In the eyes of the public, quarrying is not an environmentally friendly operation because it produces vibration, noise and dust. This was certainly the case in Hong Kong in the 1960s and 70s when permit quarries were operating. No rehabilitation programmes were included in the works at these small sites and little consideration was given to environmental aspects. The high, near-vertical rock faces that were formed as a result remained as permanent scars on completion of quarrying.

However, the concept of quarrying started to change quite significantly in the 1980s, particularly with the endorsement of the Government’s Metroplan Landscape Strategy for the Urban Fringe and Coastal Areas in 1989. This identified quarries as areas of degraded landscape requiring improvement and recommended early rehabilitation of existing contract quarries using the revenue-earning quarrying operation to produce the required final landform. Improvement works typically involved major re-contouring, mass planting and erosion control.

Since then major changes have been made to quarry contracts. There are now four quarries in operation in Hong Kong: Anderson Road; Shek O; Lamma; and Lam Tei. The first three sites are based on new contracts — the so-called quarry rehabilitation form of contract — that were negotiated in the 1990s, whereas Lam Tei Quarry is operated under a quarry contract. In all these contracts a major component of rehabilitation/landscaping is included and much focus and consideration is placed on environmental aspects and the conservation of natural resources. The aim of the projects is simply to revert the site back to a natural-looking state or to turn a once bare-looking eyesore into an area covered with trees and vegetation which is in harmony with the natural environment and suitable for future development.

This paper gives details of the arrangements and practices adopted at the existing quarries and explains why quarry rehabilitation is a ‘win-win’ situation for the environment, the Government and the community of Hong Kong.

Fig. 1. Location of existing quarries in Hong Kong

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Table 1. Details on the four quarries

<table>
<thead>
<tr>
<th>Quarry</th>
<th>Contractor/consultant</th>
<th>Year of commencement</th>
<th>Year of completion</th>
<th>Size of site, ha</th>
<th>Size of rehabilitated area (slope and platform area), ha</th>
<th>Possible final land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson Road</td>
<td>KWP Quarry Co. Ltd/Ove Arup &amp; Partners</td>
<td>1997</td>
<td>2013</td>
<td>86</td>
<td>77</td>
<td>Residential</td>
</tr>
<tr>
<td>Shek O</td>
<td>Pioneer Quarries (HK) Ltd/SMEC Asia Ltd</td>
<td>1994</td>
<td>2009</td>
<td>45</td>
<td>30</td>
<td>Residential &amp; recreational</td>
</tr>
<tr>
<td>Lamma</td>
<td>Lamma Rock Products Ltd/Binnie Black &amp; Veatch HK Ltd</td>
<td>1995</td>
<td>2002</td>
<td>49</td>
<td>34</td>
<td>Recreational &amp; sewerage pumping station</td>
</tr>
<tr>
<td>Lam Tei</td>
<td>Asia Stone Co. Ltd/SMEC Asia Ltd</td>
<td>1982</td>
<td>2003</td>
<td>30.5</td>
<td>23.5</td>
<td>Highway project</td>
</tr>
</tbody>
</table>

**CURRENT ARRANGEMENT OF QUARRY REHABILITATION WORKS**

The locations of the four quarries in Hong Kong are shown in figure 1, and details on each of the quarries are summarized in table 1. Anderson Road Quarry first started in 1956 as two quarries (Tai Sheung Tok and Anderson Road 3) but was combined into one rehabilitation quarry in 1997. Shek O and Lamma quarries commenced operations in 1965 and 1960, respectively, and were converted to rehabilitation quarries in 1994 and 1995. Lam Tei Quarry is operated under a quarry contract which also requires the contractor to complete the rock excavation based on an approved landform and landscaping plan within a definite timescale.

**Quarry rehabilitation/quarry contract**

A quarry rehabilitation/quarry contract, in addition to being an industrial undertaking, is essentially a large site formation contract with rehabilitation/landscaping being the main focus. It is a revenue-earning design-and-build contract in which the site will be developed into a pre-approved landform suitable for subsequent residential and/or recreational use. Under the terms of these contracts, fixed time periods are defined, together with penalties for non-compliance, and the contractor has no rights to rock extraction after the expiry of the contract period.

The term 'revenue earning' means that the contractor pays the Government for the rights he enjoys under the contract, such as selling or removing rock from site or processing excavated rock for sale. These activities produce earnings for the contractor which are used to cover the cost of the rehabilitation works (new roads, man-made lakes, landscaping etc) which the contractor carries out for the Government in association with the contract.

**Parties involved**

The management procedure involved in a quarry rehabilitation/quarry contract is shown in figure 2. The contract is signed between the Government and the contractor. On the Government side, the supervising officer and his representative, including resident site staff, act as the employer’s representative to administer/supervise the contract. The site agent, on behalf of the contractor, is responsible for the superintendence of the works and receives directions and instructions from the supervising officer and his representative.

During the quarrying and rehabilitation process, the contractor employs a design consultant and a landscape consultant, as well as a design checker, to carry out the design work and design check respectively. The design is vetted by all interested Government departments. The contractor is also required to comply with various contractual requirements (environmental control, safety etc). The supervising officer and his representative monitor the works to ensure that they are carried out to the standards required. They also monitor ➤
the programme and progress in accordance with interim milestones, the collection of rent/royalties, and the safety aspects.

**WIN-WIN SITUATION...**

**For the Environment**

Reducing impacts on the environment

A quarry rehabilitation contract is usually a long-term undertaking, taking more than 10 years to complete. As a result, the contractor is more willing to spend time and effort investigating and adopting innovative ways to reduce impacts on the environment and attending to matters affecting the environment and the community.

In the case of Anderson Road Quarry, the innovative methods that have been initiated and used by the contractor to reduce impacts on the environment include glory holes and tunnels, and drop-cut areas.

Glory-hole method: With this method, a vertical shaft with an inlet at the high point and a connecting tunnel at the lower point are constructed within the hill (see fig. 3). The rock excavated at the high point is dumped into the shaft and delivered, via a conveyor belt in the tunnel, to the processing plant at the low point. This arrangement has the advantage of increasing the efficiency of moving excavated rock materials from the high point to the low point, as truck movements within the quarry are reduced. Moreover, as the quarrying is carried out within concealed areas, visual and environmental impacts are also greatly reduced.

Drop cut: Drop-cut operations involve the excavation of a large void in the quarry floor, as shown in figure 4. This is a balanced cut-and-fill approach — the rock excavated from the floor is used for processing and the void produced is used to house the overburden, waste and other unsuitable rock produced in the quarry. This arrangement has the advantage of reducing truck movements outside the quarry and hence less noise and dust are produced, and less fuel is consumed.

Like many other works projects, environmental impact assessments are carried out for quarry rehabilitation works before they commence. Air quality, noise, water quality, waste disposal and blasting are assessed and assessment criteria are established. Mitigation measures and monitoring and audit requirements are also specified.

Once the works commence, regular environmental control, monitoring and auditing is carried out. Environmental issues, such as the effects of the operations on any future development works in close proximity to the site, are assessed and measures taken to mitigate the impacts on the environment in compliance with the Environmental Protection Ordinance. As can be seen from figures 3 and 4, modern processing equipment, including enclosed crushing plant and conveyors, is used to minimize any environmental impacts during the quarrying process.

**Producing a ’green’ site in quarries**

The quarry rehabilitation works include re-contouring and extensive planting. Flattening and planting of the slopes is carried out progressively from the top of the hill to the bottom, so that ’greening’ becomes apparent.
at an early stage. Depending on the final land use, the overall angles of the slope surface created range from 35° (scree slope) to 55° (bench slope), as shown in figure 5. Different methods have been adopted for different sites, taking account of the original landform and possible future land use. A soil mantle comprising completely decomposed granite, organic conditioners and nutrients is placed on the flattened slope for the planting of vegetation. To produce a site with a stable, natural-looking vegetated final landform, typically the following work is carried out:

**Landscape strategy:** Before the works commence, a landscape strategy for the site is established. In the case of Shek O Quarry, the contractor worked closely with the landscape consultant to map out a landscape strategy for the site long before the works commenced. All salient features, including woodland areas, ridge lines, beaches, main stream courses, local communities, sites of special interest, flora and fauna etc in and around the Shek O site were identified (fig. 6). Using this information the planting details were decided. For example, on the western side of the site a fire-resistant vegetation belt was proposed between the site and the adjacent areas to provide fire protection. On the eastern side a cliff feature was included to act as a physical fire barrier between the site and the adjacent Site of Special Scientific Interest. As peregrine falcons are found near the site, the design included the provision of nesting sites on the cliff features. Different species of vegetation were considered for different locations, taking into account the intensity and direction of the sunlight and wind that the site is exposed to. In preparing the details, comments from various Government departments, green groups and other concerned parties were considered and
included. Detailed methods of planting and the actual locations and types of plants to be used were decided after the works commenced.

**Trial planting:** To establish the stability performance of the slopes created in the quarry, the method of planting and the growth of various plants in relation to the slope characteristics, a trial planting exercise was carried out. In the case of Shek O Quarry, trials were initiated by the contractor in 1990 in which a scree slope covering an area of 1,480 m² was established. The area was hydroseeded with a seed mix of grasses and planted with trees, shrubs and climbers. Assessments made in 1994, and more recently, have confirmed that the trial slope created is stable. The grass, trees, shrubs and climbers planted have become well established and are thriving in the harsh, inhospitable conditions with no maintenance, as shown in figure 7.

**Conservation of flora and fauna**

The following features of the quarries help to conserve flora and fauna in the vicinity of the sites:

- **Site remoteness:** In most cases the quarries are located in relatively remote areas with no easy means of access. The conservation of flora and fauna in the vicinity of the quarries is improved when there are fewer intruders.

- **Non-interference attitude:** All the quarry operators adopt a non-interference attitude towards any animals found within or outside the quarry. This encourages the establishment of a natural habitat around the quarry. For example, when a female monkey and her baby were found in Lam Tei Quarry (fig. 8) the quarry manager instructed his staff not to feed or interfere with them, and to allow them to move freely within the quarry. As a result, the monkeys came to the quarry two or three times a week to feed on wild fruits. As well as monkeys, barking deer, wild pigs, pheasants and numerous insects and reptiles have also been found in areas within and adjoining the other quarries.

- **Ecological surveys:** To ensure that the flora and fauna are being conserved, and to monitor any change in the ecological conditions in the quarries due to the ongoing rehabilitation works, regular ecological surveys are conducted. In the case of Shek O Quarry, an ecological consultant was employed by the contractor to conduct surveys of flora, habitats, mammals, amphibians and reptiles once in each sampling year, and bird surveys three to four times in each sampling year, following on from baseline ecological surveys conducted in 1993. Based on the surveys carried out so far, it has been established that there have been no significant changes in either the habitats or the characteristics of the flora and fauna found near the quarry.

**For the Government**

The Government receives a revenue of HK$25–30 million per year from the quarry rehabilitation contracts. As part of the quarry rehabilitation works, new and stable landforms for future use, including roads, man-made lakes etc, are created for the Government:

- **Creation of a new and stable landform for future use:** The slopes in the quarries are created to the required standards and bare rock faces are replaced with a series of landscaped slopes (fig. 9). The sites so formed have many potential future uses, such as residential development in the case of Anderson Road.
Quarry and recreational use in the case of Shek O Quarry. If there were no quarry contracts and the sites were to be developed by the Government, the cost would be HK$200–600 million per site.

New road: In Shek O Quarry a new road has been constructed to replace the old Shek O Road (fig. 10) which had a dangerous junction on a 180° hair-pin bend. The road was realigned and improved and the bend eliminated with a new turning. In addition, the travel distance was reduced by almost 660m.

Marine cove: A 20m deep, 8ha marine cove will be formed in Shek O Quarry (fig. 11).

Man-made lake: A 4ha freshwater lake, believed to be the biggest lake in Hong Kong, is being formed within Lamma Quarry, as shown in figure 12. It is designed to have a natural-looking, non-engineered appearance with gently shelving edges to support a reed bed. A 16m long spillway has been constructed to discharge water into the sea.

For the Construction Industry
Shek O Quarry site was used as a casting basin for the production of precast immersed tubes for the Western Harbour Crossing and the new Airport Railway. Without this facility these units would have been fabricated outside Hong Kong and and the construction cost and time involved would have increased significantly.

For the Community
With quarrying, the rock excavated from the site can be put to good use for the production of aggregates or for other rock products, such as armour-stone, pell-mell etc. This is good in terms of sustainability and conservation of resources. If the quarrying approach is not adopted, the rock excavated will possibly be used in designated reclamation sites at public landfill areas and public barge-filling points. This will put much pressure on the decreasing public landfill capacity.

The land created after quarrying can be used for recreational purposes. In the case of Shek O Quarry, the marine cove being developed will be used by the public for watersports activities.

AN INTEGRATED APPROACH TO QUARRYING
Today, quarrying in Hong Kong not only involves the excavation and processing of rock, it is an integrated process involving land-use planning, slope works, ecology etc. The objective of current quarrying works is to turn a less-useful piece of land into a valuable site through a process of rehabilitation and, through this process, to bring engineering, industry, economic and environmental gains, as shown in figure 13.

In terms of engineering gains, stable slopes, new roads, man-made lakes etc are being formed in this way. For the industry, the rock excavated can be turned into useful construction products. In terms of economic gains, the industry provides employment and brings revenue to the Government. And for the environment, a sustainable ecology and habitats for wildlife are produced as a result of this process.

CONCLUSIONS
The concept of quarrying has changed dramatically since the 1960s and 70s. Under an imaginative scheme developed by the Government and the local industry, the four remaining active quarries in Hong Kong are now operated under rehabilitation/quarry contracts. A major component of rehabilitation/landscaping is included in the contracts and much focus and consideration is placed on the environmental...
aspects and the conservation of natural resources. The aim is to revert the sites back to a natural-looking condition, turning once bare-looking eyesores into areas covered with trees and vegetation which are in harmony with the natural environment and suitable for future development.

Through the quarry rehabilitation process there are engineering, industry, economic and environmental gains. The approach to quarrying now adopted is an integrated approach, with various aspects considered before and during the rehabilitation process (land-use planning, slope works, ecology, landscaping, planting etc).

Quarry rehabilitation is a 'win-win' situation for the environment, the Government and the community. If there was no quarry rehabilitation it is likely that the bare look of the quarry sites would remain, and if the sites were to be reformed under a site formation contract, the Government would have to pay a substantial sum.

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