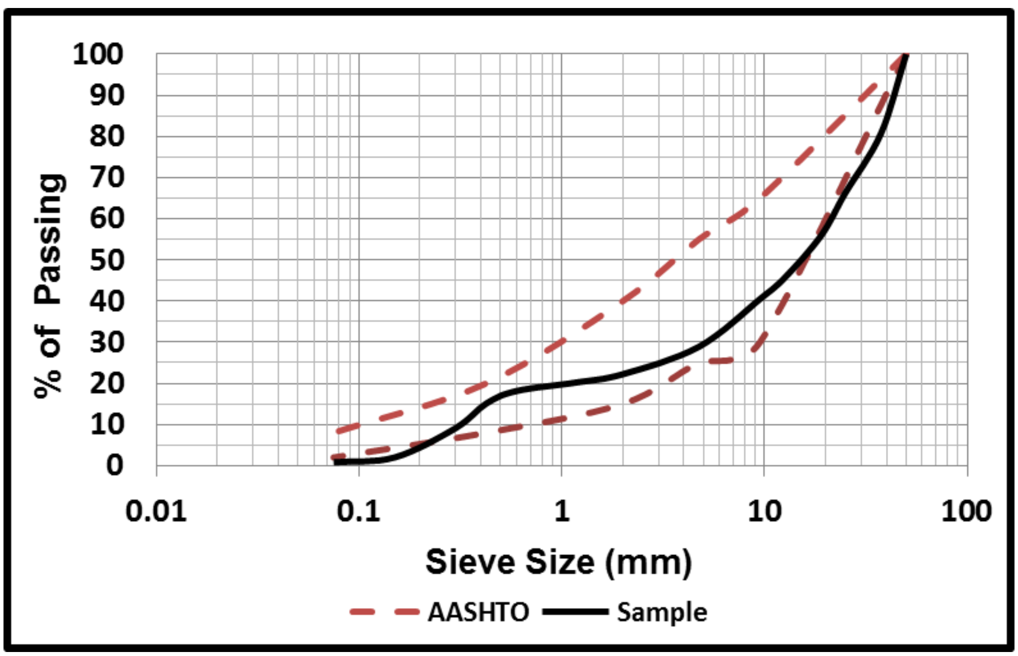

Figure 2: Gradation of crushed building debris compared with required gradation of unbound base course according to AASHTO (type A), (Croney et al. 1998).

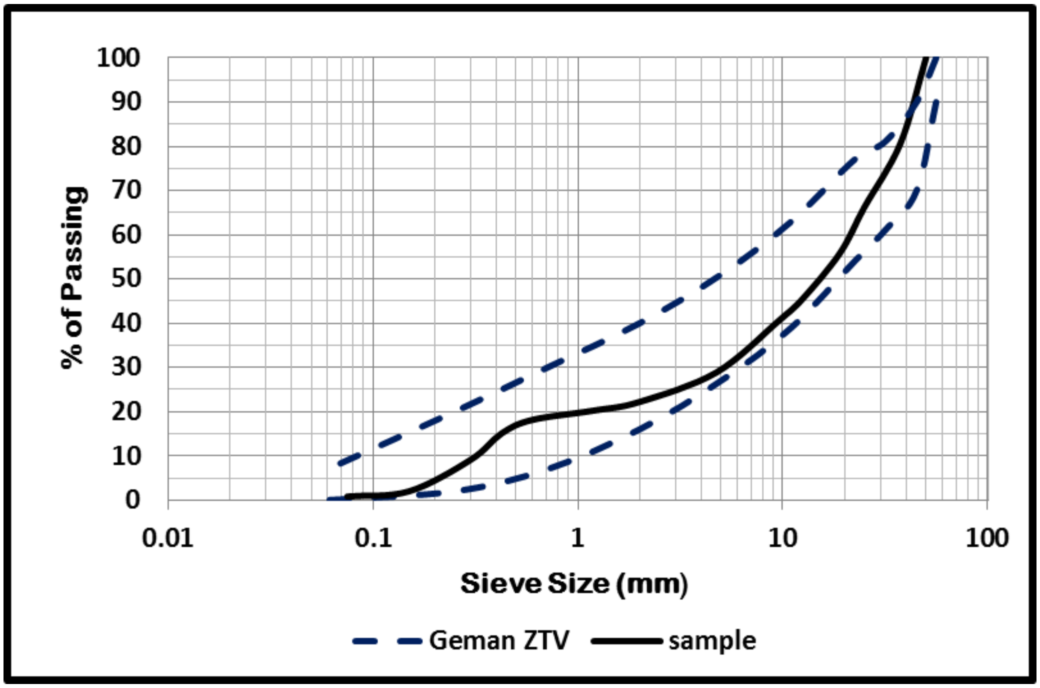

Figure 3: Gradation of crushed building debris compared with required gradation of unbound base course according to German ZTV (type 0/56) (ZTV SoB-StB, 2007).

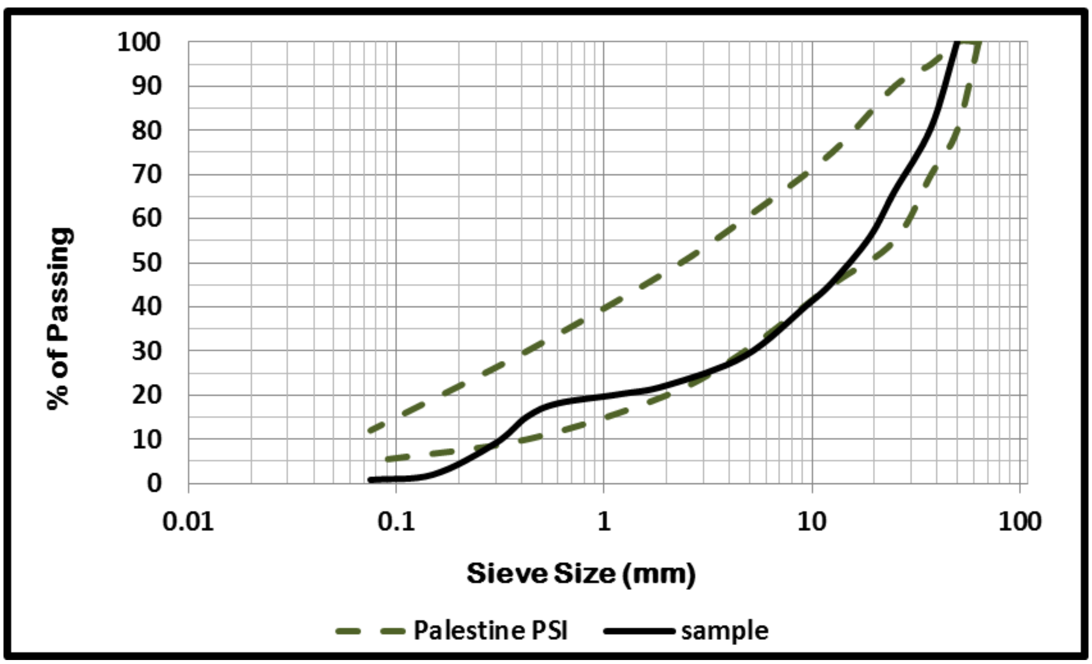

Figure 4: Gradation of crushed building debris compared with required gradation of unbound base course according to Palestinian Standard PSI (type A) (PSI, 2004).

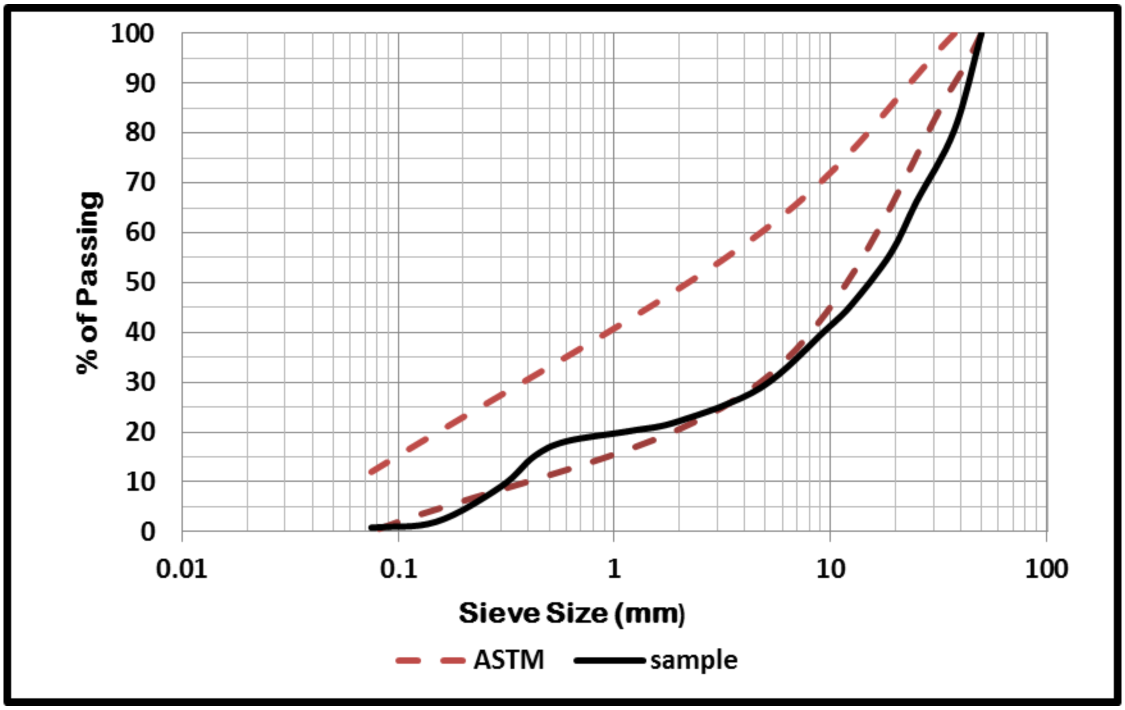

Figure 5: Gradation of crushed building debris compared with required gradation of unbound subbase according to ASTM (Croney et al. 1998).

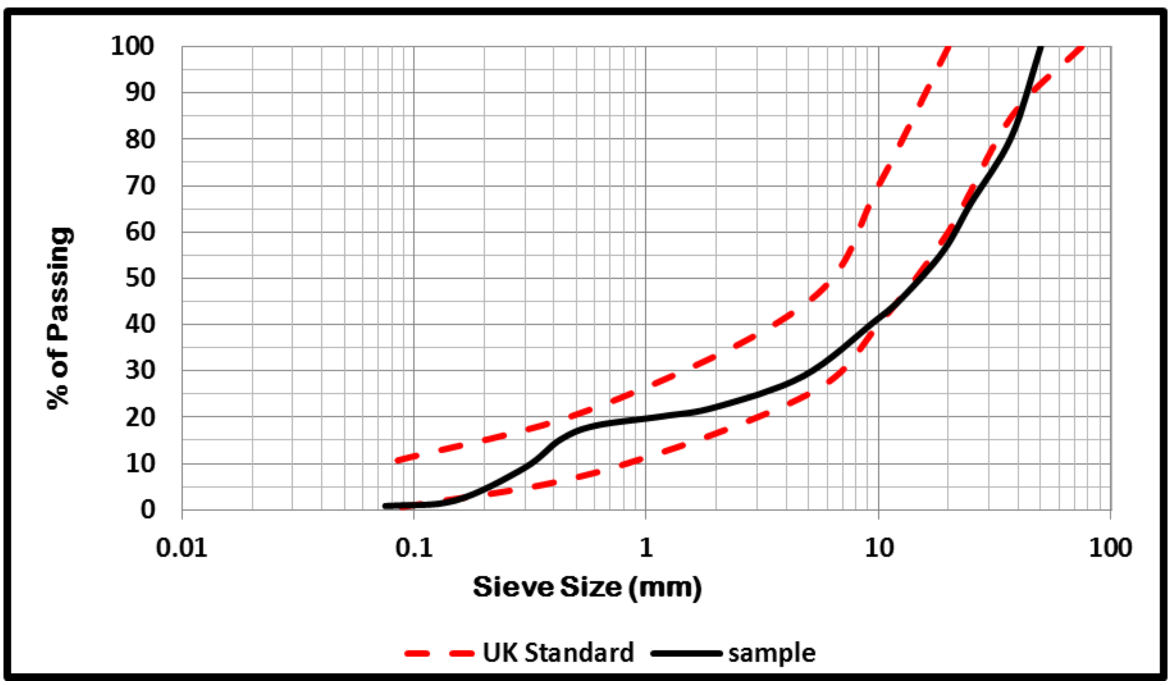

Figure 6: Gradation of crushed building debris compared with required gradation of unbound subbase according to UK Standard (type 1) (Croney et al. 1998).

From a technical point of view, the gradation can be considered as acceptable. However, the authors tried to modify the sample by adding fine material like local fine lime stone (gradation 0/4.75) in order to improve the sample gradation or at least to increase the percentage of fraction less than 0.075 mm. The existing of a limited amount of fine material less than 0.075 mm in the aggregate mixtures which are used for base and sub base courses increases the opportunity for the aggregate particles to be bounded. Figure (7) illustrates a comparison between a gradation curve of a modified sample (75% crushed building debris and 25 % fine lime stone 0/4.75 mm) and the gradation curve of the original sample (pure crushed building debris). It is here obvious that if 25% fine lime stone (gradation 0/4.75) is added to original sample, the percentage of fine fraction less than 0.075 mm will be enlarged from 0.8% to 3.8%.

Although the gradation curve of modified crushed material is slightly improved and it can be considered - due to this improvement - as well-graded material, other engineering properties like max. dry density, optimum water content and CBR aren't changed. The test results of the modified crushed material provide approximately the same values.

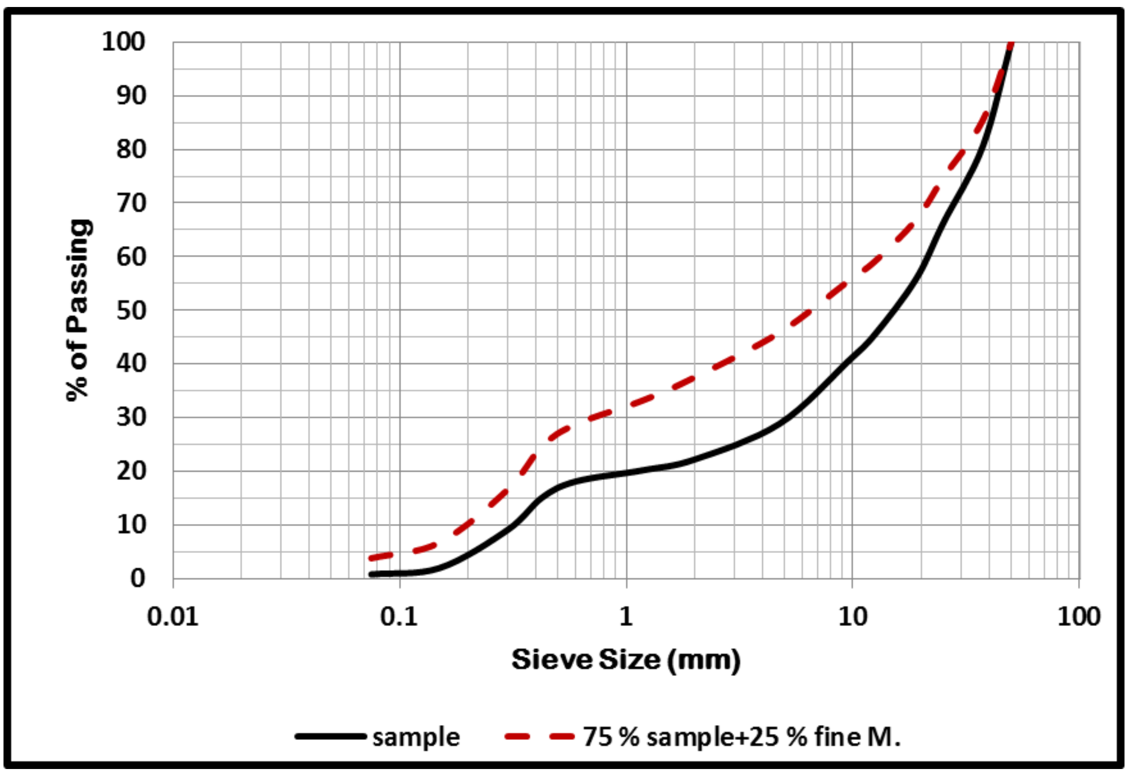

Figure 7: Comparison between gradation curves of original and improved crushed building debris .

4. Conclusions

In this research, extensive theoretical study of recycling of construction and demolition debris process was done. In addition to this, a testing program was followed to determine the technical properties of crushed material derived from destroyed buildings debris to investigate its adequacy to be used as subbase and base course material by comparing testing results with international and local specifications .The tested crushed material samples passed all tests and yielded good results except a small gradation problem that can be easily improved. So, from technical point of view construction and demolition debris is suitable for recycled aggregate production that will be used as subbase and base course material.

5. Recommendations

The Gaza Strip imports most of construction materials. These materials enter Gaza through the Israeli check-points. When the borders are closed by the Israeli forces, no material can enter, and the work in the construction projects is halted, especially in infrastructure projects. A locally available material such as recycled material has to be found in order to replace the shortage especially during border closures. Accordingly and due to the research results, it is recommended that:

1. Recycled aggregate (demolition building debris) be used in road pavements as subbase and base course material.
2. The gradation of the crushed material be improved by adding approximately 25 % fine material (lime stone) with a gradation of 0/4.75 mm to the crushed material.
3. Any of recycled aggregate components (concrete, block, tiles and sand) be made use of.
4. Further research be conducted to support the reuse of demolition debris in asphalt pavement layers.

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Appendix

Examples for destroyed buildings caused by the Israeli aggression war on the Gaza Strip in December 2008.