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Title: Reuse of Demolished Building's Debris in Post war Construction

An approach to conservation of traditional architecture

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1. Introduction:

"if God had not enabled people to defend themselves against one another, corruption would surely overwhelm the earth". 2.251.
"if God had not enabled people to defend themselves against one another, all monasteries, churches, and mosques, would surely have been destroyed". 22.40

Translation of the Holly Quran

Mediterranean is the interchange pot of civilizations, which have moved along its shores, rarely by trade, while mostly by conflicts and wars that brings destruction also. Recently, wars have been spreading in the Mediterranean from Bosnia, Albania, Cyprus, Lebanon, Israel and the ongoing destruction of Palestine, threatening the people, the built environment and the local architectural heritage.

Developed countries with limited resources can not afford total re-building of demolished cities, as what happened in the southern district of Beirut at July 2006, where thousands or even millions of tons, of rubble have to be disposed, while roads have to be cleaned for post war construction. Thus, re-use of building debris is very important for sustainable development, having many benefits as followed:

- Minimizing cleaning cost and time for reconstruction.
- Reduction of transportation cost for disposal of debris and new materials.
- Saving in material cost by utilizing recycled materials.
- Eliminate disposal of waste to landfill sites, which become full and costly.
- Conserving the environment.
- Selling recycled building materials or purchasing at lower costs, which is usual for the poor, who got used to buy second-hand building materials.

Moreover, recycling into the same architecture has a cultural crucial role probably more beneficiary than economics and environment. Bevan thinks that "the destruction of symbolic buildings and the physical fabric of cities is not merely collateral damage, but a deliberate intention by the attacker, to dominate and eliminate the memory, history and identity of the opposing side…The war in Bosnia saw an almost complete destruction of a unique and beautiful Islamic heritage, whose existence was simply denied by local Serbian" (Bevan 2006). Although, he argues, that "rebuilding in post-war cities or restoration of damaged buildings can never re-create their originality, the author thinks that rehabilitation by reusing some original material with new similar ones, could keep the image and the psychological feeling of traditional architecture.

Recycling of war demolition waste was first carried out after the Second World War in Germany to tackle the problem of disposing large amounts of demolition waste caused by the war and simultaneously generate raw material for reconstruction. Dresden was destroyed by the firebombing during World War II**,** where the largest rebuilding efforts ever in Europe, took place to restore many historical buildings. There is considerable research in advanced countries for recycling building waste, which has demonstrated possibility of using construction waste to substitute new materials. They are enforcing recycling in solid waste management rules, requiring that demolition debris, which composes about 50%, should be separated from the waste stream and segregated into recyclable and non-recyclable materials (Sherman 1996). Hopefully, most civilian buildings are demolished partially after wars, thus rehabilitation accounts for most of the building construction. However, war demolishing is different having many levels, analyzed latter by this study, after defining the related technical terms.

2. Definitions

Reuse: the subsequent use of a material, product, or component upon recovery.
Recycling: remanufacture materials into new products.
Building demolition: knocking down, or explosion of a building.
Debris: pieces of materials & rubble resulting from knocking down, or explosion.

C&D waste: Construction and demolishing remains.
Enriched uranium warhead: radioactive weapon using fuel of nuclear reactors.
Depleted uranium warhead (DU): a weapon treated by the waste product of uranium enrichment process, which is less radioactive than enriched uranium.
Deconstruction: systematic disassembly of a building in economical and safe way, to re use materials and recover rare items like old umber or antique fixtures***.***
Segregation: Keeping materials separated by type until they recycled.
RCA: recycled concrete aggregates.

3. Research problem:
There are many studies and applications of recycling and re-use of planned (civil) demolishing debris, but there is a scarcity of information about war demolishing except for land mark buildings. For instance, literature review shows that Dresden cathedral were rebuilt stone by stone using sophisticated computer modeling tool to restore its original shape, costing €180 million (Wikipedia, a).
This goes beyond the capabilities of most governments, nevertheless, ordinary people who have limited resources and seeks the know-how. Moreover, there is almost no data on the technical aspect of post-war construction of traditional vernacular architecture.

4. Aim, objectives and limitations:
The aim of this study is to drive the attention to the value of war demolished buildings' debris, and provide a technical and economical approach to the conservation of traditional architecture. The paper objective is to set up a planned process of re-using building rubble in the same architecture. It is expected that people would reconstruct their buildings, with limited means, through civil societies and building communities to help each other.
The research is concerned with traditional architecture, built with conventional local materials and techniques. It does not deal with conservation or rebuilding of monumental buildings, requiring sophisticated resources. This study is limited to the technical aspect of re-building, not design or policies, with special focus on the walls and floors' rubble which forms most of the debris.

5. Demolishing types:
5.1. Planned demolishing; by a specialized contractor, who can recover usable materials between 25% in old buildings, and 75% in new buildings. IT has been reported that this process saves up to 30% of the building cost (TIFAC).
5.2. Natural disasters' demolishing: caused by floods, earthquakes, tornados etc., their effect could be more than war demolishing. For instance, the 2001 earthquake of Gujarat, India has devastated a large number of villages and towns. This earthquake had a profound effect on structures of all types; ancient, modern, traditional masonry and contemporary reinforced concrete (UNESCO).
5.3. Systematic hostile demolishing; using bulldozers and tanks against non-military buildings. For example, crushing historic buildings in the ancient Casbah in Nablus, Palestine in 2002, was described by the head of the Israel Museum, as "non-existent damage " (Bevan 2006).

5.4. Demolishing using fire bombs, known as incendiary bombs, designed to start fires using materials such as napalm, or white phosphorus, causing extreme temperatures that could destroy most buildings made of wood or other combustible materials. However, buildings constructed of stone tend to resist incendiary destruction unless they are first blown by high explosives.(Wikipedia.b)**.** Although UN Protocols on Conventional Weapons prohibits the use of incendiary weapons against civilians, Israel has used phosphorus bombs in Gaza and Lebanon (Fisk 2006).

5.5. Dirty war demolishing; to prevent humanitarian aids and delay reconstruction, e.g. Israeli army flooded southern Lebanon with cluster bombs before war ends (Worker, J. 2007)**.** In this particular demolishing type, mine clearing should precede reconstruction.

5.6. Non-usable demolishing debris; **using radio-active weapons**. American and British forces used depleted uranium (DU) shells in Bosnia and Iraq, where years later, a plague of cancers emerged across large areas**.** More over, Israel has used enriched uranium weapons in Gaza and Lebanon (Fisk 2006). The particles of the explosion are very long-lived in the environment, and spread over long distances. It is believed that the weapon is highly carcinogenic and harmful to the environment (Rapoport 2006). Thus, recovered components and debris should not be re-used, nevertheless living in the hit area.

6. Re used materials from building debris:

Recovered materials are different according to type of demolishing and the building structure, whether wall bearing or skeleton. It is known that Mediterranean traditional architecture is usually built of stone or brick, and of wooden floors and roofs in northern and eastern regions. Wood composes about 20 % of the debris, while it is less in south of Mediterranean, as floors could be arched stone or brick. Because the largest portion of the debris is rubble, it would be studied in detail, by the end of this section. The following is a short literature review on the feasibility of recycling various C&D waste:

6.1. Wood is easily burned however, waste can be processed and used for landscaping, compost, or engineered building products. Wood chips could be compacted and injected with cement grout, to produce wood-concrete, which could be swan and nailed, to provide low-cost wood alternative (Kassai 1995). Construction timber is often treated with chemicals to prevent Termite infestation therefore it needs special care during disposal. Other problems associated are inclusion of jointing, nails, screws and fixings. Recovered wood components, in good condition are reused as it was, to preserve the building image.

6.2. Metals such as copper, bras, lead, aluminum and steel with its different types are generated during demolition in the form of pipes, conduits, sheets, wires and bars. These are the easiest and most cost-effective materials to be reused directly if in good shape. In fact, **steel** is Europe's most-recycled material with an average recycling rate of 50%. Reinforcement bars and sheets could be straightened, while scrap could be re-melted in metal yards (Ozkan 2000)**.**

6.3. Glass sheets are reusable if intact, while broken pieces can be recycled into fiberglass or used in place of sand in paving material. Glass fragments is easily processed into a number of new materials; mineral wool, to substitute quartz in sanitary ware, and to produce light-weight structural concrete.

6.4. Isolation materials e.g. asphalt layers and bituminous materials are commonly recycled, by hot or cold mixing technique either at location or at a central asphalt plant.

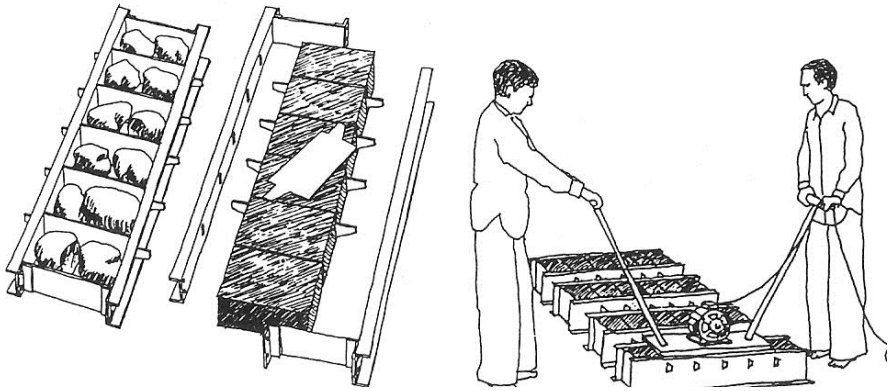
6.5. Marble floors and cladding sheets could be used even broken, in smaller sizes, by pre casting with same color terrazzo mortar, to produce larger sheets.

6.6. Sanitary ware can also be re-used if they are not chipped or cracked, but if they are, It would be better to be crushed and used as construction infill. Crushed and powdered sanitary have a pozzolanic nature same as other clay products, which could be used to produce low cost cements (Stulz & Mukerji 1993).

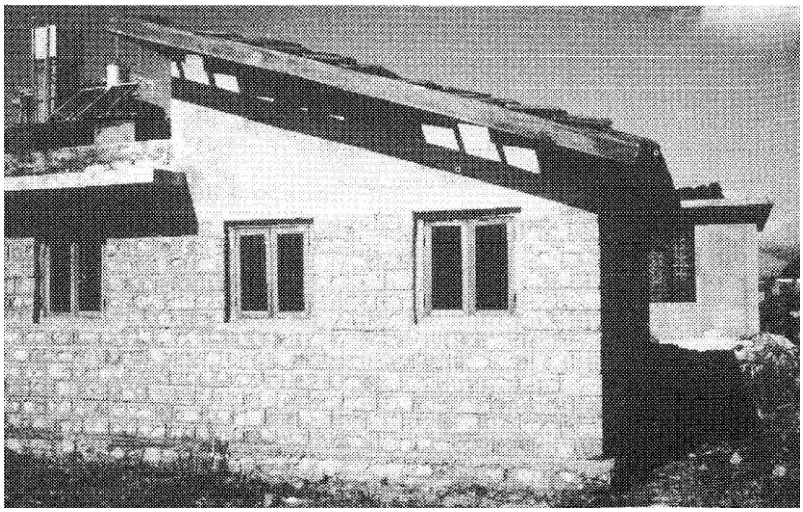
6.7. Demolition rubble containing masonry elements and concrete can be processed in crushing plants using wet or dry system, to produce recycled aggregates suitable for stucco works and concrete blocks of acceptable quality (Pernia&Ramos&Suarez&Malave 1996). Many studies have shown that RCA can be used as aggregate for new concrete.

6.7.1. Brick rubble is usually mixed with 20 % cement or lime mortar, could be reused, if they are not contaminated or mixed with vegetation or organic matters. Broken and discarded brick can be used as construction infill or aggregate for non-structural concrete. Recovered brick with minimal damage is ideal for building rehabilitation.

6.7.2. Stone has been used widely in traditional architecture for several structural purposes, according to its properties (Abd-Elmaksood 2006). As a natural material, having different ages and color, it should be reused, even broken pieces, mixed with new similar stone, to sustain the building identity and soul. Partially damaged stones could be recycled as pre cast stone blocks, mixed with same color mortar in moulds at the same size of original stones (Fig. 1). During casting, it must be noticed that stone rubble, should face the ground, to be seen in the façade latter (Fig. 2) (Stulz & Mukerji 1993).



(Fig. 1) Filling the mould with rubble stones and compacting.



(Fig.2) Stone masonry construction using pre cast rubble.
(Stulz & Mukerji 1993)

7. Concrete is the most used building material for the last century, even in traditional load bearing architecture, in foundations, sub layers and instead of wooden floors, especially in the southern of the Mediterranean. Because rubble reuse could reduce the volume of debris by 80% (US army 2004), it would be studied in depth, through the required steps and available technology as follows:

7.1. Steps of recycling rubble:

1. Checking the building site and clearing of left unexploded objects.
2. Choosing or Clearing a suitable area for material segregation. Quick removal of debris is necessary to start rehabilitation work (Fig.3).
3. In-site segregation for different recovered materials and for impurities.
4. Material classification into state (damaged, partially…) or graded sizes.
5. Clay brick rubble is crushed and used with lime as a binding material.
6. Concrete and masonry waste are crushed to produce a granular product of given particle size (Fig.4). Plants for processing of demolition rubble – RCA- are three types, differentiated based on mobility, type of crusher and process of separation.

7.2. Types of RCA plants (TIFAC):

1. Mobile plant; the material is crushed, screened and ferrous impurities are separated through magnetic separation. The plant is moved to the site and is suited to process only non-contaminated concrete or masonry waste.
2. Semi-mobile plant; removal of contaminants is carried out by hand and the end product is also screened. Magnetic separation for removal of ferrous material is carried out. End product quality is better than of a mobile unit.
3. Stationary plants are equipped for carrying out crushing, screening as well as purification to separate the contaminants. Issues necessary to Stationary plant are: plant location, road infrastructure, availability of land space, provision of weigh-bridge, provision for storage area etc.

(Fig. 3) Material segregation.

(Fig. 4) Rubble crushing.

7. Conclusion:

Developed Countries with limited resources can not afford re-building of demolished cities, where rubble piles have to be disposed. Thus, re-use of building debris in post war construction is crucial for sustainable development, having many benefits; economical, environment and more important cultural**.** Recycling the same material, built by traditional techniques, could preserve the local architectural heritage, keep the memory and identity of the nation.

Different demolishing types were analyzed, showed that some debris, e.g. radio-active, cannot be recycled. Most materials could be reused after segregation and classification, e.g.; damaged brick, stone and marble sheets are recycled into pre-cast blocks and terrazzo tiles blended with new similar material.

As the largest portion of the debris is rubble, and its recycle could reduce the volume of debris by 80%, it was studied through the required steps and available technology, which turned to be simple and inexpensive. Masonry and concrete rubble are crushed to produce a granular product of given particle size suitable for stucco works and concrete blocks. RCA could substitute 30% of natural coarse aggregate of new concrete. Crushing plants for processing of demolition rubble –RCA- are three types, based on mobility, type of crusher and process of separation. A mobile unit could be procured at low investment, useful for low quantum of waste and easily moved to the demolition site avoiding cost of waste transportation. To promote this technology, governments should first apply it on traditional public buildings, housing, and provide incentives in the initial phase.

The study has managed to set up a planned process of re-using building rubble, providing a technical and economical approach to conservation of traditional architecture.

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