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POST-WAR RUBBLE REMOVAL AND POTENTIAL USE OF RECYCLED CONSTRUCTION RUBBLE IN GAZA GOVERNORATES

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Abstract: The last Israeli war on Gaza between December 27, 2008 and January 18, 2009 resulted in extensive destruction of homes, livelihoods and infrastructure facilities that generated a considerable huge amount of mixed concrete and non-concrete rubble. According to United Nations Development Programme (UNDP), after this war, nearly 600,000 tons of rubble was generated as a result of Israel's attack on private houses, public buildings, private sector and various infrastructure facilities in the Strip. This rubble was located in scattered areas within the five governorates of the Gaza Strip. The mixture of this rubble has been a big challenge for all actors involved in rubble removal activities. United Nations Environmental Programme (UNEP) damage assessment report-2009 indicates that the rubble contains at least 10% of hazardous material such as Asbestos and Unexploded Ordinances (UXOs) which required a special attention during rubble removal process in order to make it appropriate for producing crushed reusable aggregates.

This paper is a summary of various efforts exerted by different actors and institutions involved in rubble removal activities in the Gaza Strip. The paper includes actual actions taken towards reusing of crushed concrete rubble in construction industry. Consequently, the paper will focus on two main topics as follows:

a) Post-war rubble circumstances in the Gaza Strip. This includes methodology used to identify the quantity and quality of the rubble, means and proper actions for rubble removal and experience of different actors in rubble removal activities that lead to proper recycling and production of reusable construction material, and

b) Determination of technical/applicability of reusing the recycled rubble. This part includes test results conducted for crushed concrete rubble that assist to draw a clear picture of the applications of this material in the Gaza Strip. The characteristics of such aggregates were determined and compared to international standards. The reuse alternative is investigated in road and concrete constructions throughout all performed tests.

Key words: Construction Rubble, Crushing, Sorting, Recycling, Aggregates, Material Tests, Infrastructure, Gaza Strip.

إزالة أنقاضِ ما بعد الحربِ والاستعمال المحتملِ مِنْ أنقاضِ البناءِ بعد إعادة تدويرها في محافظاتِ غزة

الملخص: أسفرت الحرب الإسرائيلية الأخيرة على غزة بين 27 ديسمبر 2008 و 18 يناير 2009 تدميراً واسع النطاق للمنازل وسبل العيش ومرافق البنية التحتية نتج عنها كميات مهولة من الأنقاض الخرسانية. ووفقاً لبرنامج الأمم المتحدة الإنمائي (UND) ،فانه بعد هذه الحرب على غزة، فإن ما يقارب 600000 طن من الركام قد تراكمت نتيجة الهجوم الإسرائيلي على المنازل الخاصة والمباني العامة والقطاع الخاص ومختلف مرافق البنية التحتية في قطاع غزة. وتتمركز هذه الأنقاض في مناطق متفرقة في المحافظات الخمس في قطاع غزة. و لقد كانت طبيعة ونوعية هذا الركام تحدياً كبيراً لجميع الأطراف المشاركة في أنشطة إزالة الأنقاض. فحسب تقرير برنامج الأمم المتحدة للبيئة (UNEP) الصادر في2009 يشير إلى أن الركام يحتوي على ما لا يقل عن 10٪ من المواد الخطرة مثل الأسبست والمواد التي لم تنفجر (الذخائر غير المنفجرة) والتي تتطلب اهتماماً خاصاً خلال عملية إزالة الركام وإعادة تدويره.هذه الورقة عبارة عن ملخص لمختلف الجهود التي تبذلها مختلف الجهات الفاعلة والمؤسسات المشاركة في أنشطة إزالة الأنقاض في قطاع غزة. الورقة تتضمن الإجراءات الفعلية المتخذة من أجل إعادة استخدام الركام الخرساني بعد تكسيره وذلك في الصناعات الإنشائية و البناء والتشييد. وبالتالي ، وعليه فإن هذه الورقة تركز على موضوعين رئيسيين على النحو التالي:

1. الحالة العامة لأنقاض ما بعد الحرب في قطاع غزة. وهذا يشمل المنهجية المستخدمة لتحديد كمية ونوعية الأنقاض والوسائل والإجراءات المناسبة لإزالتها وتجربة مختلف الجهات الفاعلة في أنشطة إزالة الأنقاض التي تؤدي إلى إعادة التدوير السليم وإنتاج مواد البناء التي يعاد استخدامها ،
2. تحديد المواصفات الفنية والهندسية لإعادة تدوير الأنقاض. هذا الجزء يتضمن نتائج الاختبارات التي أجريت للركام الخرساني بعد عملية الطحن لرسم صورة واضحة حول تطبيقات هذه المواد في قطاع غزة. ذلك مقارنة بالمعايير الدولية.

الكلمات الرئيسية : الأنقاض البناء ، الطحن والفرز وإعادة التدوير ، اختبارات المواد ، البنية التحتية ، وقطاع غزة.

1. INTRODUCTION

In recent years, the recycling, reuse and reduction of concrete rubble in the Gaza Strip as in many developing countries have received increasing attention **[1]**. The main focus of the recycling effort has been on the concrete rubble and the production of recycled aggregate since concrete rubble makes up the largest segment in the Gaza Strip, especially after Israeli disengagement from Gaza ex-settlements where more than 400,000 tons of concrete rubble was collected and stored. In addition to this rubble, more than 600,000 tons of rubble is generated as a result of last war on Gaza in January 2009, beside hundreds tons of rubble generated annually. Only small fraction of all concrete rubble in the Gaza Strip (about 10%) is recycled and reused. The remaining is deposited on temporary UNDP crushing site west of Khan-Younis.

Generally, the idea of recycling concrete rubble has been gaining more interest in the Gaza Strip for the last few years especially after long time closures and siege on the Gaza Strip that resulted in an enormous shortage of construction materials imported from outside Gaza. The reason of this phenomenon is directly connected with economic and environmental considerations that play an important role in concrete recycling process **[2]**.

2. BACKGROUND

The Israeli military, on the morning of December 27th 2008, launched a military operation on the Gaza Strip. Israeli war planes and artillery had targeted a wide range of facilities and inflicted large scale human losses and infrastructure damage on the already impoverished and isolated population of the Gaza Strip. Thousands of houses, public buildings and industrial facilities were totally damaged as a result. To date, over 1,500 Palestinians lost their lives and over 5,500 were wounded. The majority of public and government institutions including municipalities, ministries, and police and civil defense stations were destroyed, depriving the population of basic services. **[3]**

However, the last war on the Gaza Strip was only one of various rationales that played big role in deteriorating infrastructure conditions in the Strip. The three-year closure had already left most of infrastructure facilities inadequate to function. Hence, people are not able to exercise many of their most basic rights and severely reduced their access to services, amidst collapsing infrastructure and acute shortages of power, water, shelter, food and medical services. Prior to 27 December 2008, nearly 80% of the population was already receiving aid of some kind. This proportion was increased as an impact of latest war. The food sector is projecting that the food-insecure proportion of the population will rise from 56% to over 76% as a result of the latest crisis. Initial assessments by humanitarian agencies have confirmed that supplies of fuel, the provision of medical, water and sanitation services, electricity, and shelter also remain critical **[4]**.

In particular, municipal services, especially solid waste and solid waste treatment, had to be curtailed, leading to the accumulation of hundreds of tons of rubbish on the streets each day. Restrictions on the imports of essential consumables (diesel and spare parts) and other materials also reduced the efficiency of the operation of sanitary landfills and garbage collection trucks. In addition, hundreds thousands tons of construction waste that was generated from the last war on Gaza accompanied with more than 400,000 tons of concrete rubble collected from ex-settlements created more complicated problems. One of these problems is how and where to dispose this massive volume of concrete rubble taking into consideration that almost all available landfills in the Gaza Strip are already overloaded.

To overcome solid waste storage problem, Municipality of Rafah was the first who carried out crushing activities in relatively large quantities. Funded by Italian Government, the municipality was supplied by a small scale crusher capacity of 70 tons per hour and started crushing of concrete rubble generated in the south of the Gaza Strip. The produced crushed material was used by the municipality in agricultural roads. Later on a small quantity was used by UNRWA in some roads in Tal El Sultan area in Rafah.

The next large scale crushing of concrete rubble was followed by UNDP after disengagement of Israeli occupation from Gaza ex-settlements. In 2006, UNDP was assigned by quartet to remove and crush more than 700,000 tons of mixed concrete rubble from Gaza ex-settlements. Nearly 400,000 tons of this rubble was removed in very good and clean conditions. Despite great efforts exerted by UNDP to complete crushing of collected rubble, the crushing process was suspended due to the closure and inability to bring in big crushers into Gaza.

In addition to these two large trials، some private companies in a very small scale started crushing of concrete hollow blocks and recycled it. This process took place in small blocks' and interlocks' factories in the Gaza Strip and showed successful results especially after vanishing of natural crushed stones from local markets due to extended siege on Gaza.

In parallel with recycling concrete rubble, many researches and tests were conducted focusing on potential reuse of this material in construction industry. Most of conducted tests were performed taking into consideration previous international experience in this field where more than 900 million tons of concrete rubble is annually generated and partially reused in USA, Europe and Japan. **[5]**. For this purpose, United Nations Industry Development Organization (UNIDO) in October 2005 conducted a testing programme to investigate the application of construction and demolishing wastes in construction industry in the Gaza Strip. The performed testing program aimed to highlight the possibility of producing recycled aggregates from the construction and demolition wastes (CDW) and was performed on a sample taken from concrete rubble in Rafah area. The characteristics of such aggregates were determined and compared to international standards. The reuse alternative is investigated in concrete mixes and road construction throughout comprehensive testing program. The test results showed that the recycling of the CDW aggregates and its use in both concrete and road sub-base gives acceptable results **[6].**

In addition to UNIDO testing Program, UNDP in May 2006 and October 2009 conducted two testing programs. Samples for both programs were taken from concrete rubble collected from ex-settlements and from post-war rubble. Slight differences between all tests were observed **[7]**.

Beside these practical tests, many other researches and tests for educational purposes were performed. Islamic University (IU) in Gaza through its master programs has encouraged many researchers to handle this topic. Tens of researches and master thesis were conducted showing good opportunities for using crushed concrete rubble in construction industry.

3. POST-WAR RUBBLE CIRCUMSTANCES IN THE GAZA STRIP

Immediately after 18th of January 2009, many institutions including local authorities, NGOs and International organizations have intervened to conduct damage assessment for all properties affected by the war that was ended in that date. Unfortunately, due to political reasons, efforts of different actors at the beginning of damage assessment process were dispersed. However, due to huge discrepancies among assessment reports produced, all parties had to find a unique way to cooperate and achieve solid data for their damage assessment process that was reflected on quantity of generated rubble as well as its quality.

For this paper, data on damage and rubble quantities and quality was collected from variety of sources and key stakeholders while the main source was UNDP damage assessment report, UNEP report and Gaza Early Recovery and Reconstruction Needs Assessment (GERRNA). Other sources were also used such as data from local authorities, ministries, NGOs, international humanitarian and developmental organizations and others.

To prevent any discrepancies in post-war damage data, a general methodology was adopted to verify possible conflicting information among different damage assessment reports as explained in Figure (1).

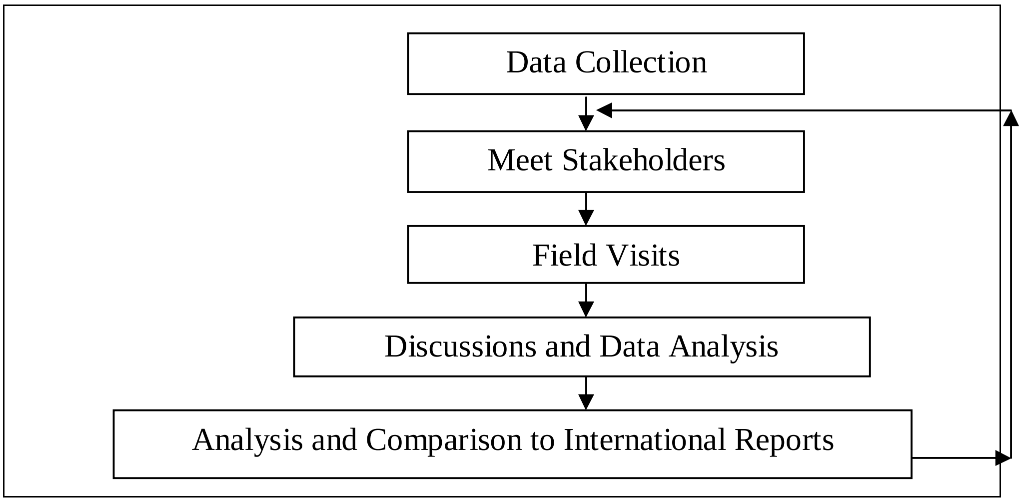

Figure (1): Damage Verification Methodology

3.1 Quality and Quantity of Post-war Generated Rubble:

3.1.1 Post-war Rubble Quantity

Two main techniques were used to identify the quantity of generated rubble in the Gaza strip. The first one was developed by Ministry of Housing and Public Works (MOHPW) and the other was adapted by UNDP as a result of its practical experience in rubble assessment during ex-settlements project. A wide difference between two methodologies was observed. The MOHPW's damage assessment had included all dead and live loads used in design of concrete buildings. That of course gave high records for rubble weight but in the same time reflected a clear picture about real damages from economical point of view. UNDP methodology was based on real weight of remaining concrete and non-concrete rubble that could be removed and reused. Neglecting design assumed loads in UNDP methodology provided more accurate weight of concrete rubble and facilitated the estimation of budgeting removal and reuse of this material.

3.1.2 Post-war Rubble Quality

To identify the quality of generated concrete rubble from construction and economical point of view it was essential to make both visual and sample inspections of all possible pollutants and contents of non-concrete materials. For this purpose, site visits carried out in the rapid as well as in detailed survey of damages. Detailed tests for hazardous materials, asbestos, and heavy metals was carried out by UNEP team that visited Gaza after the war **[8]**. Beside UNEP team, a group of mine removal experts has made a detailed assessment of each affected site and reported it for all actors working in rubble removal. The methodology and results of detailed quality and quantity assessment are shown in **Figure (2).**

3.2 Rubble Removal Achievements:

The process of post-war rubble removal is still on-going. Many actors are involved in this process such as Ministry of Housing and Public Works (MOHPW), UNDP, UNRWA, CHF, NRC and many others. Currently more than half of post-war generated rubble in Gaza Strip is removed. Nearly 150, 000 of clean removed concrete rubble was crushed and converted into reusable aggregate. **Table (1)** includes the quantities of removed rubble and number of removed sites by each actor.

Table (1):Post-war Rubble Removal Achievements in Gaza Strip (Updated May, 2010)

Area/ (Governorate)	**Removed Rubble (Tons)**	**Remove d Sites**	**Remaining Sites**	**Remaining Rubble (tons)**
Gaza/UNDP/(CIDA)	150,000	527	5	30,000
North/UNDP/(SIDA)	51,000	236	5	20,000
Middle and South	7000	20	0	0
CHF /All Areas	15,120	176	0	0
UNRWA/All	118,000	142	0	10,000
Local Authority/All	40,000	281	0	0
Totals	381,120	1382	10	60,000
Ready Crushed Material	**150,000 tons**			

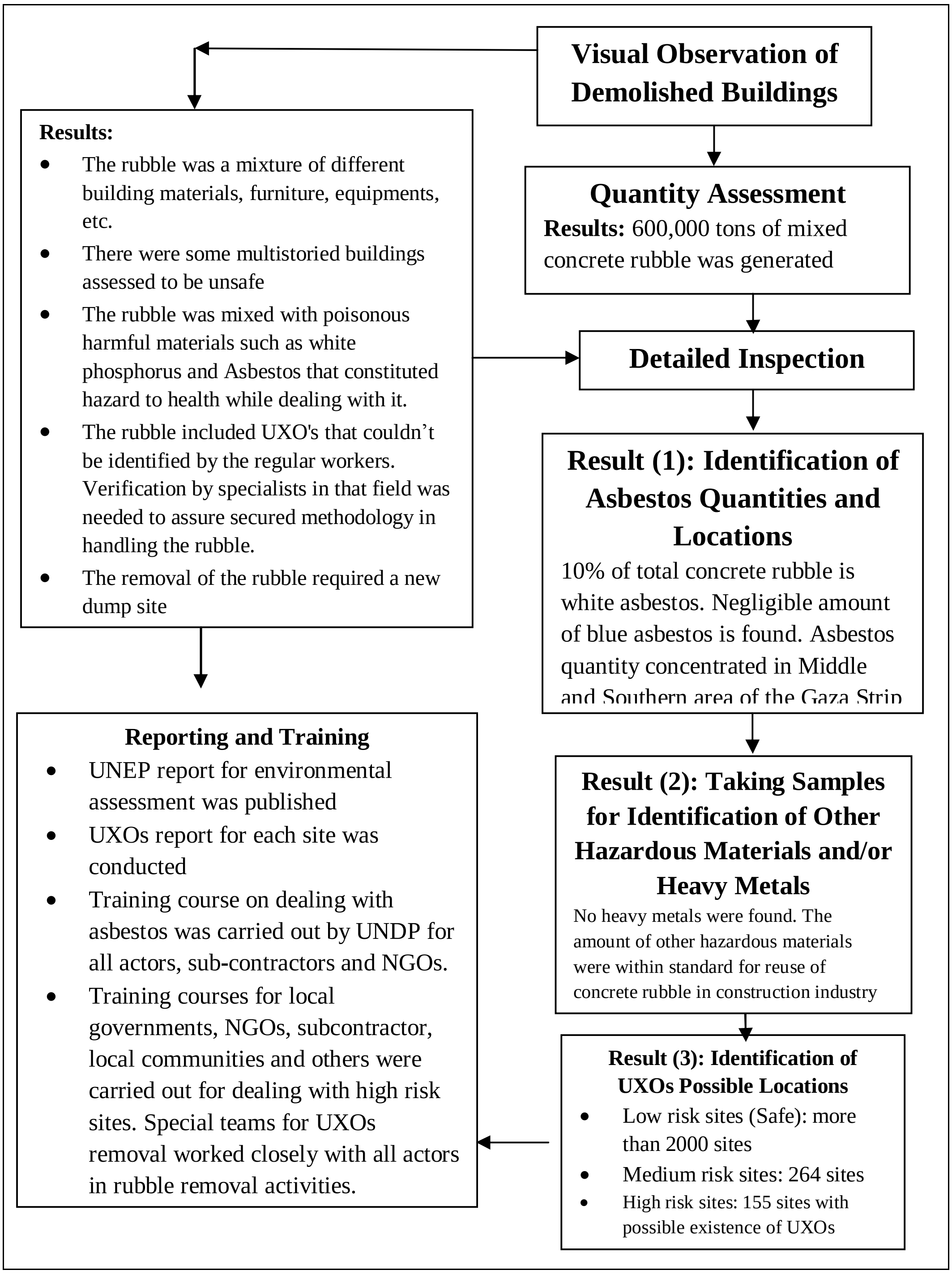

Figure (2): Detailed Post-war Rubble Assessment in the Gaza Strip

4. TESTING POTENTIAL USE OF RECYCLED CONCRETE RUBBLE

4.1 Summary of Testing Programme:

Producing of reusable crushed material was an essential step to obtain the best benefits from generated post-war rubble such as reducing the total volume of the rubble in already overloaded landfills and bridging the gap between demand and supply of construction aggregates in construction industry taking into consideration performing required tests that approve the application of such recycled material.

Therefore, the objective of testing crushed materials was to determine the technical feasibility/applicability of using the recycled concrete rubble collected from post-war affected sites in Gaza Strip in road construction as an alternative for the natural aggregate in road construction or other applications. Generally, the performed tests aimed to highlight the possibility of producing recycled aggregates from concrete rubble. The characteristics of such aggregates were determined and compared to international standards. The reuse alternative was investigated in road and concrete construction throughout all performed tests.

The test results showed that the recycling of the concrete rubble aggregates and its use in road sub-base gives acceptable results. Thus, recycled aggregates can be considered as a good alternative to natural aggregates especially in road constructions.

4.2 Design of Testing Program:

Two labs were supposed to carryout required tests. They are:

- Materials and Soil Testing Laboratory at the Islamic University of Gaza. **(IUL)**
- The Association of Engineers Laboratory **(AEL)**

Two teams from IUL and AEL labs arranged for taking a sample from 30,000 tons of crushed materials from post-war rubble. All tests were performed according to the international standards.

4.3 Analysis of Test Results

4.3.1 Sieve Analysis for Road Applications

The collected samples of crushed concrete rubble were sieved and the results were plotted on a logarithmic scale in order to compare the test results of the samples with the standard values of AASHTO for base course and sub-base materials grade (A). According to both labs, both samples showed that they were going down to lower standard limit which represents the course limit. Some of the samples were courser than the standard limits and others were slightly matching these limits.

From technical point of view, this gradation is acceptable to some extent. The large particles, greater than 2.5 cm are suitable for road applications.

However, for concrete application it is recommended to use small particles, smaller than 2.5 cm.

4.3.2 Sieve Analysis for Concrete Applications

For concrete application it was recommended to conduct three tests: Compressive Strength Test at 7 and 28 days, Slump Test and Air Content test by using small particles, smaller than 2.5 cm. These particles were available in the sieve analysis of the studied samples. In addition, the sieved particles are preferred to be classified according to the prevailing local market sizes and local common names in Gaza Strip which are: Folia, Adasia and Semsemia. Physical properties of these fractions as obtained from previous studies are shown in **Table (2).**

Table (2): Physical Properties of Concrete Aggregate Fraction

Commercial Name Used in Gaza	Size Fraction (mm)	Fineness Modulus	Unit Weight kg/m3	B.S.G	Absorpt ion %
Folia #5	25-4.75	7.42	1478.5	2.65	3.13
Adasia	12.5-4.75	6.89	1468.1	2.6	3.0
Semsemia	9.5-2.36	5.72	1526.6	2.55	2.0

Concrete mix was designed based on the physical properties obtained, at three different water/cement ratios. The labs used mix design of the Ministry of Public Works and Housing. The labs prepared the concrete samples (mixing, placing, and curing). Mixing was done using 0.20 m^3 rotating drum mixer. Standard procedures were followed in concrete mixing and specimens' preparation (cubes).

4.3.3 Results and Analysis of Gradation Tests

Results of the sieve analysis for the collected samples in comparison with AASHTO standards for road applications showed that the crushed material is classified as coarse material greater than 4.75 mm (sieve no. 4). As shown in **Table (3)**, the coarse and fine materials in the samples were on average of 76.68% and 23.32% respectively. The amount of course materials according to AASHTO should not exceed 70% and for fine materials 40%. This means that an additional amount of fine materials should be added to increase the percentage of this material.

Table (3): Course and Fine Aggregate Contents

LAB	Coarse Aggregate (%)	Fine Aggregate (%)
IUL	82	18
AEL	71.36	28.64
Average of two labs	76.68	23.32

4.3.4 Results and Analysis of Other Required Characteristics

Table (4) shows the test results for other essential requirements of crushed concrete comparing to international standards

Table (4): Test Results of Essential Characteristics of Concrete Rubble

Test Name	Standard	Average Result	Standard Requirements
Liquid Limit	BS 1377	20.25%	According to AASHTO and ASTM for sub-base and base materials, this value should not exceed 25%
Specific Gravity	ASTM-854	2.35	Lower than crushed natural rock stone
Absorption	ASTM-2216	5.55 %	
Finer than #200 sieve (%)	ASTM-1140	1.95	
Clay lumps & Friable Particles (%)	ASTM-142	0.15	According to BS 882-1992 this value is very low which is advantage for construction application
Flakiness Index	BS 812	24.5%	According to BS 882: 1992 this value should be less than 40% for road construction.
Elongation Index	BS 812	9.1%	According to BS 882: 1992 this value should be less than 40% for road construction.
Max. Dry Density	ASTM-1557	1.97 gm/cm3	Local CODE 2.15%
Optimum Water Content	ASTM-1557	10.25%	
Los Angeles Abrasion Test	ASTM-131	41.75%	AASHTO maximum allowed value, to be used in the road construction as base course material is 45% at 500 Rev.
California Bearing Ratio “CBR” at 100 Rev.	ASTM-1883	163%	Minimum required value (80%) for base course at 100% compaction according to AASHTO (T180-D) and T 193.

Sand Equivalent	ASTM-2419	66.6%	local standards for base course: Minimum 35% sand equivalent at any stage of road construction.
Impact Value	BS 812	28%	According to BS 882. 1992: this value is SUITABLE
Crushing value	BS 812	26.15%	

4.3.5 Results and Analysis of Concrete Mix

The results of concrete tests conducted for concrete mix by using crushed material at different water/cement ration are illustrated in **Table (5).**

Table (5): Test Results of Concrete Mix.

W/C Ratio	Compressive Strength (kg/cm^2)		Slump (5 min.) mm	Air Content (%)	Density (kg/m^3)
	Average 28 days	Average 7 days	Average Result	Average Result	Average Result
0.65	262.7	176.75	197.6	2.45	2242.9
0.58	309.7	221.65	140.65	2.70	2244.0
0.50	361.5	261.0	58.80	3.20	2260.6

Comparing results in **Table (5)** with international standards for concrete mix, the following observations could be obtained:

- According to (ASTM C143-90a) Standard, the average of 197.6, 140.65 and 58.8 mm for slump test indicates good performance and workability of concrete mix.
- According to (ASTM C231-91a) the air content results are within acceptable range.
- The average unit weight of concrete was 2249 kg/m3 for all samples where the unit weight of local concrete is about 2400 kg/m3. This could be justified as the unit weight of the recycled aggregate itself is smaller than the natural crushed aggregate. Also the percent of air content measured in control mixes is lower than the mix produced using recycled aggregate.
- A local mix design was used (Ministry of Public Works and Housing B250 Nominal Mix). This mix gives about 250 kg/cm^2 of compressive strength at 28 days at water to cement ratio of 0.6 and 290 kg cement content. The test results were above expectations and showed, to some extent, good indications. All values of 28 days tests were above the control value of 250 kg/cm^2. Most Tests at 7 days and 28 days showed high results compared to the control samples of natural materials. However, the results could be justified as the following:

a) The samples of crushed materials were selective and free of impurities.

b) The materials were handled, mixed and tested under high control conditions.

In addition, the ratio of 7 days to 28 days for compressive strength of concrete varies from 60% to 80%, which is within the normal ranges.

5. FINANCIAL and ENVIRONMENTAL BENEFITS

No doubt that the Post-war generated rubble was a big challenge for all population of the Gaza Strip as well as for all institutions dealing with environment and construction industry. The huge volume of the rubble accompanied with limited places and landfills to store the rubble had seriously threatened the overall environment in the Gaza Strip. In addition, the shortage of construction materials beside the high prices of very limited available construction materials especially natural aggregate made the recycle of concrete rubble as one of top priority for reconstruction process after the war. Fortunately, during removal and crushing process of post–war rubble in Gaza, almost all actors had taken into consideration the main principles to obtain best financial and environmental benefits from the whole recycle process such as protection of public health and insuring sustainability of recycling achievements **[9]**. These benefits could be summarized in two main domains: financial and environmental benefits.

5.1 Financial Benefits

After removal of a large amount of post-war generated rubble from affected sites in the Gaza Strip, the prices of sorting, removal and crushing of this material showed that the recycling of concrete rubble could be very competitive to natural crushed stone that has been using in roads and concrete industry. The removal process showed that the collected rubble contained nearly 10% of non-concrete reusable materials such as steel, wood, aluminum and others. The cost of these materials varied from 15-20 US$ per ton that reduced the total cost of removal and crushing process. In addition, the sale price for crushed concrete rubble that used in roads construction was around 7.5 US$ per ton. This price was much higher and exceeded 30 US$ per ton after screening of crushed concrete and producing aggregate for concrete construction. **Table (6)** shows the costs of removal and crushing process and cost recovery of the whole process.

Table (6): Cost Recovery of Post-war Rubble Removal and Crushing in Gaza

Process	Cost in US$/ton	Local Market Price in US$/ton
Sorting of Non-concrete Materials (10%)	0.5	15-20
Demolition and primary crushing	4	0
Transporting to crushing site	1.5	0
Crushing	4.5	7.5-30
Total	**10.50**	**22.5-50**
Local Market Price of one ton natural crushed aggregate (in normal conditions)	US$ 15.38	

As shown in **Table (6)**, the cost of demolition, transporting and crushing one ton of concrete rubble does not exceed US$ 10.5 where the benefit from such process varies from US$ 22.5 to US$ 50 per ton which is very competitive. In addition, the cost of one ton of natural crushed aggregate exported from outside Gaza is around US$ 15.38 which is higher than the total cost of the whole removal and crushing process. Moreover, the removal and crushing of concrete rubble had generated more than 150,000 job opportunity which contributed in reducing poverty conditions in the strip.

Therefore, from economic point of view, the removal and crushing process as a whole has several advantages **[10]**. The most illustrative advantage could be summarized as follows:

- Closing the material cycles for concrete rubble within its own chain. With regard to the framework of sustainable development, this fulfils one of the objectives of required sustainability.
- Recovery of suitable raw materials for construction industry that reduces the excavation of primary materials such as sand and gravel and reduces the export of expensive aggregate.
- Generated new job opportunity
- The removal and crushing process finally implies a reduction in transport costs and reduced the damping fees and landfill’s running costs. This means less fuel consumption and less exhaust gases.

5.2 Environmental Benefits:

In this time of increasing attention to the environmental impact of construction and sustainable development, recycled crushed concrete has much to offer because of its efficiency to minimize depletion of natural

resources and its direct positive impact in reducing the total area for storing huge volumes of concrete rubble **[11]**. As the available solid waste landfills are already overloaded in the Gaza Strip, any additional quantities will only make the problem more complicated. Reducing the amount of concrete rubble and reusing it in construction industry will facilitate storing of other solid waste quantities produced by residents of the Strip and will facilitate the process of collecting and transporting organic waste from households.
Moreover, sorting of non-concrete and hazardous materials from concrete rubble before crushing decreased the affect of such material on human welfare. Tests showed that the post-war rubble concrete contained around 10% of asbestos and some UXOs that were a big threat for human health. Removing these items and materials and storing them in a proper way had reduced this hazard to the minimum.

6. CONCLUSION and RECOMMENDATION

Recycled Concrete Rubble (RCR) seems to have satisfying properties for the most common exposure conditions. It can solve many of the basic problems concerning shortage of construction materials in roads and concrete construction. In addition, As natural resources diminish, the demand for recycled concrete aggregate is likely to increase, making concrete recycling the economically and environmentally preferable alternative to traditional “smash and trash” demolition. Wherever good natural aggregates are not locally available, where natural aggregate costs exceed removal and recycling costs or where disposal of existing concrete pavement or concrete structures is problematic, concrete recycling should be evaluated.
Moreover, concrete recycling appears to be profitable. In most cases, it can meet demand requirements of lower value product applications such as road base, thereby freeing up higher quality material for higher value applications. While studies have shown that RCR can be used as aggregate for new concrete, there is a need to obtain long-term in-service performance and life cycle cost data for concrete made with RCR to assess its durability and performance. If additional researches support the use of RCR, then existing specification should be revised to permit and encourage the use of recycled concrete as aggregate.

Generally, based on the results of all performed tests, it is recommended, at the first stage of the recycling of concrete rubble, to consider the utilization of this material in roads construction. The major proposed applications for recycled aggregate are:

- General bulk fills.

- Base or fill in drainage projects.
- Sub-base or surface materials in road construction.
- Agricultural and rural roads
- Bedding material under or around underground wastewater or water pipes.

However, field performance tests are necessary at a later stage to measure the value of Modulus of Deformation, which is considered as an indicator to the bearing capacity of pavement layers.

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