QUARRYING AND INERT LANDFILLING – A LANDSCAPE ASSESSMENT IN MALTA

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Abstract
Malta is a small island state of 315.59km2, with a high population density and therefore large demands on the land use. This scenario causes extensive pressure on the limited mineral resources, and also with regards to waste disposal. The extraction of aggregate and masonry blocks, for the construction industry, is carried out using open-pits, which lead to numerous negative impacts on the landscape. Quarrying alters completely the terrain, leaving scars in the territory, destroys the natural habitat and disrupts the geomorphological processes and the aquifer recharge. Due to the relatively small size of Malta, quarries tend to invariably conflict with the various land uses.
Malta depends heavily on landfills for waste disposal. This is a very land-intensive option, and without proper management, landfills lead to significant environmental problems. The disposal of construction and demolition waste constitutes a major challenge in Malta. The main strategies adopted in the case of construction and demolition waste are related to inert landfilling and recycling. The reduction of wastes and reuse of building materials, recycling and the proper disposal of building waste in approved sites are also promoted. Land reclamation is also discussed as a possible alternative. The utilisation of disused quarries for the disposal of inert waste has the advantages of providing a solution for both the disposal of construction and demolition material and also for the regeneration of these degraded areas. Quarries are therefore rehabilitated and eventually used for agricultural purposes. The effect of quarries on the landscape, their distribution and strategies for rehabilitation, are discussed in view of the surrounding land uses, environment and spaces. The potential disposal of inert waste in disused quarries leads to the eventual rehabilitation of heavily degraded areas.

Introduction.
Malta is a small island state of 315.59 km^2, with a high population density of 1,274 persons/km^2 in 2005 (1). The limited land area and high population density give rise to extensive pressures on the limited resources and inevitable land use conflicts. Both the extraction of mineral resources, and the disposal of waste generated, present major challenges for strategic future sustainable development.

Mineral Extraction in the Maltese Islands.
The development of the urban fabric in the Maltese Islands has relied on local limestone, and as a result, minerals extraction is an integral and important element of the Maltese economy. Mineral Extraction areas amount to 1.2% of the land cover of the Maltese islands (1). Limestone is broadly grouped into "softstone" (locally known as "Franka") quarried from the Lower Globigerina Layer, and "hardstone" that is quarried from the Upper and Lower Coralline Limestone layers.

Softstone is fine grained and homogenous, and is normally cut into blocks of standard size as the main building material. Extraction takes place by cutting the limestone with saws into blocks of standard sizes. Softstone quarries have large vertical-sided faces, and usually have a depth between 30 to 60 metres (2). In some cases, existing quarries had reached their land limits and were extracting at deeper levels, while older softstone shallow quarries were reopened for deeper extraction. An estimated total demand of 4 million m^3 of softstone over a 10 year period is computed.

Hardstone quality varies considerably even within a single quarry. It is classified into two classes, the first is hard and nonporous, and the second is soft, porous and less resistant to weathering. Hardstone is quarried through drilling and blasting, and marble-like material and crushed aggregates are produced. The latter is processed in crushers and screening plants, and used mainly in civil engineering applications. Fluctuations in demand can be experienced in view of major projects. An estimated total demand of 7.5million m^3 of hardstone over a 10 year period is computed.

It is estimated that annual production of softstone is around 400,000 m^3 and hardstone around 740,000 m^3. However, historically, data on production has not been comprehensive (3). Permitted reserves are in the region of 13.5 million m^3 of softstone and 28.5 million m^3 of hardstone, estimated to provide adequate production for 34 years (softstone) and 38 years (hardstone) at current production rates. The future need for hardstone and softstone in the Maltese islands reflects the construction activity in the country. Estimates reveal that part of the material extracted mostly from softstone quarries is discarded and cannot be used for construction, with important repercussions on the sustainability of the quarrying industry.

Distribution of Quarries.
The natural distribution of mineral resources has significantly influenced the location of quarries. However urban and other developments, natural and cultural sites and environmental constraints reduce the islands' exploitable limestone resources. In 1999, the overall surface area occupied by licensed softstone quarries was approximately 1.1 km^2, and that occupied by licensed hardstone quarries was approximately 1.3 km^2 (4).

While in 2002 the number of licenses and active softstone quarries has decreased from 70 to 66 since 1989, the number of hardstone quarries has increased from 26 to 28 (5). Softstone quarries are concentrated in Mqabba and Siggiewi in Malta, and Dwejra in Gozo. Hardstone quarries are sparse and are found in areas along the west and northwest coast of Malta and in central areas in Mosta and Naxxar, the south of Malta and eastern Gozo. Hardstone quarries occupy an ever increasing proportion of the quarrying footprint, primarily due to an increasing demand for hardstone, with a decreasing demand for softstone.

In many instances, most worked out quarries were left abandoned without reclamation. Table I. shows the extent of areas affected by quarrying outlining operating, derelict and restored quarry sites, in 1988 (6).

Quarry Type		Hectares (%)		
	OPERATING	**Derelict**	**Restored**	**Total**
Softstone (Malta)	77.6 (30%)	37.6 (14 %)	21.8 (8%)	137 (52%)
Hardstone (Malta)	76.7 (29%)	15.6 (6%)	6.9 (3%)	99.2 (38%)
Softstone (Gozo)	16.0 (6%)	1.2 (0%)	5.0 (2%)	22.2 (8%)
Hardstone (Gozo)	5.9 (2%)	- (-)	- (-)	5.9 (2%)
Total	176.2 (67%)	54.4(20%)	33.7(13%)	264.3(100%)

Table I. Extent of areas affected by quarrying in 1988.

The Impact of Quarrying on the Landscape.
Limestone quarrying has always been an important activity for building purposes, as is evident in various archaeological sites. Quarrying is carried out using open-pits, altering completely the terrain, leaving scars in the territory, valleys and along coastal zones, destroying the natural habitat, disrupting geomorphological processes and aquifer recharge, and invariably conflict with the various land uses (Fig. 1. & Fig. 2). Explosives used in hardstone quarrying threaten the stability of valley slopes and adjacent building development. With the increasing size of quarries, and the expansion of the footprint of built up areas including residential, industrial and recreational spaces, the proximity of quarries to other land uses has been unavoidable (Fig.3, Fig.4 & Fig.5.). Quarries may also be located in the vicinity of ecologically sensitive areas and areas of archaeological importance.

Secondary impacts can be generated on other economic activities such as in agriculture when quality soil and agricultural land may be damaged as a spill-over effect. Tourism activity also suffers a negative spill-over effect in areas of conflict, from unsightly and polluting activities. Unsightly stockpiles and unusable rubble, mechanical plant buildings that characterise quarry sites generate considerable landscape damage. The building of access roads and the generation of traffic by heavy vehicles to service quarries, may cause substantial damage also to surrounding areas. Potential contaminants, and the deposit of refuse and oils in quarries pose a threat to ground water and water courses. Noise, air pollution and dust generated by the quarrying activity are particularly related to the use of mechanical equipment, especially drilling and blasting in hardstone quarries, and have a negative impact on adjacent land uses. Following the setting up of the Local Planning Agency, and the formulation of strategic plans (7), quarrying activities including blasting and effect on the aquifer are being assessed and monitored in order to mitigate the environmental impact.

The total built-up area of the islands has increased drammatically from 4.5% in 1960's, to 23% in 2001 (8). Limestone is a non-renewable natural resource, and intensification of the building industry and economic factors tend to accelerate the rate of depletion of the resource. Moreover, in some areas, quarries were abandoned prematurely, and quarrying areas were built upon with the expansion of the urban areas. The fact that limestone is a non-renewable natural resource constitutes an important consideration in the assessment of the quarrying and construction industry. At the same time, mineral resources constitute an important input to the Maltese economy, providing the main raw material for the construction industry. Although the proportion of GDP generated by the sector is relatively low in comparison to other sectors in the economy, however it has important linkages with other domestic sub-sectors (9).

Fig.1 *Fig.2*

Fig. 1: Aerial view of Softstone Quarries in the South of Malta, and surrounding agricultrual land & airport.
Fig. 2: Aerial view of a Hardstone quarry and surrounding agricultural land at Mgarr Malta. (Source; Waste Serve Malta)

Waste Generation
Malta depends heavily on landfills for waste disposal. This is a very land-intensive option, and without proper management, landfills lead to significant environmental problems and adverse visual impact on surrounding settlements (Fig. 6). The major waste fraction by weight generated in Malta is construction and demolition waste, amounting to 88% in 2004. The trend of increase in the construction and demolition waste generated since 1996, indicates an overall increase of 112% due to major construction projects (10).

The landfills are filling up quickly since the large volume of material takes up a lot of space at the disposal sites. Consequently new disposal sites are required, with adverse impact on the limited Maltese territory. Alternative disposal options for construction waste are therefore required. Disposal of construction waste, together with municipal and industrial possibly toxic waste, is unsustainable since it reduces the possibility of material recovery.

The base material in local construction waste is limestone, varying in size from boulders to fines. However construction waste can be inert or mixed. In addition to limestone, construction waste may contain concrete and steel reinforcement, soil and vegetation, ceramic and cement tiles, glass, timber, plastic, and other materials. Inert construction waste is expected to be the non-combustible, non-dangerous solid waste fraction which retains its physical and chemical structure under expected conditions of disposal, including resistance to biological and chemical attack (11). Inert construction waste should not pose a threat to human health or the environment. Non-inert waste loses its physical and chemical structure upon disposal and can produce gas or leachate during decomposition. Mixed waste containing a small percentage of non-inert material, can be problematic and potentially harmful to human health and the environment.

Rehabilitation of old Dump Sites
The solid waste disposal sites at Maghtab, Qortin and Wied Fulija were developed at a time when the full environmental impacts of such operations were unknown. Therefore waste was disposed of, rather than managed, with concerns related to human health and negative environmental impacts as a result of leachates and gases. This led to the implementation of a solid waste management strategy to reach environmental standards associated with waste management. Malta's main dump sites were closed during May 2004. The rehabilitation of the three mentioned dumping sites is now being carried out through the introduction of the necessary environmental measures that include the reduction of the aerial impacts of the landfills, the eventual re-contouring of the waste as required for particular end-use requirements and the establishment of a vegetative cover, and the

control of aerial emissions. Following the implementation of the complete restoration, it is anticipated that the sites could serve a number of after-uses. Structural Funds have been obtained from the EU, for capital funding for this rehabilitation programme (12).

Following the closure of the old dumping sites, an engineered, non-hazardous, waste management facility (Ta' Zwejra) started operating during May 2004, with the necessary infrastructure to operate a facility for Municipal Solid Waste (MSW) with a combined gas recovery system and leachate re-circulation set up. All the necessary investment has been made to ensure an environmentally safe facility. Ta' Zwejra is the first permitted engineered landfill which has an IPPC (integrated pollution prevention permit) Permit in Malta (13).

Fig. 3

Fig. 4

Fig. 3. Quarrying activity and the village of Mgarr, Malta in the distance.
Fig. 4. Quarrying activity in a valley; Wied il-Ghasel, Mosta, Malta.

Fig. 5

Fig. 6

Fig. 5. Quarrying activity and nearby residential development at Mosta, Malta.
Fig. 6. The Main Dumping Site at Maghtab, and the surrounding landscape.

Waste Management
A number of potential waste management options can be adopted with respect to inert construction waste. Measures to minimise construction waste can include; incentives to encourage rehabilitation of existing structures rather than reconstruction, incentives to encourage the use of recycled construction materials and reuse of stone blocks, storing stone from demolished buildings and reduction in waste generated during quarrying activity. Indirect strategies can also include; the reuse of the vacant property in Malta (23% of housing stock) rather than constructing new buildings, technical research in the reuse and recycling of construction materials, and the consideration of alternative construction techniques (14)

Various potential reuse and recovery options have been considered or adopted in Malta. These include the reuse as cover-up material for landfills; use as a soil substitute; reuse of good quality stone blocks selected at source or material processing as aggregate for selected applications; and use in civil engineering works, land reclamation and inert landfilling in quarries.

In view of the high level of urbanisation and lack of open space, land reclamation projects have been considered to be particularly relevant, also with regards to the disposal of inert waste. Land reclamation works have been carried out in the past years in the development of the Malta Freeport, construction of wharfs and sea terminal. In particular the disposal of inert waste at sea, will increase the present landmass (15). The impact of land reclamation on the sensitive and dynamic coastal environment of the Maltese Islands has to be assessed and supported by specialist investigation of wave and wind action, exposure, environmental impact and other studies.

Quarry Rehabilitation

The possible afteruse for a quarry will depend on a combination of factors, that include the local demand for different uses, responding to land use pressures, the physical nature of the site and its present capability, the site characteristics required for the new use, the costs of converting between present capability and new use requirements, the surrounding land use and immediate neighbouring areas, and access and infrastructure available. Eight possible afteruses for quarry rehabilitation were identified (16): agriculture; forestry; built development; sports facilities; country parks; wildlife, conservation and education; water storage and supply; and land filled waste disposal.

In the past, some disused quarries had been crudely restored or rehabilitated, or partly infilled with inert quarry and construction waste, scrap, and domestic refuse. Some disused quarries were filled with debris and soil, and transformed into agricultural land and orchards.

While mineral extraction continues to supply the construction industry, the formation of large voids in the landscape continued over the years with little effort and concern for reclamation of the land. The utilisation of disused quarries for the disposal of inert waste has the advantages of providing a solution for both the disposal of construction and demolition material and also for the regeneration of these degraded areas. Land reclamation of disused quarries involves the disposal of well sorted and thoroughly inspected excavation and construction waste (Fig. 7. & Fig. 8). In 2004, most of Malta's inert waste (circa 98%) began to be depositied in approved quarries, thus reducing pressure on other waste facilties. Inert waste not contaminated by other waste fractions, therefore makes it easier to recycle in the future if necessary (17).

Fig. 7. Inert Landfilling in a Hardstone quarry at Mgarr, Malta.

During the first nine months of 2004, a total of 1.6 million tonnes of construction waste had been deposited in various disused quarries undergoing rehabilitation. In the period May 2003 to August 2005, over 3.57 million tonnes of construction waste have been disposed of in various quarries across the island. These quarries have been scars in the landscape for years and are now being rehabilitated into agricultural land. The cost for the disposal of construction waste in quarries has increased considerably during 2004, to Lm 1.09 incl VAT/tonne (c.2.6 Euro), and increased further to Lm1.40 incl VAT/tonne (c.3.3 Euro) as from the first of January 2005 (18). This increase in the disposal of inert waste may eventually encourage the minimization and reuse of inert waste. This may influence the demand on the minerals extraction industry.

With the number of construction projects currently on the increase, more disused quarries are expected to be rehabilitated in the future. In general it is difficult to rehabilitate quarries, while limestone is still being extracted, due to the relatively small footprint of the individual quarries. Either disused quarries or disused parts of large quarries can therefore be utilised for inert landfilling. Rehabilitated quarries in the vicinity of urban development restore the open agricultural space outside the built up areas, and the strategic open spaces between settlements.

Fig. 8. Inert Landfilling in a Hardstone Quarry, Malta.

Conclusions

The extraction, use and subsequent disposal of minerals generates considerable environemntal impact, not all of which can be effectively mitigated. The vision for the future of the quarrying of limestone in Malta, should include a management plan that works within the parameters of the principle of sustainable development, for such a finite resource.

Inert waste management strategy is implemented in the context of the various options for inert waste reduction, reuse, recycling and disposal. Inert land-filling of construction waste constitutes an option that is being carried out to alleviate the inert waste disposal problem, and at the same time reinstating the scars in the Maltese landscape resulting from the quarrying industry. However, the key elements include the separation of inert fractions at-source, and the land-filling of the material in selected quarries under strict supervision. It is practically impossible to restore the natural terrain. Yet the rehabiliation of disused quarries is an important step in the restoration of the landscape, while addressing the important issue of inert waste management.

The economic benefits of the construction industry have to be balanced with environmental considerations. Alternative options for inert waste that include also inert landfilling in disused quarries, and land reclamation, should be considered also in view of the limited land resources and conflicting land uses in an Island State.

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